PROJECT REPORT

TO: ENVIRONMENTAL EVALUATION COMMITTEE **AGENDA DATE: November 19, 2020**

FROM: PLANNING & DEVELOPMENT SERVICES **AGENDA TIME 1:30 PM / No.1**

PROJECT TYPE: Second Imperial Geothermal CUP 19-0017 SUPERVISOR DIST #2

LOCATION: 855 Dogwood Road , APN: 054-250-031-000

Imperial County, CA PARCEL SIZE: 39.99 acres

GENERAL PLAN (existing) Heber SPA AREA GENERAL PLAN (proposed) N/A

ZONE (existing) AG -2 G-SPA ZONE (proposed) N/A

GENERAL PLAN FINDINGS ☒ CONSISTENT ☐ INCONSISTENT ☐ MAY BE/FINDINGS

PLANNING COMMISSION DECISION: HEARING DATE: _____

☐ APPROVED ☐ DENIED ☐ OTHER

PLANNING DIRECTORS DECISION: HEARING DATE: _____

☐ APPROVED ☐ DENIED ☐ OTHER

ENVIROMENTAL EVALUATION COMMITTEE DECISION: HEARING DATE: 11-19-2020

INITIAL STUDY: 19-0020

☐ NEGATIVE DECLARATION ☒ MITIGATED NEG. DECLARATION ☐ EIR

DEPARTMENTAL REPORTS / APPROVALS:

PUBLIC WORKS	☐ NONE	☒ ATTACHED
AG	☒ NONE	☐ ATTACHED
APCD	☐ NONE	☒ ATTACHED
E.H.S.	☐ NONE	☐ ATTACHED
FIRE / OES	☒ NONE	☐ ATTACHED
SHERIFF	☒ NONE	☐ ATTACHED
OTHER		

REQUESTED ACTION:

(See Attached)

☐ NEGATIVE DECLARATION
☒ MITIGATED NEGATIVE DECLARATION

Initial Study & Environmental Analysis
For:

Heber 2 Geothermal Repower Project
CUP No. 19-0017
SCH # 2020069002

Prepared By:

COUNTY OF IMPERIAL
Planning & Development Services Department
801 Main Street
El Centro, CA 92243
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November 2020

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SECTION 1
INTRODUCTION

A. PURPOSE

This document is a ☐ policy-level, ☒ project level Initial Study for evaluation of potential environmental impacts resulting with the proposed installation of new geothermal energy converters and three isopentane storage tanks, located at the existing Heber 2 Geothermal Energy Complex located on APN 054-250-031 at 855 Dogwood Road, Heber, CA 92249 (see Exhibit "A" & "B").

B. CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA) REQUIREMENTS AND THE IMPERIAL COUNTY'S GUIDELINES FOR IMPLEMENTING CEQA

As defined by Section 15063 of the State California Environmental Quality Act (CEQA) Guidelines and Section 7 of the County's "CEQA Regulations Guidelines for the Implementation of CEQA, as amended", an **Initial Study** is prepared primarily to provide the Lead Agency with information to use as the basis for determining whether an Environmental Impact Report (EIR), Negative Declaration, or Mitigated Negative Declaration would be appropriate for providing the necessary environmental documentation and clearance for any proposed project.

☐ According to Section 15065, an **EIR** is deemed appropriate for a particular proposal if the following conditions occur:

- The proposal has the potential to substantially degrade quality of the environment.
- The proposal has the potential to achieve short-term environmental goals to the disadvantage of long-term environmental goals.
- The proposal has possible environmental effects that are individually limited but cumulatively considerable.
- The proposal could cause direct or indirect adverse effects on human beings.

☒ According to Section 15070(a), a **Negative Declaration** is deemed appropriate if the proposal would not result in any significant effect on the environment.

☐ According to Section 15070(b), a **Mitigated Negative Declaration** is deemed appropriate if it is determined that though a proposal could result in a significant effect, mitigation measures are available to reduce these significant effects to insignificant levels.

This Initial Study has determined that the proposed applications will not result in any potentially significant environmental impacts and therefore, a Negative Declaration is deemed as the appropriate document to provide necessary environmental evaluations and clearance as identified hereinafter.

This Initial Study and Negative Declaration are prepared in conformance with the California Environmental Quality Act of 1970, as amended (Public Resources Code, Section 21000 et. seq.); Section 15070 of the State & County of Imperial's Guidelines for Implementation of the California Environmental Quality Act of 1970 as amended (California Code of Regulations, Title 14, Chapter 3, Section 15000, et. seq.). applicable requirements of the County of Imperial; and the regulations, requirements, and procedures of any other responsible public agency or an agency with jurisdiction by law.

Pursuant to the County of Imperial Guidelines for Implementing CEQA, depending on the project scope, the County of Imperial Board of Supervisors, Planning Commission and/or Planning Director is designated the Lead Agency,

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in accordance with Section 15050 of the CEQA Guidelines. The Lead Agency is the public agency which has the principal responsibility for approving the necessary environmental clearances and analyses for any project in the County.

C. INTENDED USES OF INITIAL STUDY AND NEGATIVE DECLARATION

This Initial Study and Negative Declaration are informational documents which are intended to inform County of Imperial decision makers, other responsible or interested agencies, and the general public of potential environmental effects of the proposed applications. The environmental review process has been established to enable public agencies to evaluate environmental consequences and to examine and implement methods of eliminating or reducing any potentially adverse impacts. While CEQA requires that consideration be given to avoiding environmental damage, the Lead Agency and other responsible public agencies must balance adverse environmental effects against other public objectives, including economic and social goals.

The Initial Study and Negative Declaration, prepared for the project will be circulated for a period of 20 days (*30-days if submitted to the State Clearinghouse for a project of area-wide significance*) for public and agency review and comments. At the conclusion, if comments are received, the County Planning & Development Services Department will prepare a document entitled "Responses to Comments" which will be forwarded to any commenting entity and be made part of the record within 10-days of any project consideration.

D. CONTENTS OF INITIAL STUDY & NEGATIVE DECLARATION

This Initial Study is organized to facilitate a basic understanding of the existing setting and environmental implications of the proposed applications.

SECTION 1

I. **INTRODUCTION** presents an introduction to the entire report. This section discusses the environmental process, scope of environmental review, and incorporation by reference documents.

SECTION 2

II. **ENVIRONMENTAL CHECKLIST FORM** contains the County's Environmental Checklist Form. The checklist form presents results of the environmental evaluation for the proposed applications and those issue areas that would have either a significant impact, potentially significant impact, or no impact.

PROJECT SUMMARY, LOCATION AND EVIRONMENTAL SETTINGS describes the proposed project entitlements and required applications. A description of discretionary approvals and permits required for project implementation is also included. It also identifies the location of the project and a general description of the surrounding environmental settings.

ENVIRONMENTAL ANALYSIS evaluates each response provided in the environmental checklist form. Each response checked in the checklist form is discussed and supported with sufficient data and analysis as necessary. As appropriate, each response discussion describes and identifies specific impacts anticipated with project implementation.

SECTION 3

III. **MANDATORY FINDINGS** presents Mandatory Findings of Significance in accordance with Section 15065 of the CEQA Guidelines.

IV. **PERSONS AND ORGANIZATIONS CONSULTED** identifies those persons consulted and involved in

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preparation of this Initial Study and Negative Declaration.

V. REFERENCES lists bibliographical materials used in preparation of this document.

VI. NEGATIVE DECLARATION – COUNTY OF IMPERIAL

VII. FINDINGS

SECTION 4

VIII. RESPONSE TO COMMENTS (IF ANY)

IX. MITIGATION MONITORING & REPORTING PROGRAM (MMRP) (IF ANY)

E. SCOPE OF ENVIRONMENTAL ANALYSIS

For evaluation of environmental impacts, each question from the Environmental Checklist Form is summarized and responses are provided according to the analysis undertaken as part of the Initial Study. Impacts and effects will be evaluated and quantified, when appropriate. To each question, there are four possible responses, including:

1. **No Impact:** A "No Impact" response is adequately supported if the impact simply does not apply to the proposed applications.

2. **Less Than Significant Impact:** The proposed applications will have the potential to impact the environment. These impacts, however, will be less than significant; no additional analysis is required.

3. **Less Than Significant With Mitigation Incorporated:** This applies where incorporation of mitigation measures has reduced an effect from "Potentially Significant Impact" to a "Less Than Significant Impact".

4. **Potentially Significant Impact:** The proposed applications could have impacts that are considered significant. Additional analyses and possibly an EIR could be required to identify mitigation measures that could reduce these impacts to less than significant levels.

F. POLICY-LEVEL or PROJECT LEVEL ENVIRONMENTAL ANALYSIS

This Initial Study and Negative Declaration will be conducted under a ☐ policy-level, ☒ project level analysis. Regarding mitigation measures, it is not the intent of this document to "overlap" or restate conditions of approval that are commonly established for future known projects or the proposed applications. Additionally, those other standard requirements and regulations that any development must comply with, that are outside the County's jurisdiction, are also not considered mitigation measures and therefore, will not be identified in this document.

G. TIERED DOCUMENTS AND INCORPORATION BY REFERENCE

Information, findings, and conclusions contained in this document are based on incorporation by reference of tiered documentation, which are discussed in the following section.

1. Tiered Documents

As permitted in Section 15152(a) of the CEQA Guidelines, information and discussions from other documents can be included into this document. Tiering is defined as follows:

"Tiering refers to using the analysis of general matters contained in a broader EIR (such as the one prepared

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for a general plan or policy statement) with later EIRs and negative declarations on narrower projects incorporating by reference the general discussions from the broader EIR; and concentrating the later EIR or negative declaration solely on the issues specific to the later project."

Tiering also allows this document to comply with Section 15152(b) of the CEQA Guidelines, which discourages redundant analyses, as follows:

"Agencies are encouraged to tier the environmental analyses which they prepare for separate but related projects including the general plans, zoning changes, and development projects. This approach can eliminate repetitive discussion of the same issues and focus the later EIR or negative declaration on the actual issues ripe for decision at each level of environmental review. Tiering is appropriate when the sequence of analysis is from an EIR prepared for a general plan, policy or program to an EIR or negative declaration for another plan, policy, or program of lesser scope, or to a site-specific EIR or negative declaration."

Further, Section 15152(d) of the CEQA Guidelines states:

"Where an EIR has been prepared and certified for a program, plan, policy, or ordinance consistent with the requirements of this section, any lead agency for a later project pursuant to or consistent with the program, plan, policy, or ordinance should limit the EIR or negative declaration on the later project to effects which:

(1) Were not examined as significant effects on the environment in the prior EIR; or

(2) Are susceptible to substantial reduction or avoidance by the choice of specific revisions in the project, by the imposition of conditions, or other means."

2. Incorporation By Reference

Incorporation by reference is a procedure for reducing the size of EIRs/MND and is most appropriate for including long, descriptive, or technical materials that provide general background information, but do not contribute directly to the specific analysis of the project itself. This procedure is particularly useful when an EIR or Negative Declaration relies on a broadly-drafted EIR for its evaluation of cumulative impacts of related projects (*Las Virgenes Homeowners Federation v. County of Los Angeles* [1986, 177 Ca.3d 300]). If an EIR or Negative Declaration relies on information from a supporting study that is available to the public, the EIR or Negative Declaration cannot be deemed unsupported by evidence or analysis (*San Francisco Ecology Center v. City and County of San Francisco* [1975, 48 Ca.3d 584, 595]). This document incorporates by reference appropriate information from the "Final Environmental Impact Report and Environmental Assessment for the "County of Imperial General Plan EIR" prepared by Brian F. Mooney Associates in 1993 and updates.

When an EIR or Negative Declaration incorporates a document by reference, the incorporation must comply with Section 15150 of the CEQA Guidelines as follows:

- The incorporated document must be available to the public or be a matter of public record (CEQA Guidelines Section 15150[a]). The General Plan EIR and updates are available, along with this document, at the County of Imperial Planning & Development Services Department, 801 Main Street, El Centro, CA 92243 Ph. (442) 265-1736.

- This document must be available for inspection by the public at an office of the lead agency (CEQA Guidelines Section 15150[b]). These documents are available at the County of Imperial Planning & Development Services Department, 801 Main Street, El Centro, CA 92243 Ph. (442) 265-1736.

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- These documents must summarize the portion of the document being incorporated by reference or briefly describe information that cannot be summarized. Furthermore, these documents must describe the relationship between the incorporated information and the analysis in the tiered documents (CEQA Guidelines Section 15150[c]). As discussed above, the tiered EIRs address the entire project site and provide background and inventory information and data which apply to the project site. Incorporated information and/or data will be cited in the appropriate sections.

- The material to be incorporated in this document will include general background information (CEQA Guidelines Section 15150[f]). This has been previously discussed in this document.

Appendices

Appendix A - Site Photographs
Appendix B - Biological Resources Clearance Memorandum
Appendix C - Cultural Resources Clearance Memorandum (CONFIDENTIAL)
Appendix D - Water Quality Management Plan
Appendix E - Geo-technical Site Conditions Memorandum and Technical Report
Appendix F - Air Emissions Memorandum
Appendix G - Isopentane Hazard Assessment
Appendix H - Imperial County Reclamation Plan Application
Appendix I- 2020 Heber 2 Mitigation
Appendix J- Attachment for Heber 2 responses
Appendix K- Heber 2 Isopentane tank
Appendix L - Heber 2 Hazard Assessment update
Appendix M - Heber 2 responses to comments

ATTACHMENTS

H2RP-1	HEBER CUP 06-0006
H2RP-2	PERMIT TO OPERATE
H2RP-4	BRYANT HART FAULT RUPTURE
H2RP-5	USGS SWELLING CLAY MAPS
H2RP-6	HEBER 2 IID WATER SUPPLY CONTACT
H2RP-7	PM 10 PM 2.5 PLANS
H2RP-8	ASTM
H2RP-9	CALIFORNIA AMBIENT AIR QUALITY
HPRP-10	CDFW DATA IMPERIAL, CNDDB MAPS IMPERIAL CO, CNDDB BIOS 10 & 5 MILE
H2PR-11	CA DIR SAFETY HEALTH PROTCOL
H2RP-12	CALRECYCLE INTEGRATED
H2RP-13	CAL DTSC
H2RP-14	CALTRANS TECHNICAL NOISE SUPPLE
H2RP-15	SCENIC HWY DATA
H2RP-16	CALIFORNIA GROUNDWATER
H2RP-17	OPR GENERAL PLAN GUID
H2RP-18	USEPA NAAQS CIRTERIA AIR POLL
H2RP-19	USGS SAN ANDRES FAULT
H2RP-20	HEBER 2 PROJECT INFO

RECORDS INDEX FOR HEBER 2 REPOWER PROJECT

Figures

Figure 1 - Location of Heber 2 Geothermal Power Plant ..... **Error! Bookmark not defined.**
Figure 2 – Proposed and Existing Facilities ..... **Error! Bookmark not defined.**
Figure 3 – Facility Integration Diagram .....
Figure 4 – Example of Proposed ORMAT Energy Converters .....
Figure 5 – Example of Proposed Above Ground Storage Tank (10,000 gallon).....
Figure 6 – Photo of Project Site (June 13, 2019) .....

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II. Environmental Checklist

1. **Project Title**: Heber 2 Geothermal Repower Project Initial Study IS 19-0020 SCH # 2020069002
2. **Lead Agency**: Imperial County Planning & Development Services Department
3. **Contact person and phone number**: David Black, Planner IV, (442)265-1736
4. **Address**: 801 Main Street, El Centro CA, 92243
5. **E-mail**: davidblack@co.imperial.ca.us
6. **Project location**: APN 054-250-031-000; 855 Dogwood Road, Heber, CA 92249. See Exhibit A and B.
7. **Project sponsor's name and address**: Second Imperial Geothermal Company; 6140 Plumas St., Reno, NV 89519
8. **General Plan designation**: Heber SPA area
9. **Zoning**: A-2-G-SPA, General Agriculture (A-2), Geothermal Overlay Zone (G), and in the Heber Specific Plan Area (SPA)
10. **Description of project**: Perform CUP amendment to allow for installation of two new water-cooled ORMAT Energy Converters (OECs) to replace six old units from 1992; three 10,000 gallon isopentane above ground storage tanks; and, additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex. All proposed facilities would be developed within the existing Heber 2 Complex and fence line. The total project disturbance from developing the new facilities is approximately 4 acres. The CUP amendment application also proposes to renew the permitted life of the entire Heber 2 Complex (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049).

    The proposed facility upgrades would allow the Heber 2 Complex to run more efficiently and refurbish the Heber 2 Complex to the original nameplate capacity (33 megawatts) without expanding the existing facility beyond the current footprint, and produce clean renewable energy in the Imperial Valley for the next three decades.
11. **Surrounding land uses and setting**: Briefly describe the project's surroundings: Surrounding land uses include a solar energy facility to the west of the Project Site, a commercial aggregate/rock supplier to the south, and agriculture to the north and east. The primary use in the general surrounding area is agriculture. The closest residences to the Project Site are in the town of Heber, approximately 3,500 feet to the northeast of the Heber 2 Complex.
12. **Other public agencies whose approval is required** (e.g., permits, financing approval, or participation agreement.): None
13. **Have California Native American tribes traditionally and culturally affiliated with the project area requested consultation pursuant to Public Resources Code section 21080.3.1? If so, is there a plan for consultation that includes, for example, the determination of significance of impacts to tribal cultural resources, procedures regarding confidentially, etc.?**

    Note: Conducting consultation early in the CEQA process allows tribal governments, lead agencies, and project proponents to discuss the level of environmental review, identify and address potential adverse impacts to tribal cultural resources, and reduce the potential for delay and conflict in the environmental review process. (See Public Resources Code, Section 21080.3.2). Information may also be available from the California Native American Heritage Commission's Sacred Lands File per Public Resources Code, Section 5097.96 and the California Historical Resources Information System administered by the California Office of Historic Preservation. Please also note that Public Resources Code, Section 21082.3 (c) contains provisions specific to confidentiality.

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ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:

The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" as indicated by the checklist on the following pages.

☐	Aesthetics	☐	Agriculture and Forestry Resources	☐	Air Quality
☒	Biological Resources	☐	Cultural Resources	☐	Energy
☒	Geology /Soils	☐	Greenhouse Gas Emissions	☒	Hazards & Hazardous Materials
☐	Hydrology / Water Quality	☐	Land Use / Planning	☐	Mineral Resources
☐	Noise	☐	Population / Housing	☐	Public Services
☐	Recreation	☐	Transportation	☐	Tribal Cultural Resources
☐	Utilities/Service Systems	☐	Wildfire	☐	Mandatory Findings of Significance

ENVIRONMENTAL EVALUATION COMMITTEE (EEC) DETERMINATION

After Review of the Initial Study, the Environmental Evaluation Committee has:

☐ Found that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

☒ Found that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

☐ Found that the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

☐ Found that the proposed project MAY have a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

☐ Found that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier EIR or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier EIR or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the proposed project, nothing further is required.

CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE DE MINIMIS IMPACT FINDING: ☐ Yes ☐ No

EEC VOTES	YES	NO	ABSENT
PUBLIC WORKS	☒	☐	☐
ENVIRONMENTAL HEALTH SVCS	☐	☐	☒
OFFICE EMERGENCY SERVICES	☐	☐	☒
APCD	☒	☐	☐
AG	☒	☐	☐
SHERIFF DEPARTMENT	☐	☐	☒
ICPDS	☒	☐	☐

Jim Minnick, Director of Planning/EEC Chairman — Date: 11-23-2020

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PROJECT SUMMARY

See attached Initial Study for additional information.

A. Project Location: The proposed development would occur entirely on the 39.99-acre Assessor's Parcel Number (APN) 054-250-031. This parcel also includes geothermal facilities for the Goulds 2 and Heber South projects. The address for the Heber 2 Complex is 855 Dogwood Road, Heber, CA. 92249. The legal description is Tract 44, Township 16 South, Range 14 East, SBB&M. See Exhibit A and B.

B. Project Summary: Install two new water-cooled ORMAT Energy Converters (OECs) to replace six old units from 1992; install three 10,000-gallon isopentane above ground storage tanks; and, additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex. All proposed facilities will be developed within the existing Heber 2 Complex and fence line. The total project disturbance from developing the new facilities is approximately 4 acres. The CUP amendment application also proposes to renew the permitted life of the entire Heber 2 Complex (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049). The proposed facility upgrades would allow the Heber 2 Complex to run more efficiently and refurbish the Heber 2 Complex to the original nameplate capacity **(33 megawatts)** without expanding the existing facility beyond the current footprint, and produce clean renewable energy in the Imperial Valley for the next three decades.

C. Environmental Setting:
Within the existing Heber 2 Complex, the Project Site is vacant of any vegetation or topographic features, consisting of exposed gravel and/or soil. No wetlands or jurisdictional waters are located on the Project Site. The closest jurisdictional water is the New River, located approximately 1.3 miles to the southwest of the Project Site, across Willoughby Road. The Project Site is not suitable habitat for any sensitive species.

D. Analysis: Taking into account the numerous voluntary environmental protection measures proposed by the Applicant, the Project is not expected to result in any significant effects. All impacts in the Initial Study were identified to be Less Than Significant or No Impact, primarily due to the fully developed nature of the Project Site as an existing geothermal energy complex. Therefore, no additional mitigation measures were prescribed.

E. General Plan Consistency: The proposed Project is consistent with the General Plan, located within the geothermal energy overlay zone allowing for major geothermal projects. All proposed developments would occur within the fence-line of the existing Heber 2 Geothermal Energy Complex and not increase the footprint on the energy facility. Construction activities and facility operations would be performed in line with the elements of the General Plan (Land Use; Housing; Circulation and Scenic Highways; Noise; Seismic and Public Safety; Conservation and Open Space; Agricultural; Geothermal and Transmission; Water).

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Exhibit "A"
Vicinity Map
Figure 1

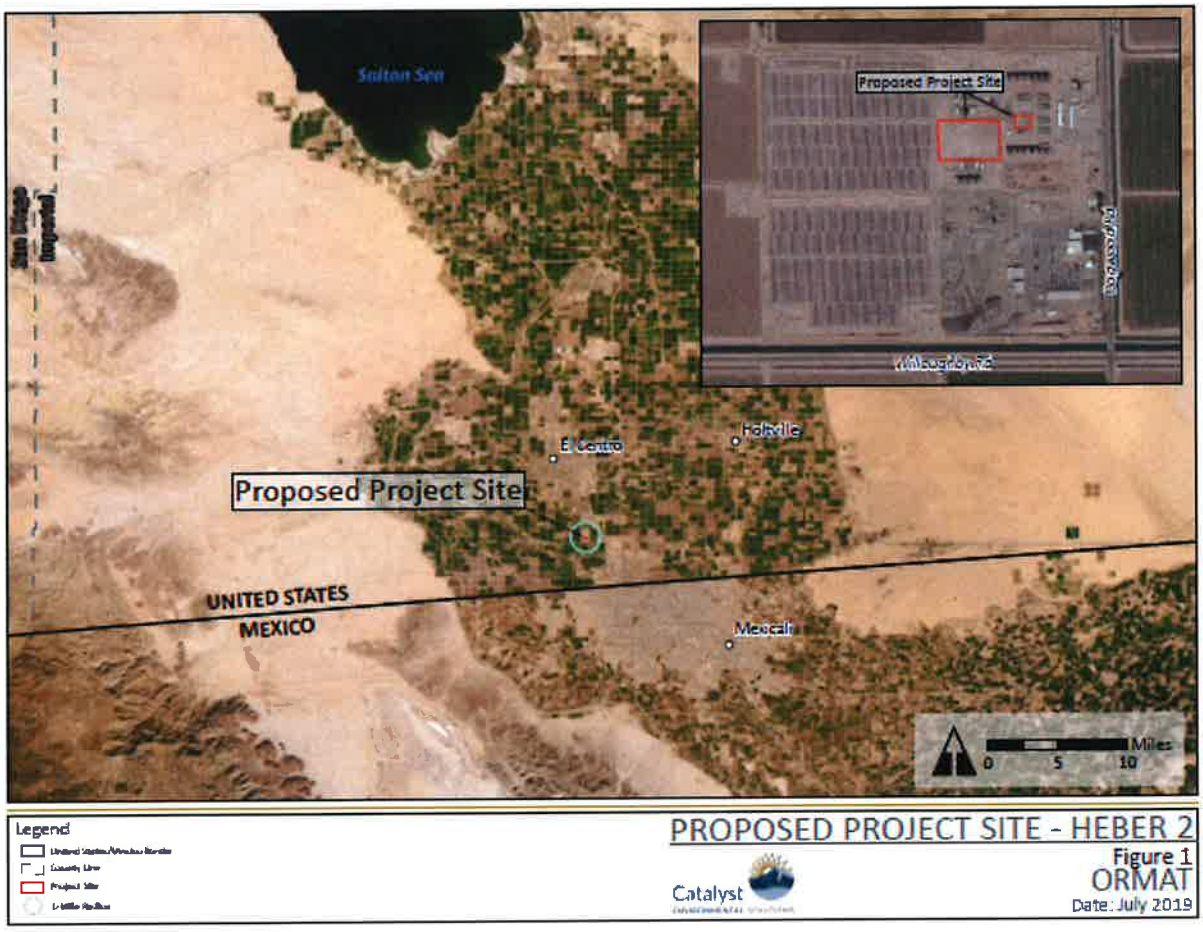

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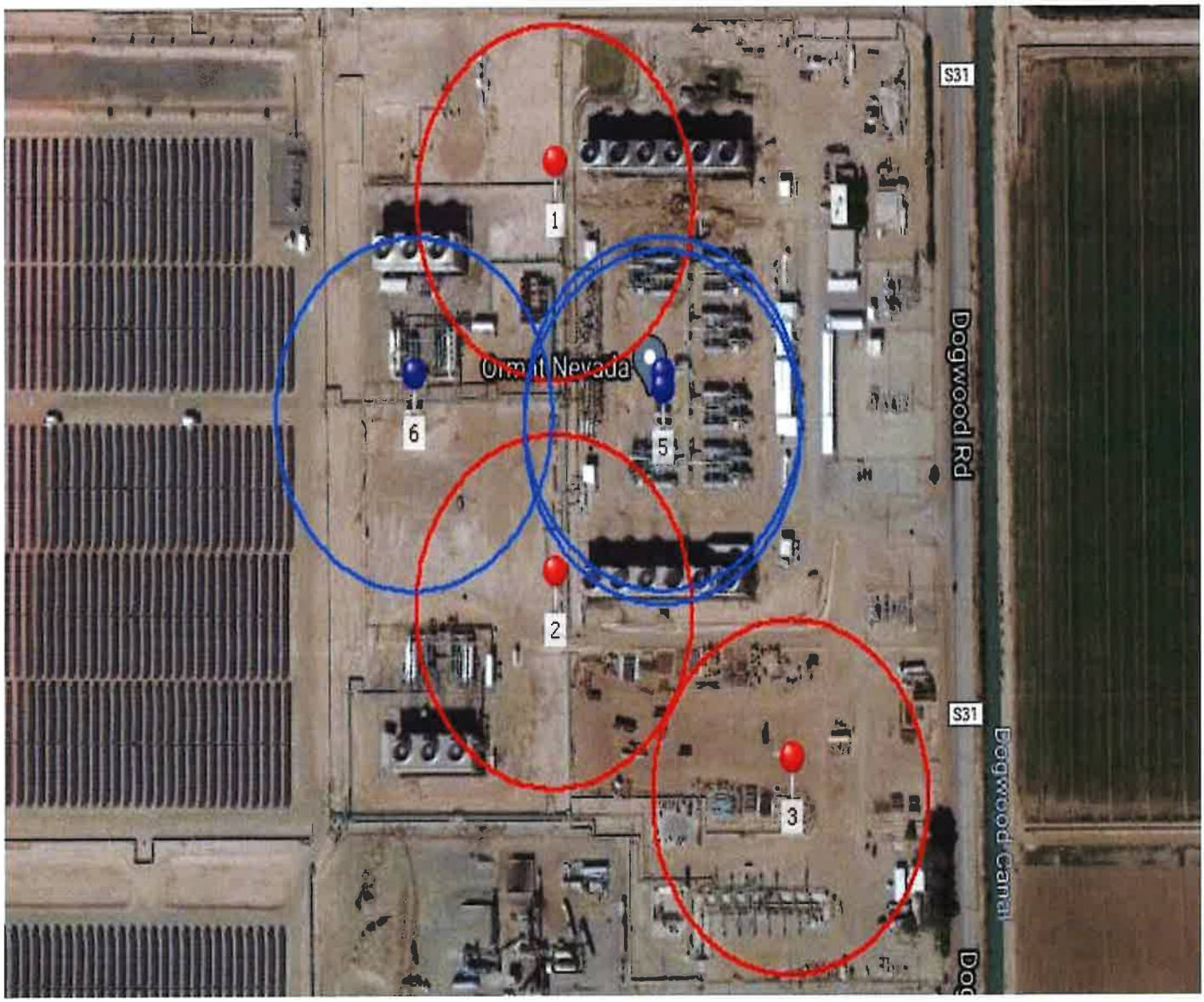
Exhibit "B"
Site Plan
Figure 2



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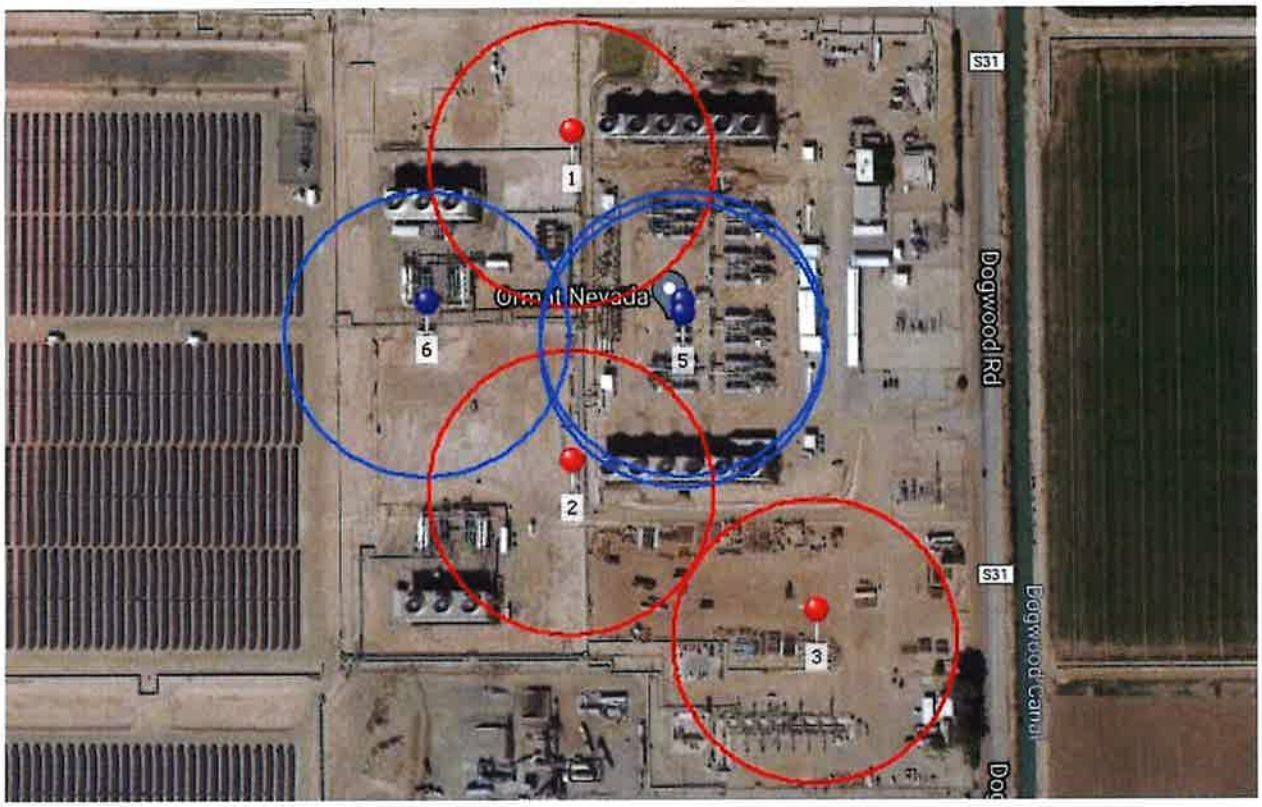

Figure 4- Example of Proposed ORMAT Energy Converters



Figure 5 Example of Proposed Above Ground Storage Tank (10,000 gallon)

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Figure 6- Photo of Project Site (June 13, 2019)

EVALUATION OF ENVIRONMENTAL IMPACTS:

1) A brief explanation is required for all answers except "No Impact" answers that are adequately supported by the information sources a lead agency cites in the parentheses following each question. A "No Impact" answer is adequately supported if the referenced information sources show that the impact simply does not apply to projects like the one involved (e.g., the project falls outside a fault rupture zone). A "No Impact" answer should

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be explained where it is based on project-specific factors as well as general standards (e.g., the project will not expose sensitive receptors to pollutants, based on a project-specific screening analysis).

2) All answers must take account of the whole action involved, including off-site as well as on-site, cumulative as well as project-level, indirect as well as direct, and construction as well as operational impacts.

3) Once the lead agency has determined that a particular physical impact may occur, then the checklist answers must indicate whether the impact is potentially significant, less than significant with mitigation, or less than significant. "Potentially Significant Impact" is appropriate if there is substantial evidence that an effect may be significant. If there are one or more "Potentially Significant Impact" entries when the determination is made, an EIR is required.

4) "Negative Declaration: Less Than Significant With Mitigation Incorporated" applies where the incorporation of mitigation measures has reduced an effect from "Potentially Significant Impact" to a "Less Than Significant Impact." The lead agency must describe the mitigation measures, and briefly explain how they reduce the effect to a less than significant level (mitigation measures from "Earlier Analyses," as described in (5) below, may be cross-referenced).

5) Earlier analyses may be used where, pursuant to the tiering, program EIR, or other CEQA process, an effect has been adequately analyzed in an earlier EIR or negative declaration. Section 15063(c)(3)(D). In this case, a brief discussion should identify the following:

   a) Earlier Analysis Used. Identify and state where they are available for review.
   b) Impacts Adequately Addressed. Identify which effects from the above checklist were within the scope of and adequately analyzed in an earlier document pursuant to applicable legal standards, and state whether such effects were addressed by mitigation measures based on the earlier analysis.
   c) Mitigation Measures. For effects that are "Less than Significant with Mitigation Measures Incorporated," describe the mitigation measures which were incorporated or refined from the earlier document and the extent to which they address site-specific conditions for the project.

6) Lead agencies are encouraged to incorporate into the checklist references to information sources for potential impacts (e.g., general plans, zoning ordinances). Reference to a previously prepared or outside document should, where appropriate, include a reference to the page or pages where the statement is substantiated.

7) Supporting Information Sources: A source list should be attached, and other sources used or individuals contacted should be cited in the discussion.

8) This is only a suggested form, and lead agencies are free to use different formats; however, lead agencies should normally address the questions from this checklist that are relevant to a project's environmental effects in whatever format is selected.

9) The explanation of each issue should identify:

   a) The significance criteria or threshold, if any, used to evaluate each question; and
   b) The mitigation measure identified, if any, to reduce the impact to less than significance

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

I. *AESTHETICS*

Except as provided in Public Resources Code Section 21099, would the project:

a) Have a substantial adverse effect on a scenic vista or scenic highway? ☐ ☐ ☐ ☒

a) No Impact. No scenic vistas or scenic highways are present on or in the vicinity of the Project Site; therefore, no impacts would occur to these aesthetic resources.

b) Substantially damage scenic resources, including, but not limited to trees, rock outcroppings, and historic buildings within a state scenic highway? ☐ ☐ ☐ ☒

b) No Impact. The Project would be developed within an existing power plant, on undeveloped lands with no scenic characteristics (i.e., site lacks vegetation, topography, or buildings), and no state scenic highways exist in the vicinity of the Project Site. Therefore, the Project would not impact any scenic resources.

c) In non-urbanized areas, substantially degrade the existing visual character or quality of public views of the site and its surrounding? (Public views are those that are experienced from publicly accessible vantage point.) If the project is in an urbanized area, would the project conflict with applicable zoning and other regulations governing scenic quality? ☐ ☐ ☒ ☐

c) Less Than Significant. During the construction phase, a crane may be visible to travelers on Dogwood Road or in the vicinity of the Project Site. However, crane use is anticipated to be temporary (less than eight months) and would be removed from the Project Site after construction of the proposed facilities is complete.

The Project will be developed within an existing power plant, and the proposed facilities would blend in with the existing energy facilities. The proposed facilities would render no noticeable changes to the Heber 2 site/plant to travelers on Dogwood Road or in the vicinity of the Project Site. The Imperial County General/Zoning Plan allows for "Major Geothermal" projects on the Project Site and, taking into account the existing power plant, the Project would not impact the visual character of the site or its surroundings.

d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area? ☐ ☐ ☐ ☒

d) No Impact. The Project would not introduce any new light sources to the Project Site or surrounding area. Lighting is present at the Heber 2 Complex, but no additional lighting is proposed as part of the Project.

II. *AGRICULTURE AND FOREST RESOURCES*

In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:

a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use? ☐ ☐ ☐ ☒

a) No Impact. The Project Site is presently used for geothermal energy operations and is uncultivated. No Prime, Unique, or Important farmlands are present on the Project Site (DOC 2016). No land use or farmland conversion would occur as result of the

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

Project.

b) Conflict with existing zoning for agricultural use, or a Williamson Act Contract? ☐ ☐ ☐ ☒

b) No Impact. The Project Site is zoned for agriculture and geothermal energy projects, and the Project does not conflict with Imperial County's General/Zoning Plan. The Project Site is not subject to a Williamson Act contract.

c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)), timberland (as defined by Public Resources Code section 4526), or timberland zoned Timberland Production (as defined by Government Code Section 51104(g))? ☐ ☐ ☐ ☒

c) No Impact. The Project site is not zoned for, nor does it contain, forest land or timber land. As such, the Project would not impact forest or timberlands.

d) Result in the loss of forest land or conversion of forest land to non-forest use? ☐ ☐ ☐ ☒

d) No Impact. The Project site does not contain any forest land and would not convert any forest lands; therefore, the Project would not impact forest lands.

e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use? ☐ ☐ ☐ ☒

e) No Impact. There is no farmland or forest land present on the Project Site, which is used for ongoing geothermal energy generation (DOC 2016). The proposed facilities would be constructed within the existing power plant site and no offsite disturbances would occur; therefore, no conversion of farmland or forest land would occur as result of the Project.

III. *AIR QUALITY*

Where available, the significance criteria established by the applicable air quality management district or air pollution control district may be relied upon to the following determinations. Would the Project:

a) Conflict with or obstruct implementation of the applicable air quality plan? ☐ ☐ ☒ ☐

a) Less Than Significant. The Project Site is located within the ICAPCD, and the Heber 2 Complex has an existing Permit to Operate (PTO) issued by ICAPCD. Emissions of criteria pollutants, which are limited to fugitive releases of isopentane, a volatile organic compound (VOC), are monitored at the Heber 2 Complex. Modeling was performed to forecast the amount of potential isopentane emissions (Appendix **F)** to evaluate a potential significant exceedance of the limits established in the Imperial County CEQA Air Quality Handbook.

Current isopentane emissions at the Heber 2 Complex are approximately 117.5 lbs/day, and the modeled future emissions with the new facilities are estimated to be 64.5 lbs/day (**Table 2**). Under the existing PTO, the Heber 2 Complex is authorized to emit between 137 and 218 lbs/day of isopentane (dependent on time of year). The expected change in isopentane emissions with the new facilities would decline by approximately 53 lbs/day or 3.1 tons/year, which is significantly less than the existing emissions profile of the Heber 2 Complex and well under the authorized release amount. SIGC is applying to ICAPCD for a new PTO with reduced emissions thresholds to 137 to 202 lbs/day. Therefore, considering the emissions reduction from the new facilities, the Project would not conflict with or obstruct the implementation of the ICAPCD air quality plan.

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

Table Existing and Modeled Future Isopentane Emissions

Heber 2 Complex Total Emissions

Isopentane Emissions	lbs / day	tons / year
Actual Emissions (2017 – 2018)	117.5	14.9
Estimated Potential Future Emissions	64.5	11.8
Emissions Increase	-52.9	-3.1
Permit Limit (varies)	137 - 218	

b) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard? ☐ ☐ ☒ ☐

b) Less Than Significant. The Project would not violate any air quality standards or plan. The Heber 2 Complex has a PTO from the ICAPCD, which specifies the amount of isopentane, a VOC, authorized for release. The Heber 2 Complex is permitted to release between 137 and 218 lbs/day, depending on time of year. As noted in **Table 2** above, isopentane emissions with the new facilities are expected to decrease approximately 53 lbs/day, for a total of 64.5 lbs/day. SIGC is applying to ICAPCD for a new PTO with reduced emissions thresholds to 137 to 202 lbs/day. Therefore, considering the emissions reduction from the new facilities, the Project would not violate the existing PTO or contribute to an existing air quality violation.

Emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition (i.e. particulate matter, ozone). As described in Section 2.1.7, air quality measures would be implemented during construction of the proposed facilities to minimize the potential for fugitive dust and particulate matter releases. All air quality control measures would be in line with the Imperial County 2018 PM_{10} Plan and Imperial County 2018 $PM_{2.5}$ Plan. Through the application of these measures, the construction of the Project would limit visible dust emissions and particulate matter emissions to 20 percent opacity and/or 150 lbs/day, and therefore, be in compliance with Imperial County's approach to minimizing these construction-related emissions.

c) Expose sensitive receptors to substantial pollutants concentrations? ☐ ☐ ☒ ☐

c) Less Than Significant. Significant adverse cumulative air quality impacts could occur if the proposed Project resulted in a cumulatively considerable net increase of a criteria pollutant for which ICAPCD exceeds federal and state ambient air quality standards and has been designated as an area of non- attainment by the USEPA and/or CARB. The ICAPCD is a non-attainment area for ozone and fine particulate matter.

To determine whether air quality impacts from a proposed project are significant, the project's potential contribution to cumulative impacts would be assessed utilizing the same significance criteria as for project-specific impacts. Therefore, if an individual project generates construction or operational emissions that exceed the ICAPCD's recommended daily thresholds for project-specific impacts, that project would also cause a cumulatively considerable increase in emissions for those pollutants for which the ICAPCD is in nonattainment and therefore, would be considered to have significant adverse cumulative air quality impacts.

As discussed in Section 2.1.7, air quality measures would be implemented during construction of the proposed facilities to minimize the potential for fugitive dust and particulate matter releases. All air quality control measures would be in line with the Imperial County 2018 PM_{10} Plan and Imperial County 2018 $PM_{2.5}$ Plan. Through the application of these measures, the construction of the Project would limit visible dust emissions and particulate matter emissions to 20 percent opacity and/or 150 lbs/day, and therefore, be in compliance with Imperial County's approach to minimizing these construction-related emissions. Ozone, which is formed by a complex series of chemical reactions and the precursors of which stem from the use of fuel-combusting equipment (e.g., backhoes, trucks), would also be limited to the construction phase of the Project. To limit the amount ozone emissions from construction equipment, vehicles and equipment would be turned off when not in use and not left idling to minimize unnecessary

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

emissions. The temporary and relatively low amount of ozone emissions from the construction equipment would result in a less than significant cumulative effect to the existing nonattainment status of the ICAPCD.

d)	Result in other emissions (such as those leading to odors adversely affecting a substantial number of people?	☐	☐	☒	☐

d) Less Than Significant. Land uses that are considered more sensitive to changes in air quality than others are referred to as sensitive receptors. Land uses such as primary and secondary schools, hospitals, and convalescent homes are sensitive to poor air quality because the very young, the old, and the infirm are more susceptible to respiratory infections and other air quality-related health problems than the general public. Residential uses are considered sensitive because people in residential areas are often at home for extended periods of time, so they could be exposed to pollutants for extended periods. Recreational areas are considered moderately sensitive to poor air quality because vigorous exercise associated with recreation places a high demand on the human respiratory function.

The nearest sensitive receptors to the Project Site are the residences approximately 3,500 feet to the northeast of the Project Site. As discussed in **Appendix F**, air emissions from the Heber 2 Complex would be limited to isopentane, which is a VOC. The Heber 2 Complex is permitted to release between 137 and 218 lbs/day, depending on time of year. Isopentane emissions with the new facilities are estimated to decrease by approximately 53 lbs/day of isopentane, representing approximately a 54 percent decrease from current emissions and well below permitted limits (**Table 2**).The Project would not exceed the release limits established in the PTO, which are health-based; therefore, the Project would not expose any sensitive receptors to a significant exposure of pollutant concentrations.

Isopentane has a petroleum-like odor; however as noted previously, the Project would result in a decrease of approximately 53 lbs/day of isopentane, representing approximately a 54 percent decrease from current emissions and well below permitted limits (Table 2). Utilizing the existing Heber 2 power generation infrastructure, the additional facilities will not produce a significant odor. No odor complaints have ever been filed against the Heber 2 facilities and the existing facilities are not a significant source of odor. Further, the Project Site is located in an agrarian area that is not densely populated. The closest residences are located 3,500 feet to the northeast of the Project Site. During construction, diesel emissions from construction equipment may be sources of odor. These emissions would be temporary and minimal based on the small number of heavy vehicles that would be required for Project construction. Therefore, Project-related odors would be limited to the temporary construction phase and would not result in a significant source of odor to a substantial number of people.

IV. *BIOLOGICAL RESOURCES* *Would the project:*

a)	Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies or regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service?	☐	☒	☐	☐

a) Potentially Significant Unless Mitigated:. The potential for sensitive species to occur on or in the vicinity of the Project Site was evaluated using information from the U.S. Fish and Wildlife (USFWS) Information, Planning, and Consultation System (IPaC System); California Natural Diversity Database (CNDDB); and California Native Plant Society (CNPS) Rare Plant Program.

No federally listed threatened or endangered plant species have the potential to occur on or near the project site (USFWS 2019a). Five plant species listed by the CNPS have the potential to occur in the Heber quadrangle (CNPS 2019):

1. Watson's amaranth (*Amaranthus watsonii*)
2. Abrams' spurge (*Euphorbia abramsiana*)
3. California satintail (*Imperata brevifolia*)
4. ribbed cryptantha (*Johnstonella costata*)
5. winged cryptantha (*Johnstonella holoptera*)

No federally listed threatened or endangered wildlife species have the potential to occur on the Project Site and no critical habitat exists on or near the Project Site (USFWS 2019a, b). No California special status species are known to occur on the Project Site (CDFW 2019).

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The following six migratory bird species are listed by IPaC as having the potential to occur in the vicinity of the Project Site:

6. Burrowing owl (*Athene cunicularia*)
7. Costa's hummingbird (*Calypte costae*)
8. Gila woodpecker (*Melanerpes uropygialis*)
9. Long-billed curlew (*Numenius americanus*)
10. Rufous hummingbird (*Selasphorus rufus*)
11. Whimbrel (*Numenius phaeopus*)

The Project Site appears to be devout of any vegetation or water resources; the proposed disturbance area is not suitable habitat for any of the sensitive species identified above. The Project Site is not designated by Imperial County for native habitat or conservation. However, the following mitigation will be required prior to construction to mitigate any possible occurrence prior to construction and operation of project upgrades.

Mitigation BR-1: Prior to any construction activities commencing on site, contractors shall attend a Worker Environmental Awareness Program (WEAP) regarding sensitive biological resources potentially occurring within the BSA. A person knowledgeable about the biology of the covered species shall present the program. At a minimum, the program shall cover the distribution of special-status species, general behavior and ecology of these species, their sensitivity to human activities, their legal protection, the penalties for violation of state and federal laws, reporting requirements, project mitigation measures, and measures to implement in the event that this species is found during construction. A fact sheet containing this information shall also be prepared and distributed. The program shall be presented to all members of the construction crew prior to the start of project construction activities. New employees shall receive formal, approved training prior to working onsite. Upon completion of the orientation, employees will sign a form stating that they attended the program and understand all protection measures. These forms shall be made available to CDFW upon request.

Mitigation BR-2: In accordance with the Staff Report on Burrowing Owl Mitigation (CDFW 2012), a preconstruction take avoidance survey shall be conducted (CDFW 2012). If the burrowing owl is absent, then no mitigation is required. If present, the following mitigation shall be implemented.
If burrowing owls and their habitat can be protected in place on or adjacent to a project site, then disturbance impacts shall be minimized through the use of buffer zones, visual screens, or other measures in accordance with CDFW (2012).

Occupied burrows shall be avoided during the breeding period from February 1 through August 31 (CDFW 2012). "Occupied" is defined as a burrow that shows sign of burrowing owl occupancy within the last 3 years. Occupied burrows shall also be avoided during the non-breeding season.

Burrow exclusion is a technique of installing one-way doors in burrow openings during the non-breeding season to temporarily exclude burrowing owls, or permanently exclude burrowing owls and close burrows after verifying burrows are empty by site monitoring and scoping (CDFW 2012).

Mitigation for permanent impacts to nesting, occupied, and satellite burrows and/or burrowing owl habitat is required such that the habitat acreage, number of burrows and burrowing owls impacted are replaced based on the burrowing owl life history information provided in Staff Report on Burrowing Owl Mitigation (CDFW 2012). Coordination with CDFW may be necessary for the development of site-specific avoidance and mitigation measures.

Mitigation BR-3: Protection of nesting birds would be required in compliance with the MBTA and to avoid impacts to nesting birds. To avoid impacts to nesting birds and to comply with the MBTA, clearing of vegetation should occur between non nesting (or non-breeding) season for birds (generally, September 1 to February 1). If this avoidance schedule is not feasible, the alternative is to carry out the clearing of vegetation associated with construction under the supervision of a qualified biologist. This shall entail a pre-construction nesting bird survey conducted by a qualified biologist within 14 days prior to initiating ground disturbance activities. The survey shall consist of full coverage of the proposed disturbance limits and a 500 foot buffer. The buffer shall be determined by the biologist and will take into account the species nesting in the area and the habitat present. If no active nests are found, no additional measures are required. If "occupied" nests are found, the nest locations shall be mapped by the biologist, utilizing GPS equipment. The nesting bird species shall be documented and, to the degree feasible, the nesting stage (e.g., incubation of eggs, feeding of young, near fledging). The biologist shall establish a no disturbance buffer around each active nest. The buffer will be determined by the biologist based on the species present and surrounding habitat. No construction or ground disturbance activities shall be conducted within the buffer until the biologist has determined the nest is no longer active and has informed the construction supervisor that activities may resume.

Mitigation BR-4 If pre-construction surveys determine either the presence of special status species or sensitive biological resources, a construction monitor may be needed during construction. If determined necessary, construction monitoring shall be conducted by a qualified biologist. The biologist shall be given authority to execute the following functions:
• Establish construction exclusion zones and make recommendations for implementing erosion control measures in temporary impact areas.

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- Ensure all construction activities stay within the staked construction zone and do not go beyond the limits of disturbance.
- Minimize trimming/removal of vegetation to within the Project impact area.
- Restrict non-essential equipment to the existing roadways and/or disturbed areas to avoid disturbance to existing adjacent native vegetation.
- Install and maintain appropriate erosion/sediment control measures, as needed, throughout the duration of work activities.

During construction, biological monitors shall inspect and verify field conditions, as needed, to ensure that wildlife and vegetation adjacent to the BSA are not harmed. The biological monitor shall coordinate with the construction supervisor and construction crew and shall have the authority to stop any activity that has the potential to affect special-status species or remove vegetation not specified in this report.

b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service? ☐ ☒ ☐ ☐

b) Possible Significant Unless Mitigated. As discussed in Section 3.1.4, no water resources or sensitive communities are present on or near the Project Site (see Figure 6 above and Appendix A). Neither construction nor operation of the proposed facilities would create any substantially adverse offsite impacts. Therefore, no impacts to riparian habitat or sensitive natural communities would occur as a result of the Project. Additionally, as proposed as an Environmental Protection Measure, **SIGC will perform a pre-construction survey to verify the absence of any sensitive species (i.e. burrowing owl please see above mitigation BR-1- BR-4).**

c) Have a substantial adverse effect on state or federally protected wetlands (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means? ☐ ☐ ☐ ☒

c) No Impact. As discussed in Section 3.1.4, no wetlands or water resources are present on the Project Site; therefore, no impacts to wetland, riparian resources, or jurisdictional waters would occur as result of the Project.

d) Would the project interfere substantially with the movement of any resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites? ☐ ☒ ☐ ☐

d) Possible Significant Unless Mitigated. The existing Heber 2 Complex site is entirely fenced for security purposes, precluding wildlife from using the site as habitat or for migration. Further, the Project Site is entirely devoid of vegetation or water features that could be used as suitable resident or migratory habitat. Therefore, it appears the development of the proposed facilities within the existing plant site would not remove suitable wildlife habitat or migratory corridor/connectivity, nor would the facilities impede the use of nursery sites. Additionally, as proposed as an Environmental Protection Measure, **SIGC will perform a pre-construction survey to verify the absence of any sensitive species (i.e. burrowing owl. Please see mitigation BR-1 – BR-4).**

e) Conflict with any local policies or ordinance protecting biological resource, such as a tree preservation policy or ordinance? ☐ ☐ ☐ ☒

e) No Impact. No local policies or ordinances protecting biological resources, including the Fish and Game Natural Areas established in the Imperial County General Plan, pertain to the Project Site. Further, the Project Site is completely devoid of any vegetation or water resources that could serve as suitable habitat for trees or wildlife. Therefore, no impacts to any local policies/ordinances would be impacted by the Project.

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan? ☐ ☐ ☐ ☒

f) No Impact. There are no HCPs or similar conservation areas/plans for the Project Site or its vicinity. Therefore, the Project would not impacted any HCPs or other conservation plans.

V. *CULTURAL RESOURCES Would the project:*

a) Cause a substantial adverse change in the significance of a historical resource pursuant to §15064.5? ☐ ☐ ☐ ☒

a) No Impact. A records search of the California Historical Resources Information System (CHRIS), which is managed by the California Office of Historic Preservation (OHP), for previous cultural and historic resource surveys previously performed on/near the Project Site was performed did not identify any recorded historical resources on the Project Site or immediate vicinity (Appendix C). Further, there are no buildings or structures present on the Project Site. Therefore, the Project would not result in any impacts to historical resources.

b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to §15064.5? ☐ ☐ ☐ ☒

b) No Impact. The CHRIS records search did not identify any recorded cultural or archaeological resources on the Project Site or immediate vicinity (Appendix C). Considering that the Project Site was completely disturbed when the Heber 2 Complex was constructed, the probability of encountering an unforeseen/buried resource is very low. As discussed in Section 2.1.8 above, Project construction personnel would monitor areas during surface disturbing activities and if any potential cultural or archaeological resources are encountered, all construction affecting the discovery site would be suspended immediately until a qualified archaeologist has reviewed the findings. An Unanticipated Discoveries Plan would be prepared prior to resuming construction. Therefore, the Project is anticipated to result in no significant effects to archaeological or cultural resources.

c) Disturb any human remains, including those interred outside of dedicated cemeteries? ☐ ☐ ☒ ☐

c) Less Than Significant. Considering that the Project Site was completely disturbed when the Heber 2 power plant was constructed, the probability of encountering unforeseen/buried human remains is very low. As discussed in Section 2.1.8 above, Project construction personnel would monitor areas during surface disturbing activities and if any potential cultural or archaeological resources are encountered, all construction affecting the discovery site would be suspended immediately until a qualified archaeologist has reviewed the findings. An Unanticipated Discoveries Plan would be prepared prior to resuming construction. Therefore, the Project is anticipated to result in no or less than significant effects to human remains.

VI. *ENERGY Would the project:*

a) Result in potentially significant environmental impact due to wasteful, inefficient, or unnecessary consumption of energy resources, during project construction or operation? ☐ ☐ ☐ ☒

a) No Impact: The proposed facility upgrades would allow the Heber 2 Complex to run more efficiently and refurbish the Heber 2 Complex to the original nameplate capacity (33 megawatts) without expanding the existing facility beyond the current footprint, and produce clean renewable energy in the Imperial Valley for the next three decades.

b) Conflict with or obstruct a state or local plan for renewable energy or energy efficiency? ☐ ☐ ☐ ☒

b) No Impact: The Project would allow for the continued operation of a permitted major geothermal energy power plant that utilizes the geothermal energy zone established by Imperial County. The proposed facilities would not increase the use of the geothermal

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

resource/reservoir, rather allow the existing Heber 2 Complex to operate more efficiently and return its nameplate energy generation capacity to 33 MW. The Heber 2 Complex has been producing renewable energy since 1992 and the proposed facilities would allow for that to be extended until 2049, assisting with meeting the state mandates for renewable energy and reducing greenhouse gas emissions.

VII. *GEOLOGY AND SOILS Would the project:*

a) Directly or indirectly cause potential substantial adverse effects, including risk of loss, injury, or death involving: ☐ ☒ ☐ ☐

Potentially Significant Unless Mitigated. As discussed in Section 3.1.2, the Imperial Valley is seismically active and contains numerous active faults (ICPDS 2015). A formal geotechnical investigation of the Project Site's soil characteristics, seismic conditions, storm-water infiltration, site stability, and potential for liquefaction was conducted. A summary memorandum and full technical report are attached as **Appendix E.** A computer-aided search assessed known faults and seismic zones within 36 miles of the Project Site. The Imperial Fault located 9.4 miles southwest of the Project Site was the closest mapped Earthquake Fault Zone. The Project Site is not located in an established fault zone as identified by the Alquist-Priolo Earthquake Fault Zoning Maps (Bryant 2007). In the event of an earthquake, seismic ground-shaking could be experienced in the vicinity of the Project Site, as is typical throughout Southern California. The Project Site is not located in a landslide zone. The Project Site is not located in a potential seiche, tsunami, or mudflow zone.

No deep subsurface activities (i.e. deeper than 6 feet) are proposed as part of the Project; thus, no ruptures to faults or fissures would occur as a result of the Project. Seismic ground-shaking and seismically induced liquefaction could result in structural damage to power plant infrastructure and facilities. However, the Project does not involve any infrastructure or facilities that would include human occupancy, and the risk of injury at the Project Site associated with ground-shaking, landslides, tsunami/seiche or liquefaction is very low. However, the following mitigation will be required prior to issuance of a grading permit to help mitigate in the unlikely event of any of the above occurrences.

Mitigation GS-1: Prior to approval of a grading or a building permit, a California certified civil/geotechnical engineer shall prepare a geotechnical investigation of the Project site that includes appropriate subsurface exploration, laboratory testing, and evaluation of potential geotechnical constraints to critical Project structures, including liquefaction, corrosion, seismic shaking and shrink swell evaluations. The report shall include specific recommendations to address issues identified in the geotechnical investigation of the Project site to meet State and County seismic building code requirements. An ICPDS approved third party environmental monitor shall be on site during geotechnical investigations.

1) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42? ☐ ☒ ☐ ☐

1) Potentially Significant Unless Mitigated. As discussed in Section 3.1.2, the Imperial Valley is seismically active and contains numerous active faults (ICPDS 2015). A formal geotechnical investigation of the Project Site's soil characteristics, seismic conditions, storm-water infiltration, site stability, and potential for liquefaction was conducted. A summary memorandum and full technical report are attached as Appendix E. A computer-aided search assessed known faults and seismic zones within 36 miles of the Project Site. The Imperial Fault located 9.4 miles southwest of the Project Site was the closest mapped Earthquake Fault Zone. The Project Site is not located in an established fault zone as identified by the Alquist-Priolo Earthquake Fault Zoning Maps (Bryant 2007). In the event of an earthquake, seismic ground-shaking could be experienced in the vicinity of the Project Site, as is typical throughout Southern California. The Project Site is not located in a landslide zone. The Project Site is not located in a potential seiche, tsunami, or mudflow zone.

No deep subsurface activities (i.e. deeper than 6 feet) are proposed as part of the Project; thus, no ruptures to faults or fissures would occur as a result of the Project. Seismic ground-shaking and seismically induced liquefaction could result in structural damage to power plant infrastructure and facilities. However, the Project does not involve any infrastructure or facilities that would include human occupancy, and the risk of injury at the Project Site associated with ground-shaking, landslides, tsunami/seiche or liquefaction is very low. Therefore, impacts to people or structures from the Project

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

would be less than significant.

Mitigation Please see GS-1

2)	Strong Seismic ground shaking? **2) Potentially Significant Unless Mitigated** (see mitigation GS-1)	☐	☒	☐	☐
3)	Seismic-related ground failure, including liquefaction and seiche/tsunami? **3) Potentially Significant Unless Mitigated** (see mitigation GS-1)	☐	☒	☐	☐
4)	Landslides? **4) Less than Significant** (see above a)	☐	☐	☒	☐
b)	Result in substantial soil erosion or the loss of topsoil?	☐	☐	☒	☐

b) Less Than Significant. Minor excavation and compaction activities would occur to prepare the appropriate bases for the OEC units and the ABSTs. The Project Site is an active geothermal energy station and does not contain high-value topsoil. Any soils excavated for site preparation would be backfilled to the excavation areas, assuming that these soils are free of debris. No pervious surfaces would be created as part of the Project, and storm-water would be allowed to infiltrate on bare soils, which represent the current conditions. Therefore, less than significant soil impacts are anticipated to occur as result of the Project.

c)	Be located on a geologic unit or soil that is unstable or that would become unstable as a result of the project, and potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction or collapse?	☐	☒	☐	☐

c) Potentially Significant Unless Mitigated. Development of the proposed facilities would not appear to result in the destabilization of any soils or geologic units that could cause a landslide, subsidence, or liquefaction. The primary soil unit present on the Project Site is dry silty clays, which are not expansive or unstable soils (Olive, 1989). However, **Mitigation GS-1** would appear to mitigate any significant impacts on the construction and operation of Project.

d)	Be located on expansive soil, as defined in the latest Uniform Building Code, creating substantial direct or indirect risk to life or property?	☐	☐	☐	☒

d) No Impact. Development of the proposed facilities would not result in the destabilization of any soils or geologic units that could cause a landslide, subsidence, or liquefaction. The primary soil unit present on the Project Site is dry silty clays, which are not expansive or unstable soils (Olive, 1989). Therefore, no impacts on unstable soils or geologic units would occur from the Project.

e)	Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?	☐	☐	☐	☒

e) No Impact. The Project does not include any septic tanks or wastewater disposal systems; thus, no impact to soils from wastewater systems/management would occur as a result of the Project.

f)	Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☒	☐

f) Less Than Significant. Considering that the Project Site was completely disturbed when the Heber 2 power plant was constructed, the probability of encountering an unforeseen/buried human remains is very low. As discussed in Section 2.1.8 above, Project construction personnel would monitor areas during surface disturbing activities and if any potential cultural or archaeological resources are encountered, all construction affecting the discovery site would be suspended immediately until a qualified archaeologist has reviewed the findings. An Unanticipated Discoveries Plan would be prepared prior to resuming construction.

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

Therefore, the Project is anticipated to result in no or less than significant effects to human remains.

VIII. *GREENHOUSE GAS EMISSION* *Would the project:*

a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment? ☐ ☐ ☒ ☐

a) Less Than Significant. The construction of the Project involves diesel- and gasoline-fueled equipment, such as trucks, excavators, and powered hand tools. These tools emit greenhouse gases, but these emissions would be minor, temporary (approximately eight months), and well under the 10,000 CO_2e lb/day threshold established by AB 32.

Greenhouse gas emissions from the Heber 2 Complex after the new facilities are developed would not increase. Therefore, greenhouse gas emissions as result of the Project would be less than significant.

b) Conflict with an applicable plan or policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases? ☐ ☐ ☒ ☐

b) Less Than Significant. The Project would not contribute a significant amount of greenhouse gases, with most being emitted during the temporary construction phase. Long-term emissions from the Heber 2 Complex would remain the same or very similar to the existing emissions profile. Therefore, less than significant impacts to any greenhouse gas reduction plans, policy, or regulations would be caused, and only during Project construction.

IX. *HAZARDS AND HAZARDOUS MATERIALS* *Would the project:*

a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials? ☐ ☒ ☐ ☐

12. **Potentially Significant unless Mitigated.** The Project would utilize isopentane as the motive fluid to generate energy from the geothermal resource/fluids. The Project proposes to install three additional 10,000-gallon ABSTs for additional isopentane storage/use. Isopentane is a regulated substance by the USEPA. The Heber 2 Complex is classified as Prevention Program 3 and is regulated by USEPA's Risk Management Program for Chemical Accidental Release Prevention (40 CFR 68.20-68.42) because isopentane is stored on site in excess of 10,000 lbs. Isopentane would be delivered to the Project Site by a licensed commercial transport company, in accordance with US DOT regulations for the transport of dangerous goods.

An Updated Hazard Assessment (HA) was prepared to assess the potential effects and risks of the additional isopentane storage/use by the Project (**Appendix G**). The HA analyzed the isopentane storage/use by identifying the worst-case scenarios and endpoints of concern (as defined by EPA RMP and 40 CFR 68.22) including the following:

13. Explosion (an overpressure of 1 psi)
14. Radiant Heat/Exposure Time (a radiant heat of 5 kW/m^2 for 40 seconds)
15. Lower Flammability Limit (as provided by NFPA)

Using these criteria, the HA assessed the worst-case scenario of a catastrophic failure of one of the three new 10,000-gallon isopentane tanks. As modeled in the HA, the worst-case scenario event would have an impact up to 0.3 miles, or 1,584 feet. The closest potentially affected public are the residences approximately 3,500 feet to the northeast of the isopentane tanks. Therefore, the public or environment would not be exposed to a significant hazard through the Project's use/storage/transport of isopentane.

RMP has developed an updated worst-case modeling scenario for the isopentane currently and soon to be stored at the Heber 2 facility. According to the EPA Risk Management Plan regulations, the worst-case release is defined as "the release of the largest quantity of a regulated substance from a vessel failure that results in the greatest distance to a specified endpoint" (40 CFR § 68.3).

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To determine the worst case release quantity, the EPA regulations dictate "for substances in vessels, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity" must be analyzed (40 CFR § 68.25). In compliance with these regulations, RMP modeled the worst-case scenario as the catastrophic failure of one 10,000-gallon isopentane storage vessel. With the incorporation of a concrete containment area as mitigation, the endpoint radius resulting from the release of one vessel was determined to stay within the property boundary and not to reach any new (#1, #2, and #3) or existing (#4, #5,) vessels. Please see attached Figure 7.

The only overlap of concern is in regard to vessel locations #4 and #5 where they reside in one another's areas of impact. However, plans to construct a blast wall between the two existing tanks will eliminate this concern. The EPA's Offsite of Consequences Analysis process, is recognized by process safety professionals as being highly conservative, rendering these scenarios very unlikely.

A certified fire protection engineer survey and analysis of current and proposed fire suppression and detection equipment will be performed to evaluate the current systems performance and coverage of protection prior to construction. This analysis will evaluate proposed fire suppression and detection equipment in conjunction with existing equipment and be reviewed and approved by the Fire Department and OES prior to building permits approval. Isopentane leak or fire will require a large scale evacuation area and create a large scale hazardous material incident with a large operational zone.

Mitigations: HZ

1. To minimize potential extremely dangerous condition to firefighters and hazardous material teams Imperial County Fire Department is requiring that a Drone be purchase for Imperial County Fire Department. The final cost, details, and equipment of the drone shall be determined prior the issuance of the building permit. Additionally, the following requirements will be conditioned in the proposed Conditional Use Permit. The drone usage will help reduce required monitoring and compliance impacts to a level of less than significant.
2. All isopentane storage tanks will be protected by approved automatic fire suppression equipment. All automatic fire suppression will be installed and maintained to the current adapted fire code and regulation.
3. An approved automatic fire detection system will be installed as per the California Fire Code. All fire detection systems will be installed and maintained to the current adapted fire code and regulations.
4. Fire department access roads and gates will be in accordance with the current adapted fire code and the facility will maintain a Knox Box for access on site.
5. Compliance with all required sections of the firecode.
6. Applicant will provide product containment areas(s) for both product and water run-off in case of fire applications and retained for removal.
7. Each tank will be equipped with an automated water suppression system.
8. Each tank will be equipped with two flame detectors and one gas detector (for a total of 6 flame detectors and 3 gas detectors for the three tanks).
9. In the case of an isopentane leak, the gas detector(s) will detect it immediately and send a notification to the operator at the control room (manned 24/7) in order to mobilize fixing the leak.
10. In case of a fire, the flame detector(s) will detect it and immediately start the automatic fire suppression system.
11. In case of a fire, there will also be a horn and strobe system that will turn on automatically to alert the plant employees.
12. Concrete containment areas for isopentene ,
13. vessels rarely filled to 90% capacity,
14. isopentane safety- control measures,
15. A blast wall between currently operational isopentene tanks #4 & #5.
16. To minimize the potential for a cascading failure event of the proposed isopentane tanks and to limit potential impacts within the existing Heber 2 Complex fence line, the three proposed isopentane tanks shall be located as set forth in the attached Figure 7.

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

17. Diking and impoundment of the proposed isopentane tanks shall be installed to minimize the magnitude and extent of a tank failure.

b) Create a significant hazard to the public or the environment through reasonable foreseeable upset and accident conditions involving the release of hazardous materials into the environment? ☐ ☒ ☐ ☐

a) Significant unless Mitigated see above (a) for Mitigations

c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school? ☐ ☐ ☐ ☒

c) No Impact. There are no schools or sensitive receptors within a quarter-mile of the Project Site (Appendix G). The closest potential sensitive receptors are located approximately 3,500 feet to the northeast of the Project Site. Therefore, no significant impacts to schools or sensitive receptors from nominal isopentane releases/emissions would occur due to the Project.

d) Be located on a site, which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment? ☐ ☐ ☐ ☒

d) No Impact. The Project Site is not located on a site that is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, therefore, would not create a significant hazard to the public or environment.

e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard or excessive noise for people residing or working in the project area? ☐ ☐ ☐ ☒

e) No Impact. The Project Site is not located in an airport land use plan or within two miles of an active airport. Therefore, the Project would have no impact on ongoing or planned airport activities or people/employees.

f) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan? ☐ ☐ ☐ ☒

f) No Impact. The proposed facilities would be located within the existing Heber 2 Complex site and would not interfere with any emergency response or evacuation plans. Construction equipment delivering large components of the proposed facilities may temporarily block Dogwood Road to ensure safe delivery of the components, but these blockages are expected to be temporary (i.e., 5 minutes) and not significantly impede traffic flow. Therefore, no impacts to emergency response or evacuation plans would occur as result of the Project.

g) Expose people or structures, either directly or indirectly, to a significant risk of loss, injury or death involving wildland fires? ☐ ☐ ☐ ☒

g) No Impact. The Project Site is not located in areas considered wildlands, as the vast majority of the surrounding area is cultivated farmlands. The Project Site does not lie within a fire hazard zone and is not subject to risk of wildland fires (CalFire, 2007). Therefore, there would be no impact associated with risk from wildlands fire.

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	Potentially Significant Impact **(PSI)**	Potentially Significant Unless Mitigation Incorporated **(PSUMI)**	Less Than Significant Impact **(LTSI)**	No Impact **(NI)**

X. ***HYDROLOGY AND WATER QUALITY*** ***Would the project:***

a) Violate any water quality standards or waste discharge requirements or otherwise substantially degrade surface or ground water quality? ☐ ☐ ☐ ☒

a) No Impact. The proposed Project would not discharge any waste fluids or substances, nor violate any water quality standards; therefore, no impacts to water quality would occur as result of the Project.

b) Substantially decrease groundwater supplies or interfere substantially with groundwater recharge such that the project may impede sustainable groundwater management of the basin? ☐ ☐ ☐ ☒

b) No Impact. The proposed Project would not require additional groundwater/geothermal fluids. One production and two injection wells are present on the Heber 2 site and the quantity of injection fluid would remain the same under the Project. Therefore, no impacts to groundwater supplies would occur as result of the Project.

c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river or through the addition of impervious surfaces, in a manner which would: ☐ ☐ ☒ ☐

c) **No Impact.** The Project would not divert or alter any existing streams or canals on/near the Project Site. The Project would create less than 200 square feet of impervious surface to accommodate the proposed facilities. The remainder of the Project Site would be exposed dirt/gravel. Therefore, the Project would not increase storm-water runoff or result in on- or off-site flooding.

(i) result in substantial erosion or siltation on- or off-site; ☐ ☐ ☒ ☐

i) **Less Than Significant.** The Project would not divert or alter any existing streams or canals on/near the Project Site. The Project Site was graded during the original construction of the Heber 2 Complex in 1992 and site preparation activities would not significantly alter the existing grade of the Project Site. A Water Quality Management Plan (WQMP) prepared for the Project assesses potential effects to storm-water and provides recommendations and Best Management Practices (BMPs) to minimize potential erosion and siltation effects (**Appendix D**). Through the application of the WQMP, construction effects from site preparation would not result in a less than significant effect to existing drainage patterns.

(ii) substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or offsite; ☐ ☐ ☒ ☐

ii) **Less Than Significant.** The Project would not divert or alter any existing streams or canals on/near the Project Site. The Project Site was graded during the original construction of the Heber 2 Complex in 1992 and site preparation activities would not significantly alter the existing grade of the Project Site. A Water Quality Management Plan (WQMP) prepared for the Project assesses potential effects to stormwater and provides recommendations and Best Management Practices (BMPs) to minimize potential erosion and siltation effects (**Appendix D**). Through the application of the WQMP, construction effects from site preparation would not result in a less than significant effect to existing drainage patterns.

(iii) create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff; or; ☐ ☐ ☒ ☐

iii) **Less than Significant.** The Project would not divert or alter any existing streams or canals on/near the Project Site. The

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

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(iv) impede or redirect flood flows? ☐ ☐ ☒ ☐

iv) **Less Than Significant.** The Project would not divert or alter any existing streams or canals on/near the Project Site. The Project Site was graded during the original construction of the Heber 2 Complex in 1992 and site preparation activities would not significantly alter the existing grade of the Project Site. A Water Quality Management Plan (WQMP) prepared for the Project assesses potential effects to stormwater and provides recommendations and Best Management Practices (BMPs) to minimize potential erosion and siltation effects (**Appendix D**). Through the application of the WQMP, construction effects from site preparation would not result in a less than significant effect to existing drainage patterns.

d) In flood hazard, tsunami, or seiche zones, risk release of pollutants due to project inundation? ☐ ☐ ☐ ☒

d) No Impact. The Project Site is not located in a potential seiche, tsunami, or mudflow zone. Additionally, the Geotechnical Analysis (Appendix E) concludes that liquefaction would not occur at the Project Site due to the cohesive nature of the subsurface soils. Therefore, the Project would not expose any people or structures to a significant risk of loss, injury, or death involving a seiche, tsunami, or mudflow.

e) Conflict with or obstruct implementation of a water quality control plan or sustainable groundwater management plan? ☐ ☐ ☒ ☐

e) Less Than Significant. Construction of the proposed facilities would not significantly alter the existing stormwater drainage pattern or grade. The existing site condition is exposed soils and gravel, and after site preparation, this area would be returned to a soil/gravel surface. The Project would create less than 200 square feet of impervious surface to accommodate the proposed facilities. The remainder of the Project Site would be exposed dirt/gravel that follows the existing grade of the Site. Stormwater would be allowed to infiltrate and would follow the existing drainage patterns to the existing Heber 2 stormwater facilities. With less than 200 square feet of impervious surfaces being developed as part of the Project, the amount of stormwater to the existing basins would not increase. Therefore, the Project would cause a less than significant addition of stormwater to the existing stormwater infrastructure and would create a less than significant amount of stormwater pollution. The proposed facilities would not discharge any fluids or substances to surface waters; therefore, construction of the Project is the only phase during which water quality may be impacted. Construction activities would have the potential to expose site soils to erosion and mobilize sediments in stormwater. However, with the application of the WQMP (**Appendix D**), on- and off-site erosion and siltation impacts to water quality related to construction of the Project would be less than significant.

XI. *LAND USE AND PLANNING Would the project:*

a) Physically divide an established community? ☐ ☐ ☐ ☒

a) No Impact. As discussed in Section 3.1, the Project Site is zoned for major geothermal energy projects by Imperial County, and the Project is consistent with the standards and objectives set forth in the Imperial County Renewable Energy Plan. Therefore, the Project is consistent with the land use designations established by Imperial County and will not result in an incompatible land use. Furthermore, the closest residents are approximately 3,500 feet to the northeast to the Heber 2 site and would not experience a physical effect from the construction or operation of the proposed facilities.

b) Cause a significant environmental impact due to a conflict with any land use plan, policy, or regulation adopted for the purpose of avoiding or mitigating an environmental effect? ☐ ☐ ☐ ☒

b) No Impact. The Project Site is zoned as A-2-G-SPA, for General Agriculture (A-2), Geothermal Overlay Zone (G), and in the Heber Specific Plan Area (SPA). The Project site is entirely within the Imperial County Geothermal Overlay Zone. "Major Geothermal Projects" in the overlay zone are permitted through the CUP process, as was the original Heber 2 project. The Heber SPA is intended "to allow for commercial, residential, industrial, renewable energy and other employment oriented development in a mixed used orientation" (Land Use Element of the Imperial County General Plan, 2015). Therefore, the proposed Project conforms to the standards and goals

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

set forth in the Imperial County General Plan and the Renewable Energy and Transmission Element of County of Imperial General Plan (2015) and would not result in an effect to land use/planning. No habitat conservation plans or natural community conservation plans are designate for the Project Site; therefore, the Project would not result in any impact to these plans or programs.

XII. ***MINERAL RESOURCES*** ***Would the project:***

a)	Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	☒

a) No Impact. The Project would allow for the continued operation of a permitted major geothermal energy power plant that utilizes the geothermal energy zone established by Imperial County. The proposed facilities would not increase the use of the geothermal resource/reservoir, rather allow the existing Heber 2 Complex to operate more efficiently and return its nameplate energy generation capacity to 33 MW. The Heber 2 Complex has been producing renewable energy since 1992 and the proposed facilities would allow for that to be extended until 2049, assisting with meeting the state mandates for renewable energy and reducing greenhouse gas emissions. Therefore, the Project would result in no impacts to a known mineral resource.

b)	Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☒

b) No Impact. The Project Site is zoned by Imperial County for major geothermal energy projects, and the Project is in conformance with this land use designation. The proposed facilities would not increase the use of the geothermal resource/reservoir, rather allow the existing Heber 2 Complex to operate more efficiently and return its nameplate energy generation capacity to 33 MW. The Project would not prohibit any additional development of geothermal energy facilities in Imperial County. Therefore, the Project would not result in the loss of availability of this unique local geothermal resource.

XIII. ***NOISE*** ***Would the project result in:***

a)	Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☒

a) No Impact. Per the Imperial County Noise Ordinance, the noise limit for the Project Site, which is considered an Industrial facility by the ordinance, is 75 decibels (one-hour average sound level) and allowed to operate 24 hours per day. The proposed facilities would not represent a significant new source of noise, as the OECs and storage tanks are fully contained units (see Figure 4 and Figure 5 above for pictures of the proposed facilities). Further, the new OEC units would replace dated equipment, and may result in a reduction in operational noise. Considering the Project is within the "normally acceptable" range established by Imperial County and the Project is not anticipated to increase noise emissions from the existing plant, the Project operation would result in a less than significant noise impact. Additionally, the closest receptors to facility noise are located approximately 3,500 feet to the northwest of the Project Site and well out of range from hearing the facility. The Heber 2 Complex has never received a noise complaint.

Construction activities would be limited to 7 a.m. to 7 p.m. Monday through Friday, and 9 a.m. to 5 p.m. on Saturday, per the Imperial County Noise Ordinance. During construction, noise emissions would be periodic and temporary, depending on the use of the heavy equipment (i.e., semi-truck trailers, flatbed trucks, excavators/bulldozers, and a crane). Smaller hand tools such as drills, compressors, and welding equipment would be used consistently during the construction phase (approximately eight months). Construction noise from the development of the proposed facilities would likely be drowned out from the existing noise conditions at the Heber 2 Complex, which is permitted to emit up to 75 decibels any time of the day (§90702.00 – Sound Level Limits). Further, there are no sensitive receptors in close proximity to the Heber 2 site, and the closest residence is over 3,500 feet away from the Project Site. Therefore, Project construction and operation would not expose of noise to people and would not exceed county noise ordinance levels.

b)	Generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	☒	☐

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

b) Less Than Significant: The only phase of the Project that would generate vibration or ground-borne noise is the site preparation activities, which include minor excavation and compaction. Site preparation activities would result in varying degrees of temporary ground vibration, depending on the specific construction equipment used and operations involved. All heavy, mobile construction equipment would be temporary.

c) For a project located within the vicinity of a private airstrip or an airport land use plan or where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels? ☐ ☐ ☐ ☒

c) No Impact The project site is not located within the vicinity of a private airstrip and or airport land use plan or within two miles of a public airport or public use airport.

XIV. *POPULATION AND HOUSING* *Would the project:*

a) Induce substantial unplanned population growth in an area, either directly (for example, by proposing new homes and business) or indirectly (for example, through extension of roads or other infrastructure)? ☐ ☐ ☐ ☒

a) No Impact. The Project would require a temporary increase in labor force (15 workers) during the short-term construction period (approximately eight months). It is assumed that the workforce would be from southern California and would likely not require accommodations. The Project does not involve the construction of any new housing or commercial areas that would attract new residents to the area. The proposed project improvements are designed within the existing footprint to the current ongoing geothermal operation. The expansion would not appear to induce population growth in the area. The construction of work is temporary and any additional full time work would not appear to be substantial impact.

b) Displace substantial numbers of existing people or housing, necessitating the construction of replacement housing elsewhere? ☐ ☐ ☐ ☒

b) No Impact. Construction of the proposed Project would not displace any existing people in the vicinity of the Project Site. Therefore, no impacts to residents would occur as result of the Project The project development within the existing geothermal facility will be to replace, repair and update is electrical generation site. There would not appear to be any displacement of full time workers. The construction is temporary.

XV. *PUBLIC SERVICES*

a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services: ☐ ☐ ☒ ☐

1) Fire Protection? ☐ ☐ ☒ ☐

1) Less Than Significant. Considering that the existing environment is an operating geothermal energy plant, the Project would not significantly increase the demand for public services. Additional fire response could be needed in the instance of a catastrophic event with an isopentane tank. A Hazard Assessment (**Appendix G & L**) was prepared for the Project and concluded that the likelihood of a catastrophic event is highly unlikely. Therefore, potential impacts to public services are less than significant. The applicant has agreed to supply a drone for project site which would be used by the Fire Department to inspect and insure the safety of personnel on site during operation and inspection of facility.

2) Police Protection? ☐ ☐ ☐ ☒

2) No Impact. This proposed project would not appear to impact police protection at the site or nearby neighborhoods. The construction is within the footprint of the existing facility. The Project would not result in any new security risks, nor an increase in

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

population or housing; therefore, the Project would not impact police protection services.

3) Schools? ☐ ☐ ☐ ☒

3) No Impact. The Project would not result in an increase in population or housing and would not require additional school services.

4) Parks? ☐ ☐ ☐ ☒

4) No Impact. The Project would not result in an increase in population or housing and would not increase demand/use for local parks.

5) Other Public Facilities? ☐ ☐ ☐ ☒

5) No Impact. The Project would not put an increased burden on off-site public services, including existing fire, police, school and other governmental services. Therefore, no impact would occur.

XVI. *RECREATION*

a) Would the project increase the use of the existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated? ☐ ☐ ☐ ☒

a) No Impact. The Project would require a temporary increase in labor force during the short-term construction period (approximately eight months). It is assumed that the workforce would be local and not require accommodations. Therefore, the Project would not result in an increase in population that would increase use of existing neighborhood or regional recreational facilities. Therefore, no impact would occur as result of developing the Project.

b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse effect on the environment? ☐ ☐ ☐ ☒

b) No Impact. Development of the proposed facilities would not restrict or preclude access to any recreational opportunities or assets/parks in the area. The Project would require a temporary increase in labor force during the short-term construction period (approximately eight months). It is assumed that the workforce would be local and not require accommodations. Therefore, the Project would have no impact on the in demand/use of recreational facilities that would have an adverse physical effect on the environment.

XVII. *TRANSPORTATION* ***Would the project:***

a) Conflict with a program plan, ordinance or policy addressing the circulation system, including transit, roadway, bicycle and pedestrian facilities? ☐ ☐ ☒ ☐

1) **Less Than Significant**. Lone site access is provided via Dogwood Road, which is classified as a Regional Arterial in the Imperial County Long Range Transportation Plan (2013). Dogwood Road's Average Daily Traffic (ADT) is approximately 15,000 vehicles per day and its level of service (LOS) is E. LOS E indicates that this arterial is operating at capacity and traffic flow can be irregular.

Construction of the proposed facilities may result in nominal and short-term increases in vehicle trips by construction workers and construction vehicles on area roadways. These trips would include construction workers commuting to and from the Project Site, haul truck trips associated with the transfer and disposal of materials, and material and equipment deliveries. The number of construction-related trips would vary each day, depending on construction phase, planned activity, and material needs.

Construction traffic on roadways in the immediate vicinity of the Project site and along haul routes could result in nominal and short-term increases in traffic volumes. The presence of construction trucks, with their slower speeds and larger turning radii, may temporarily reduce roadway capacities in the immediate vicinity of the Project Site. These nominal impacts of construction traffic would be most noticeable in the immediate vicinity of the Project site and less noticeable farther away and on regional roadways. Considering that no

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

new employees would be hired to support the new facilities, all traffic-related impacts would be temporary and only occur during the construction phase (eight months).

Therefore, Project construction would cause incremental, short-term increases in traffic but construction-related trips are expected to be approximately 25-40 per day and well under the thresholds for developing a transportation management plan (i.e. 800 commercial/industrial trips). Therefore, Project construction would not conflict with any applicable transportation plans (i.e., Imperial County State Transportation Improvement Program/Plan, 2016) or contribute to a long-term decrease in LOS.

b) Would the project conflict or be inconsistent with the CEQA Guidelines section 15064.3, subdivision (b)? ☐ ☐ ☒ ☐
b) Less Than Significant. Please see **(a)**

c) Substantially increases hazards due to a geometric design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)? ☐ ☐ ☐ ☒
c) No Impact. The Project does not include any aviation-related use and would have no impact on airports. The Project would also not require any modification of flight paths for existing airports. Therefore, no impact to air traffic patterns would occur as result of the Project.

d) Result in inadequate emergency access? ☐ ☐ ☐ ☒
d) No Impact. All proposed facilities would be constructed within the existing Heber 2 Complex site and not introduce any transportation hazards, design features, or incompatible uses with surrounding roadways. Therefore, there would be no increase to hazards due to the Project design. Emergency vehicle access is identified and designated at the Heber 2 site, and these areas would not be changed as result of the proposed developments. Therefore, no impacts to emergency access to the plant site or surrounding area would occur under the Project.

XVIII. *TRIBAL CULTURAL RESOURCES*

a) Would the project cause a substantial adverse change in the significance of a tribal cultural resource, defined in Public Resources Code Section 21074 as either a site, feature, place, cultural landscape that is geographically defined in terms of the size and scope of the landscape, sacred place or object with cultural value to a California Native American tribe, and that is: ☐ ☐ ☐ ☒

(i) Listed or eligible for listing in the California Register of Historical Resources, or in a local register of historical resources as define in Public Resources Code Section 5020.1(k), or ☐ ☐ ☐ ☒

(i) No Impact. There are no known tribal cultural resources present on the Project Site. The Project Site is completely devoid of any vegetation, water, or natural features that could be defined as a tribal cultural resource or traditional use area. Further, considering the Project Site was entirely disturbed when the Heber 2 power plant was developed, the probability of encountering an unforeseen/buried tribal cultural resource is very low. As described in Section 2.1.8 above, Project construction personnel would monitor areas during surface disturbing activities and if any potential tribal cultural resources are encountered, all construction affecting the discovery site would be suspended immediately until a qualified archaeologist has reviewed the findings. An Unanticipated Discoveries Plan would be prepared prior to resuming construction. Therefore, the Project is anticipated to result in no impacts to tribal cultural resources.

(ii) A resource determined by the lead agency, in its discretion and supported by substantial evidence, to be significant pursuant to criteria set forth in subdivision (c) of Public Resources Code Section 5024.1. In applying the criteria set forth is subdivision (c) of Public Resource Code Section ☐ ☐ ☐ ☒

EEC ORIGINAL PKG

	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

5024.1, the lead agency shall consider the significance of the resource to a California Native American Tribe.
(ii) No Impact please see(i)

XIX. ***UTILITIES AND SERVICE SYSTEMS*** ***Would the project:***

a)	Require or result in the relocation or construction of new or expanded water, wastewater treatment or stormwater drainage, electric power, natural gas, or telecommunications facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☒

a) No Impact. Construction of the proposed facilities would not generate/discharge any wastewater. Portable toilets would be brought on-site per California Code of Regulations, Title 8, Section 1526, Subchapter 4, Construction Safety Orders Article 3, General §1526, Toilets at Construction Jobsites and disposed of at the appropriate wastewater facility, resulting in no impact to RWQCB requirements. Heber 2 Complex employees have permanent bathrooms in the existing facilities, and no new wastewater would be generated from the operation of the proposed facilities. Therefore, no impacts to wastewater would occur as a result of the Project.

b)	Have sufficient water supplies available to serve the project from existing and reasonably foreseeable future development during normal, dry and multiple dry years?	☐	☐	☐	☒

b) No Impact. The Project would not require any additional water supplies and no new water rights would be required. Therefore, no impacts to any water entitlements or resources would occur as a result of the Project.

c)	Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☒

c) No Impact. Project construction would not generate any wastewater, and Project operation would not increase the amount of wastewater generated at the existing Heber 2 Complex. Therefore, no impacts to the wastewater treatment utility's service capacity would occur under the Project.

d)	Generate solid waste in excess of State or local standards, or in excess of the capacity of local infrastructure, or otherwise impair the attainment of solid waste reduction goals?	☐	☐	☐	☒

d) No Impact: Project construction waste generation would likely be limited to packaging for equipment and supplies, and construction personnel waste (i.e., wrappers, food waste). There are two active waste disposal facilities/landfills in Imperial County that are accepting wastes and these facilities have the capacity to service to the Project. Operation of the proposed facilities would not generate any solid waste. Therefore, the Project would not result in an impact to the waste disposal facilities in Imperial County.

e)	Comply with federal, state, and local management and reduction statutes and regulations related to solid waste?	☐	☐	☐	☒

e) No Impact. Project construction waste generation would likely be limited to packaging for equipment and supplies, and construction personnel waste (i.e., wrappers, food waste). No hazardous wastes would be generated as result of Project construction or operation. Operation of the proposed facilities would not generate any solid wastes. All construction wastes would be disposed of at the appropriate receiving facility, and there are two active waste disposal facilities/landfills operating in Imperial County that can service the Project. Therefore, the Project would not violate any federal, state, or local solid wastes statutes or regulation.

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

XX. *WILDFIRE*

If located in or near state responsibility areas or lands classified as very high fire hazard severity zones, would the Project:

a) Substantially impair an adopted emergency response plan or emergency evacuation plan? ☐ ☐ ☐ ☒

a) No Impact: The Second Imperial Geothermal Co. site is not located or near state responsibility, areas or lands classified as very high, high or moderate hazard severity zones.

b) Due to slope, prevailing winds, and other factors, exacerbate wildfire risks, and thereby expose project occupants to pollutant concentrations from a wildfire or the uncontrolled spread of a wildfire? ☐ ☐ ☐ ☒

2) No Impact: The project site, Second Imperial Geothermal Co. project is not located or near state responsibility, areas or lands classified as very high, high or moderate hazard severity zones. The project appears to be surrounded by agricultural related land.

c) Require the installation or maintenance of associated infrastructure (such as roads, fuel breaks, emergency water sources, power lines or other utilities) that may exacerbate fire risk or that may result in temporary or ongoing impacts to the environment? ☐ ☐ ☐ ☒

c) No Impact: The existing Heber 2 Emergency Response Plan addresses project construction and operations. The proposed work is within the existing footprint of ongoing geothermal activities in the Heber 2 plant site. There appears to be no impacts to existing roads, emergency water sources, power lines or other utilities in or near this work.

d) Expose people or structures to significant risks, including downslope or downstream flooding or landslides, as a result of runoff, post-fire slope instability, or drainage changes? ☐ ☐ ☐ ☒

d) No Impact: The project is located on mostly flat terrain. The existing geothermal facility has been in operation for a number of years and there would appear to no impacts from landslides, runoff or drainage changes.

Note: Authority cited: Sections 21083 and 21083.05, Public Resources Code. Reference: Section 65088.4, Gov. Code; Sections 21080(c), 21080.1, 21080.3, 21083, 21083.05, 21083.3, 21093, 21094, 21095, and 21151, Public Resources Code; Sundstrom v. County of Mendocino,(1988) 202 Cal.App.3d 296; Leonoff v. Monterey Board of Supervisors, (1990) 222 Cal.App.3d 1337; Eureka Citizens for Responsible Govt. v. City of Eureka (2007) 147 Cal.App.4th 357; Protect the Historic Amador Waterways v. Amador Water Agency (2004) 116 Cal.App.4th at 1109; San Franciscans Upholding the Downtown Plan v. City and County of San Francisco (2002) 102 Cal.App.4th 656.

Revised 2009- CEQA
Revised 2011- ICPDS
Revised 2016 – ICPDS
Revised 2017 – ICPDS
Revised 2019 – ICPDS

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	Potentially Significant Impact (PSI)	Potentially Significant Unless Mitigation Incorporated (PSUMI)	Less Than Significant Impact (LTSI)	No Impact (NI)

SECTION 3
III. MANDATORY FINDINGS OF SIGNIFICANCE

The following are Mandatory Findings of Significance in accordance with Section 15065 of the CEQA Guidelines.

a)	**Does the project have the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal, eliminate tribal cultural resources or eliminate important examples of the major periods of California history or prehistory?**	☐	☐	☐	☐
b)	**Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.)**	☐	☐	☐	☐
c)	**Does the project have environmental effects, which will cause substantial adverse effects on human beings, either directly or indirectly?**	☐	☐	☐	☐

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IV. PERSONS AND ORGANIZATIONS CONSULTED

This section identifies those persons who prepared or contributed to preparation of this document. This section is prepared in accordance with Section 15129 of the CEQA Guidelines.

A. COUNTY OF IMPERIAL

- Jim Minnick, Director of Planning & Development Services
- Michael Abraham, AICP, Assistant Director of Planning & Development Services
- David Black, Project Planner
- Imperial County Air Pollution Control District
- Department of Public Works
- Fire Department
- Ag Commissioner
- Environmental Health Services
- Sheriff's Office

B. OTHER AGENCIES/ORGANIZATIONS

- **DTSC Imperial CUPA**

(Written or oral comments received on the checklist prior to circulation)

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VI. NEGATIVE DECLARATION – County of Imperial

The following Negative Declaration is being circulated for public review in accordance with the California Environmental Quality Act Section 21091 and 21092 of the Public Resources Code.

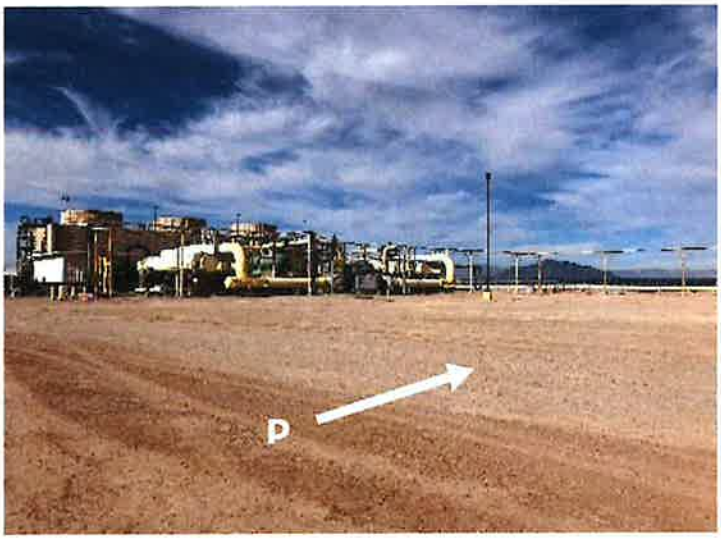
Project Name: Heber 2 Geothermal Repower Project

Project Applicant: Second Imperial Geothermal Company

Project Location: The proposed development would occur entirely on the 39.99-acre Assessor's Parcel Number (APN) 054-250-031. This parcel also includes geothermal facilities for the Goulds 2 and Heber South projects. The address for the Heber 2 Complex is 855 Dogwood Road, Heber, CA 92249. The legal description is Tract 44, Township 16 South, Range 14 East, SBB&M. See Exhibit A and B.

Description of Project: Perform CUP amendment to allow for installation of two new water-cooled ORMAT Energy Converters (OECs) to replace six old units from 1992; three 10,000 gallon isopentane ground storage tanks; and, additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex. All proposed facilities would be developed within the existing Heber 2 Complex and fence line. The total project disturbance from developing the new facilities is approximately 4 acres. The CUP amendment application also proposes to renew the permitted life of the entire Heber 2 Complex (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049). The proposed facility upgrades would allow the Heber 2 Complex to run more efficiently and refurbish the Heber 2 Complex to the original nameplate capacity (33 megawatts) without expanding the existing facility beyond the current footprint, and produce clean renewable energy in the Imperial Valley for the next three decades.

The proposed Project Site is within the existing Heber 2 power plant area, and all proposed facilities would be located within the existing fence line and permit area. As an active energy generation facility, the Project Site is devoid of any vegetation, streams/wetlands, or existing facilities (**Figure 6**). As observed in **Figure 2** (site plan), **Figure 6** (photo of Project Site), and **exhibits A & B** (site photos), the proposed facilities would be installed in the vacant, undeveloped areas of the Heber 2 site.



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The Project Site is entirely within APN 054-250-031, which is zoned as A-2-G-SPA, for General Agriculture (A-2), Geothermal Overlay Zone (G), and in the Heber Specific Plan Area (SPA). The Project Site is entirely within the Imperial County Geothermal Overlay Zone. "Major Geothermal Projects" in the overlay zone are permitted through the CUP process, as was the original Heber 2 project. The Heber SPA is intended "to allow for commercial, residential, industrial, renewable energy and other employment oriented development in a mixed used orientation" (Land Use Element of the Imperial County General Plan, 2015). Therefore, the proposed Project conforms to the standards and goals set forth in the Imperial County General Plan and the Renewable Energy and Transmission Element of County of Imperial General Plan (2015).

Surrounding land uses include a solar energy facility to the west of the Project Site, a commercial aggregate/rock supplier to the south, and agriculture to the north and east. The primary use in the general surrounding area is agriculture. The closest residences to the Project Site are in the town of Heber, approximately 3,500 feet to the northeast of the Project Site.

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VII. FINDINGS

This is to advise that the County of Imperial, acting as the lead agency, has conducted an Initial Study to determine if the project may have a significant effect on the environmental and is proposing this Negative Declaration based upon the following findings:

☐ The Initial Study shows that there is no substantial evidence that the project may have a significant effect on the environment and a NEGATIVE DECLARATION will be prepared.

☒ The Initial Study identifies potentially significant effects but:

(1) Proposals made or agreed to by the applicant before this proposed Mitigated Negative Declaration was released for public review would avoid the effects or mitigate the effects to a point where clearly no significant effects would occur.

(2) There is no substantial evidence before the agency that the project may have a significant effect on the environment.

(3) Mitigation measures are required to ensure all potentially significant impacts are reduced to levels of insignificance.

A NEGATIVE DECLARATION will be prepared.

If adopted, the Negative Declaration means that an Environmental Impact Report will not be required. Reasons to support this finding are included in the attached Initial Study. The project file and all related documents are available for review at the County of Imperial, Planning & Development Services Department, 801 Main Street, El Centro, CA 92243 (442) 265-1736.

NOTICE

The public are invited to comment on the proposed Negative Declaration during the review period.

11-23-2020 — Jim Minnick, Director of Planning & Development Services

Date of Determination

The Applicant hereby acknowledges and accepts the results of the Environmental Evaluation Committee (EEC) and hereby agrees to implement all Mitigation Measures, if applicable, as outlined in the MMRP.

Applicant Signature — Date

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SECTION 4

VIII. RESPONSE TO COMMENTS

N/A

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Responses to Heber 2 IS/ND Comments and Recommended Clarifications and Supplements

Date: 9/28/20

To: Imperial County Planning Department

From: Ben Pogue (Catalyst) on Behalf of ORMAT/SIGC

RE: CURE Comment Letter on Heber 2 IS/ND

Introduction and Purpose

The purpose of this memorandum is to provide clarifying information to the Imperial County Planning Department (ICPD) and its affiliate departments in response to comments submitted by Adams Broadwell Joseph & Cardoza (ABJC) on behalf of California Unions for Reliable Energy (CURE) on the Initial Study and Negative Declaration (IS/ND) for the Heber 2 Repower Project (Project). The two primary sections of this memorandum include a summary outline of the CURE letter and a comment summary matrix with responses.

As discussed below, in response to comments received from the Imperial County Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed below. CEQA contemplates the move from ND to Mitigated Negative Declaration (MND) based on comments on the IS/ND , and we support the County in revising the CEQA decision to a MND and recirculating the IS/MND for a 30 day public review period.

CURE Comment Letter Issues Outline

This outline provides the basis of issues raised in the CURE comment letter. Those headings in bold represent primary issues, with the sub-issues outlined below. The issues identified in this outline are summarized and responded to in the comment matrix in the following section.

I. **Statement of Interest**
II. **An EIR Must be Prepared**
III. **The IS/ND Fails to Adequately Describe the Project**
    a. The IS/ND's Description of the Project's Construction Activities is Inadequate and Flawed
    b. The IS/ND Fails to Describe Emissions from Reclamation Activities
    c. The IS/ND's Numerous Errors Prohibits the Public from Fully Evaluating the Project's Impacts
IV. **The IS/ND Fails to Accurately Describe the Project's Baseline Conditions**
    a. The IS/ND Fails to Accurately Describe the Project's Baseline Generating Capacity and Associated Impacts, As Well As Its Baseline Emissions
    b. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site
V. **The County Has Violated CEQA by Piecemealing Environmental Review and Permitting for the Expansion of the Heber Geothermal Facilities as Separate Projects**
VI. **Substantial Evidence Supports a Fair Argument that the Project May Have Significant Impacts Which Must be Analysed in an EIR**

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a. There is a Fair Argument that Construction Emissions from the Project Could Have a Significant Impact on Public Health and the Environment
b. There is a Fair Argument that the Project Could Result in Significant Impacts to Public Health from Valley Fever
c. The IS/ND's Methods for Evaluating a Hazard Analysis and the Possibility of Accidents or Explosions at the Site Are Inadequate and Unsupported.
d. There is a Fair Argument that Extending the Life of the Project Could Result in Geologic Impacts
e. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project
f. The IS/ND Fails to Disclose the Project's Construction or Operational GHG Emissions, and Relies on an Inapplicable Significance Threshold
g. There is a Fair Argument that the Project Will Have Significant Impacts on Water Supply

VII. The IS/ND Concedes that Mitigation is Required

a. The IS/ND Fails to Consider Feasible Mitigation to Reduce Potentially Significant Impacts to Less than Significant Levels for Construction and Operations

VIII. The IS/ND Fails to Properly Evaluate Potentially Significant Cumulative Impacts.

IX. The Project May Require a CEC License.

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Comment Summaries and Responses

CURE Letter Section	Substantive Comment Summary	Response
I. Statement of Interest	ABJC discloses its representation of its client, the California Unions for Reliable Energy (CURE). The IS/ND fails to meet the basic requirements of CEQA. The County must prepare an EIR.	No substantive technical comment provided. Comment lauds renewable energy development and subsequently criticizes the Heber 2 Repower Project. The IS/ND was based on site specific and technically substantiated information on the baseline conditions of the Project site and potential impacts. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. The following Mitigation Measure HAZ-1 is considered: HAZ-1: To minimize the potential for a cascading failure event of the new isopentane tanks and to limit any potential impacts within the existing Heber 2 Complex fence line, the three isopentane tanks shall be located as set forth in Attachment B. Further, diking and impoundment of the proposed isopentane tanks shall be installed consistent with the Hazard Memorandum (Attachment C) to minimize the magnitude and extent of a tank failure, and the detailed design of the project shall ensure that the Project's features satisfy the design criteria assumed in the Hazard Assessment (Attachment C). As observed in Figure 9 of the Hazard Assessment (Attachment C), the area of potential effect for each new isopentane tank would not overlap, thus preventing a consequential catastrophic event. CEQA contemplates the move from ND to MND based on comments on the IS/ND, and we support the County in revising the CEQA decision to a MND and recirculating the IS/MND for a 30-day public review period. See following comments explaining why a MND is appropriate, instead of the EIR CURE requests.
II. An EIR Must Be Prepared	CURE attempts to employ the "fair argument rule" under CEQA that an EIR must be prepared to address significant impacts, but does not site any specific IS/ND sections or analyses.	The proposed Project site is entirely within the existing and permitted plant boundary, and is entirely void of any vegetation, habitat, waterbodies, and existing facilities. The purpose of the Project is to repower the Heber 2 geothermal facilities by replacing old ORMAT Energy Converters (OECs) with state-of-the-art OECs that run more efficiently and emit less emissions, and install three new isopentane tanks to support operations. No facilities are

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		proposed outside of the existing facility's fence line. Due to the Project's limited nature, no significant environmental impacts were anticipated. The IS confirmed that the Heber 2 Project would not result in any significant impacts and no mitigation was required, thus the issuance of an ND. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed below. CEQA contemplates the move from ND to MND based on comments on the IS/ND. This comment identifies air quality, cumulative air quality, public health, water supply, biological resources, and impacts form hazardous materials are not technically substantiated. See responses included in Issue VI below that elaborates on these specific resources and discussions on the information and methods used to reach significance conclusions in the MND.
III. The IS/ND Fails to Accurately Describe the Project	CURE sites that CEQA prohibits the "piecemealing" of a larger project into many smaller projects, resulting in numerous environmental reviews for a single project.	A subsidiary of ORMAT is proposing to upgrade and develop additional geothermal energy generation at the Heber 1 plant, approximately 1 mile to the east of the Heber 2 site. The Heber 1 and Heber 2 facilities are physically and electrically separate, as they do not share any facilities, including geothermal production wells, pipeline, OECs, isopentane tanks, or transmission facilities. These geothermal energy facilities were developed at separate times (not as a single project), have never shared any facilities or lands/leases, and are permitted under separate CUPs issued by Imperial County. Further, these projects are treated as separate projects by relevant utilities and regulatory agencies, including each facility has separate Power Purchase Agreements, Interconnection Agreements, Imperial County Air Pollution Control District (ICAPCD). ICAPCD implements state and federal laws that determine how projects are either treated as separate or grouped under an air quality "bubble." ICAPCD' s determination that Heber 1 and Heber 2 are separate facilities is substantial evidence that they facilities are in fact two separate projects. There are three principle tests under CEQA with respect to determine whether two projects are separate CEQA projects.

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		In the seminal CEQA test for piecemealing, *Laurel Heights Improvement Association v. Regents of the University of California ("Laurel Heights")*[1], the California Supreme Court set forth a two prong test for determining whether future phases of a project or other foreseeable consequences of an approved land use must be included as a part of a project for the purposes of environmental review. This important and often cited case provides the clearest guidance as to the standard that will be applied by courts in evaluating whether an agency improperly segmented environmental review of a project. The first prong set forth in *Laurel Heights* is that an agency must analyse the environmental effects of a project's future expansion or other action if it is a "reasonably foreseeable consequence of the initial project." In this case, neither Heber 1 nor Heber 2 is a reasonably foreseeable consequence of the other. The projects are separated physically by nearly a mile and share no common critical infrastructure. One project can run with or without the other. The second *Laurel Heights* prong is that an agency must analyse the environmental effects of a project's future expansion or other action if it "will likely change the scope or nature of the initial project or its environmental effects." Again, the projects' physical and operational separation provide that neither project will affect the nature or scope of the other project or its environmental effects. See below for more factual discussions demonstrating that consistent with the *Laurel Heights* case, Heber 1 and Heber 2 are separate and independent CEQA projects. The second important CEQA test is the "independent utility" test. In *Del Mar Conservancy, Inc. v. City Council of the City of San Diego*, 10 Cal. App. 4th 712 (1992), the courts examine whether a project has "independent utility" that warrants separate environmental review and approval, even if it is arguably

[1] *Laurel Heights Improvement Assn. v. Regents of University of California*, 47 Cal. 3d 376, 396 (Cal. 1988).

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		part of a larger project. This test is derived from federal case law regarding the National Environmental Policy Act ("NEPA"), and has traditionally been applied in the context of the segmentation of environmental review of road projects, but has been applied in other contexts as well.[2] Under this test, it is appropriate for an individual portion of a larger road construction project to be reviewed and approved separately from the larger project if the segment has independent utility, and will serve a purpose even if the larger project is not constructed.[3] In this case, Heber 1 and Heber 2 each have independent utility; that is, each project operates to provide a separate and distinct set of benefits to the project owners. Each is contracted separately. Each sells its own electrical output. The projects do not sell to the same offtakers and each has separate and wholly unrelated contractual obligations, as just some examples of the independent utility of each. Under this CEQA test, Heber 1 and Heber 2 have "independent utility". The third CEQA test is called the "Crucial Functional Element" test, a corollary to the independent utility test. Unlike the independent utility test, which outlines when a project that is arguably part of a larger one can be reviewed and approved separately, the crucial function element test determines when a smaller project must be reviewed as a part of the larger project. Under this test, if a project is a "'required' or 'crucial element' without which" another

[2] See *Planning and Conservation League v. Castaic Lake Water Agency*, 180 Cal. App. 4th 210, 237 (2009)(applying independent utility test in upholding adequacy of EIR in case regarding transfer of water entitlements).

[3] *Del Mar Conservancy, Inc. v. City Council of the City of San Diego*, 10 Cal. App. 4th 712, 734 (citing to *Daly v. Volpe,* 514 F.2d 1106, 1109-1110 (1975)). In the original NEPA cases, *Daly v. Volpe*, three other criteria were also considered: whether the segment (1) is of substantial length and between logical terminal points; (2) is long enough to ensure adequate opportunity for consideration of alternatives; (3) will fulfill important state and local needs. However, as the independent utility criteria has been broken out as a separate test under both NEPA and CEQA case law, only the independent utility criteria is discussed above.

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		project "could not go forward," environmental review of the two cannot be piecemealed, and both projects as a whole must be addressed in an environmental review document. In the case of Heber 1 and Heber 2, neither project is "required or a critical element" of the other. Each operates independently, without sharing critical infrastructure. Neither is necessary for the other to be able to function as neither provides the other with any critical functional element. Each function separately. These three cases are fact-specific analyses. Applying the facts in this case demonstrates that Heber 1 and Heber 2 are separate CEQA projects. The following are some additional facts demonstrating two separate projects. For example, the proposal to repower Heber 2 does not depend on the outcome of the Heber 1 proposal (and vice versa). The points below are guidance provided in the CEQA Deskbook (Figure 2-2: Evaluation of Related Activities in a CEQA Document; 2012) for when two actions should be addressed in a single CEQA review. A copy of this guidance is also enclosed as Attachment F. While Action A and Action B, in this case, could be either Heber 1 and Heber 2, regardless of order, since this response is based on the CURE letter received on Heber 2, Action A below is read as Heber 2 and Action B is Heber 1, as follows: 1. When "Action B" is reasonably foreseeable consequence of "Action A". 2. When "Action B" is a future expansion of "Action A" and will be significant because it will likely change the scope, nature, and impacts of "Action A". 3. When "Action A" cannot proceed without essential public services that would be provided by "Action B". 4. When "Action A" and "Action B" are integral parts of the same project. <u>Response to CEQA Deskbook Hypothetical 1</u>: While Heber 1 and Heber 2 are being proposed in close temporal proximity, the result of either project is not dependent on the outcome of the other project. In other words, for example, if Heber 1 is declined a permit, and Heber 2 is permitted, Heber 2 will still be developed regardless of the fact that Heber 1 was declined (and vice versa).

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		Response to CEQA Deskbook Hypothetical 2: Since Heber 1 and Heber 2 do not share any critical facilities or infrastructure and are separated by almost a mile, and neither proposal includes facilities that would be shared, these actions are not reflective of a connected or future expansion at either plant. Any future expansions at Heber 1 and Heber 2 would remain independent from one another, simply due to the fact that the plants were developed as independent facilities and are not designed to operate in conjunction with each other. Response to CEQA Deskbook Hypothetical 3: Heber 1 and Heber 2 operate independently from one another. For example, ORMAT could shut down operations entirely at either plant and the other would not be affected whatsoever. These facilities do not share any public services, whereas the Heber 2 Repower Project could not proceed without the approval of Heber 1 (and vice versa). Response to CEQA Deskbook Hypothetical 4: As discussed above, the outcome of either proposal is not dependent on the other. In other words, for example, if Heber 1 is declined a permit, and Heber 2 is permitted, Heber 2 will still be developed regardless that Heber 1 was declined (and vice versa). Further, Heber 1 and Heber 2 are located approximately one mile apart from each other and share no facilities. There are no facilities in either proposal that would connect Heber 1 and Heber 2, thereby remaining completely independent geothermal plants at both sites.
III.a. The IS/ND's Description of the Project's Construction Activities is Inadequate and Flawed	CURE claims that a description of the proposed construction activities is provided, and that construction emissions are not calculated.	The CUP application clearly states that construction is anticipated to last up to eight months and provides a list of the equipment to be use. Further, construction emissions were calculated and accounted for in the IS/ND, relying on the modelling done as part of the APCD. For purposes of responding to this comment, Attachment E (Air Emissions Memorandum) includes the results of the modelling of construction and operation emissions for both criterial pollutants and GHG. As observed, construction emissions for criteria pollutants and GHG emissions are significantly less than the regulatory thresholds.

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III.b. The IS/ND Fails to Describe Emissions from Reclamation Activities	Reclamation emissions are not calculated.	A Reclamation Plan was submitted as part of the Heber 2 CUP Amendment Application to demonstrate the process for site abandonment and returning the condition of the site to a natural state and comply with the County requirements. Per common practice, final site reclamation (in 30 years at the termination of the CUP) would be permitted in the run up to site closure. Emissions calculations for reclamation activities in 2050 would be submitted to ICAPCD for a Permit to Construct. The reason for not speculating at this time is because the ambient air conditions, including attainment and non-attainment zones, may be considerably different in 30 years. Moreover, future potential effects are necessarily speculative. In trying to determine if an impact may be significant, CEQA provides "Argument, speculation, unsubstantiated opinion or narrative, or evidence that is clearly inaccurate or erroneous, or evidence that is not credible, shall not constitute substantial evidence." (14 C.C.R. 15064(f)(5).) Further, CEQA also provides that, "If, after thorough investigation, a Lead Agency finds that a particular impact is too speculative for evaluation, the agency should note its conclusion and terminate discussion of the impact." (14 C.C.R. 15145).
III.c. The IS/ND's Numerous Errors Prohibits the Public from Fully Evaluating the Project's Impacts	The IS/ND is rife with inconsistent, misleading, and confusing statements making it impossible for a reader to assess the conclusions. CURE sites: • CURE sites a missing appendix the cultural and historic resources records review. • Figure 6 does not provide substantive support. • That Heber 1 and Heber 2 are the same facility. • The IS misuses the term "complex" and fails to disclose baseline and future generation, and incorrectly identifies the units that would be modified.	• Pursuant to the National Historic Preservation Act, Appendix C contains confidential information pertaining to the location of identified sites/resources in the project vicinity, as recorded in prior surveys. This information is not for public release, and thus, held in confidence by Imperial County. • As noted, Figure 6 (as well as the multiple pictures in Appendix A of the IS/ND and the MND) shows a photograph of the Project site, which is a "dirt lot", as stated by CURE. The purpose of this photography is to provide the reader with a visual aid of the proposed development site and verify that the site is, in fact, void of any water resources and sensitive communities. • See the response to Issue III above for a discussion as to why Heber 1 and Heber 2 are entirely independent facilities. • The term "Heber 2 Complex", as used in the CUP Amendment Application, refers to Heber 2, Goulds 2, and Heber South geothermal facilities (not Heber 1). The term "Complex" was applied because these facilities are interdependent on each other for operations and the CUP Amendment Application is requesting the extension of the permit life all three facilities (collectively, the Heber 2 Complex) until 2050. The

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		figures in the CUP Amendment Application provide clarity on the relationship between the three geothermal units that comprise the Heber 2 Complex, and demonstrates the location of each unit's OECs. As provided in Attachment A, no modifications are proposed for Goulds 2 or Heber South, only the Heber 2 plant, and conditions would remain the same as present baseline conditions at Goulds 2 and Heber South. Attachment A also provides a breakdown of the current and proposed energy generation at the Heber 2 Complex, breaking down overall generation by each power station. As noted in Attachment A, the Heber 2 Repower Project would generate 27 MW. The CUP Amendment Application states that the Heber 2 Complex would generate 33 MW. To avoid confusion, we recommend adding a note to the CUP Amendment Application with the table in Attachment A to clarify the generation capacity for each Heber 2 Complex geothermal unit (Heber 2, Goulds 2, and Heber South).
IV. The IS/ND Fails to Accurately Describe the Project's Baseline Conditions	An EIR must include description of the physical environmental conditions in the Project vicinity.	The affected environment descriptions provided in the CEQA Checklist submitted in support of the CUP Amendment Application and the IS/ND are technically substantiated by numerous detailed resource reports. The site specific information collected for this Project reflects a detailed characterization of the baseline conditions to measure potential effects against, primarily quantitatively where feasible, and qualitatively where necessary.
IV.a. The IS/ND Fails to Accurately Describe the Project's Baseline Generating Capacity and Associated Impacts, as well as Its Baseline Emissions	CURE attempts to provide "correct" air emissions calculations, and that the project underestimates emissions by 2/3rds.	The ICAPCD makes a determination on whether to treat individual facilities as a single source for the purposes of determining compliance with state and federal air quality laws and regulation. Attachment A provides a breakdown of the baseline and proposed generation capacity. An Authority to Construct and Permit to Operate (ACPO) was submitted to the Imperial County Air Pollution Control District, and as noted in the application, the existing Air District Permit (No. 2217A-5) includes any emissions for the entire Heber 2 Complex, which includes the geothermal units of Heber 2, Heber South, and Goulds 2. Therefore, baseline emissions from all subject facilities has been accounted for and properly assessed in the ACPO application. For purposes of responding to this comment, the enclosed Air Emissions Memorandum provides the historic (baseline) and the proposed future emissions. As observed, the modelled emissions show a decrease in future isopentane emissions of -3.0 lb/day or -4.0

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		tons/year. Therefore, through the use of more efficient equipment (e.g., the new OECs) would lead to a decrease in emissions.
IV.b. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site	The County failed to make a reasonable effort to describe baseline biological conditions, and account for sensitive species on the site.	As noted by CURE, a comprehensive records search for biological resources, vegetation, and sensitive species was performed to identify species that could occupy the project site and surrounding area. All databases used in this research (e.g., IPac, CNDDB, etc.) are managed by public agencies and serve as the standard for determining the biological community present in/near a project site. After a review of the records, a wildlife biologist performed a reconnaissance-level survey of the Project Site, concurring that the site is completely void of any habitat and sensitive species. These efforts were recorded and provided as an Appendix B to the CUP. For a site that is a "dirt lot" by CURE's own admission, and confirmed with site photographs and supporting technical documentation, a reasonable effort was made to describe the baseline biological conditions and potentially occurring sensitive species. Further, as provided in the CUP Amendment Application, the Environmental Protection Measures section, "pre-construction surveys would occur to ensure the absence of any sensitive species". As provided in the CURE letter, a Google Earth snapshot of a common crow flying by the Project site does not constitute evidence that sensitive species are likely present (14 C.C.R. 15064(f).) As documented through verifiable database research and a site-specific survey (as provided in Appendix B of the CUP), the site does not contain suitable habitat and no sensitive species occur on the site. Further, due to the industrialized nature of the site, avian species are likely to avoid the site. Again, the Project site would be surveyed prior to construction to verify the absence of any special status species.
V. The County Has Violated CEQA by Piecemealing Environmental Review and Permitting for the Expansion of the Heber Geothermal Facilities as Separate Projects	CURE alleges that the IS/ND does not accurately reflect that Heber South and Goulds 2 are part of the Heber 2 Complex.	The CUP Amendment Application clearly states that the Heber 2 Complex include the generation units of Heber 2, Goulds 2, and Heber South, and the proposal seeks to extend the life of the overall complex by 30 years. The term "Complex" was applied because these facilities are interdependent on each other for operations and the CUP Amendment Application is requesting the extension of the permit life all three facilities until 2050. The enclosed Figure 1 provides clarity on the relationship between the three geothermal units that comprise the Heber 2 Complex, and demonstrates the location of each unit's OECs. As provided in Attachment A, no modifications are proposed for Goulds 2 or Heber South, only the Heber 2 unit, and conditions would remain the same as present baseline conditions at the Goulds 2 and Heber South portions of the

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		Heber 2 Complex. Attachment A also provides a breakdown of the current and proposed energy generation at the Heber 2 Complex, breaking down overall generation by each unit.
VI. Substantial Evidence Supports a Fair Argument that the Project May Have Significant Impacts Which Must be Analysed in an EIR	An EIR must be prepared under the "Fair Argument" standard.	See response to Issue II above.
VI.a. There is a Fair Argument that Construction Emissions from the Project Could Have a Significant Impact on Public Health and the Environment	Because the IS/ND fails to provide details on construction schedule and equipment, emissions calculations are insufficient. IS/ND does not describe the existing baseline thresholds.	The IS/ND directly responded to the questions and issues identified in the CEQA Checklist Section III (Air Quality). A detailed and sophisticated air emissions model was prepared for the Project to apply to the ICAPCD for a Permit to Construct and Operate (PCO). For clarification, the PCO application is enclosed to this memo. A detailed CEQA Checklist was enclosed as part of the CUP Amendment Application. The Checklist included a detailed description of the Affected Environment for air quality, including a table that identified attainment and non-attainment emissions in the Imperial Valley. This information allowed the County to accurately characterize the existing ambient air conditions and make an informed impact conclusion. Further, an Air Emissions Memorandum was attached to the CUP Amendment Application as Appendix F. That analysis remains valid, confirming no potentially significant effects. In addition, in response to comments received, the Air Emissions Memorandum (Attachment E) provides information to address the comments received on potential construction emissions, further confirming no potentially significant effects.
VI.b. There is a Fair Argument that the Project Could Result in Significant Impacts to Public Health from Valley Fever	The IS/ND does not adequately account for construction workers contracting Valley Fever.	The IS/ND includes Best Management Practices for dust control and worker safety, including: • The Project would comply with the Imperial County Air Pollution Control District (ICAPCD) Regulation VIII (Fugitive Dust Control), the Imperial County 2018 PM10 Plan, and the Imperial County 2018 PM2.5 Plan. • Project equipment and worker vehicles would be turned off when not in use and not left idling to minimize unnecessary emissions. • Water would be applied to the development site and during site preparation and construction to control fugitive dust.

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		• Earth moving work would be completed in phases (as necessary) to minimize the amount of disturbed area at one time. • Construction vehicles and heavy equipment that use non-surfaced facility roads/areas will be restricted to 10 mph to control fugitive dust. • During windy conditions, barriers would be constructed and/or additional watering is conducted to minimize wind-blown fugitive dust. • Vehicle access would be restricted to the disturbance area via signage/fencing. Collectively, these measures would mitigate for the potential contraction of Valley Fever. While not required to mitigate any potentially significant effects, these Applicant proposed Mitigation Measures and practices will be included in the Mitigation and Monitoring Plan for the project.
VI.c. The IS/ND's Methods for Evaluating a Hazard Analysis and the Possibility of Accidents or Explosions at the Site Are Inadequate and Unsupported	Hazard Analysis should be based on a worst-case scenario.	The Hazard Assessment (HA) prepared for the CUP Amendment Application (Appendix G of CUP Application) and IS/ND was developed to comply with the regulatory standard for assessing a catastrophic event. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. CEQA contemplates the move from ND to MND based on comments on the IS/ND. Accordingly, new Mitigation Measure HAZ-1 requires the following: HAZ-1: To minimize the potential for a cascading failure event of the new isopentane tanks and to limit any potential impacts within the existing Heber 2 Complex fence line, the three isopentane tanks shall be located as set forth in Attachment B. Further, diking and impoundment of the proposed isopentane tanks shall be installed consistent with the Hazard Memorandum (Attachment C) to minimize the magnitude and extent of a tank failure, and the detailed design of the project shall ensure that the Project's features satisfy the design criteria assumed in the Hazard Assessment (Attachment C). As observed in Figure 9 of the Hazard Assessment (Attachment C), the area of potential effect for each new isopentane tank would not overlap, thus preventing a consequential catastrophic event.
VI.d. There is a Fair Argument that Extending the Life of the Project Could Result in Geologic Impacts	The IS/ND fails to analyze geologic impacts of extending the life of the facilities.	An extensive geotechnical investigation was performed in support of the CUP Amendment Application (Appendix G) and the IS/ND. This geologic characterization served as the basis for measuring impacts against. As observed in the project description, no new wells or alteration of the pressure regime and

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		geothermal utilization program at Heber 2 are proposed, only the replacement of the OECs and the addition of the isopentane tanks. Therefore, there would be no impacts to the baseline geologic conditions or increased potential for subsidence in the nearby area. Additionally, the California Department of Conservation (CDOC) reviewed the IS/ND and concluded that no potential significant impacts from the existing geothermal wells and utilization. The CDOC concurrence on no significant impacts is enclosed to supplement this conclusion.
VI.e. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project	Avian fatality monitoring at nearby solar facilities show high levels of avian mortality.	See response above for Issue IV.b above. Additionally, as observed in the CUP project description, no new transmission lines (or solar facilities, as volunteered in the CURE comment) or changes to existing Heber 2 substation are proposed; therefore, baseline conditions would remain the same and the Project would not cause any significant impacts to avian species.
VI.f. The IS/ND Fails to Disclose the Project's Construction or Operational GHG Emissions, and Relies on an Inapplicable Significance Threshold	The IS/ND fails to meaningfully describe or analyse the Project's construction and operational GHG emissions.	The potential GHG emissions associated with project construction and operations are discussed in the IS/ND CEQA Checklist Section III (Air Quality) and the enclosed Air Quality Memorandum (Attachment E). As observed, construction emissions for criteria pollutants and GHG emissions are significantly less than the regulatory thresholds. The construction phase is expected to emit 982 CO2e tons per year. This figure represents the total construction emissions and are temporary as development is expected to take 8 months.
VI.g. There is a Fair Argument that the Project Will Have Significant Impacts on Water Supply	CURE claims that the Project will use more water and the Project should seek an alternative water supply per the Basin Plan.	As noted by CURE, the Project would not require any additional water to operate, and all water would be supplied via existing IID permits. Heber 2 will remain as a retail water customer with IID with no changes in water consumption to support the existing or proposed facilities. Therefore, no significant impacts to the existing baseline conditions would occur.
VII. The IS/ND Concedes that Mitigation is Required	The IS/ND defers the formulation of mitigation measures. An EIR must be prepared.	CURE's comments confuse Best Management Practices and Applicant Proposed Measures that were included in the project description of the CUP as voluntary measures, with mitigation measures. An Applicant Proposed Measure is volunteered by the Applicant and should be considered as part of the Project. A mitigation measure, conversely, is a condition of approval issued by the County to reduce the magnitude and/or duration of a significant impact. Therefore, the conditions of what qualifies as a mitigation measures cited in the CURE comment, does not apply. In response to comments received from the Fire

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		Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed above.
VII.a. The IS/ND Fails to Consider Feasible Mitigation to Reduce Potentially Significant Impacts to Less than Significant Levels	The County should consider and implement a mitigation plan as part of an EIR.	The IS/ND correctly concluded that no significant impacts would occur and that mitigation is not required because all potential impacts would be less than significant. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed above in Issue I.
VII.a.1. Construction Mitigation	The IS/ND does not include mitigation for fugitive dust and it is assumed that ozone emissions are significant.	Contrary to CURE's comment, the IS/ND contains numerous voluntary measures to control fugitive dust, as provided in response to Issue VI.b above, and included in the CUP Amendment Application.
VII.a.2. Operational Mitigation	The Project should implement an extensive leak detection and repair program to mitigate for ROG emissions.	The project owner implements leak and repair programs, consistent with applicable laws, ordinances, regulations, and standards. The PCO issued by the ICAPCD will also address potential for leaks and related issues. There are no significant effects associated with project operations and thus no need for additional mitigation measures.
VIII. The IS/ND Fails to Properly Evaluate Potentially Significant Cumulative Impacts	An EIR must discuss significant cumulative impacts.	Under Section 3 of the IS/ND (Mandatory Findings of Significance), the IS/ND considers cumulative effects as less than significant. Cumulative effects for this Project would be limited to off-site Project impacts that coincide with effects from another past, present, or reasonably foreseeable future action. This area of overlap is referred to as the Area of Potential Effect. There are no other projects occurring or proposed in the Heber 2 Area of Potential Effect, and therefore, no significant cumulative effects would occur as result of the Project.
IX. The Project May Require a CEC License	CURE alleges that the Project will result in 92 MW and require a CEC license.	The comments on generating capacity and CEC jurisdiction are incorrect on the facts and the applicable law. With respect to the facts, the Heber 2 project will result in a ***net*** increase of only 16 MWs. See Attachment A. With respect to the law, Heber 2 will not result in a net increase of 50 MWs or greater and thus is not CEC jurisdictional. The CEC has exclusive jurisdiction over the certification of proposed thermal powerplants 50 MWs or greater. Specifically, the Public Resources Code vests the CEC with "the exclusive power to certify all sites and related facilities in the state." A site is defined as "any location on which a facility is constructed or is proposed to be constructed."

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		(Pub. Resources Code § 25119.) A facility is defined as "any thermal powerplant or electric transmission line." (Pub. Resources Code § 25110.) A "thermal powerplant" is defined to mean "any stationary or floating electrical generating facility using any source of thermal energy, with a generating capacity of 50 megawatts or more, and any facilities appurtenant thereto." (Pub. Resources Code § 25120.) Accordingly, the CEC has jurisdiction over new thermal projects 50 MWs or greater and "a change or addition to an existing facility" resulting in a net increase of 50 MWs or greater. ((Pub. Resources Code § 25500.) For existing facilities like Heber 2, the CEC's jurisdiction depends on the net increase in generating capacity. The requirement for a net increase of fifty MWs or more is set forth in the California Supreme Court's only ruling on CEC jurisdiction: "We hold that 'facility' in sections 25500 and 25123, as the term applies here, collectively refers to the entirety of the existing powerplants at the Harbor Generating Station. The plain, common sense meaning of sections 25500 and 25123 is that any alteration, replacement, or improvement of equipment *that results in a 50-megawatt net increase in an existing station's total generating capacity* is subject to the Energy Commission's certification jurisdiction. (*Department of Water and Power, City of Los Angeles V. Energy Resources Conservation And Development Commission*, 2 Cal.App.4th 206, 221; emphasis added.)" As set forth in Table 1, the Heber 2 project does not "result[] in a 50-megawatt net increase in an existing station's total generating capacity." Accordingly, the CEC has no jurisdiction over Heber 2. Further, without any citation to any authority, CURE claims there are "four factors" that determine CEC jurisdiction. No authority is cited because no such authority exists. The four factors cited by CURE do not exist in statute, regulation, or CEC practice. CEC jurisdiction does not attach to Heber because the project will not result in a net increase of generating capacity of 50 MWs or greater.
X. Conclusion	An EIR must be prepared for the Project.	The issues identified in this paragraph are discussed in detail above as to why there are no significant impacts and an IS/ND is therefore the appropriate level of CEQA compliance.

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Attachments

- Attachment A – Table of Present and Proposed Geothermal Energy Generation by Unit at the Heber 2 Complex
- Attachment B – Site Plan with Adjusted Isopentane Tank Locations
- Attachment C - Hazard Memorandum and Hazard Assessment
- Attachment D - California Department of Conservation Concurrence (Email from Curtis Welty on July 22, 2020)
- Attachment E - Air Quality Memorandum
- Attachment F - CEQA Deskbook Reference for the Evaluation of Related Activities in a CEQA Document

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IX. MITIGATION MONITORING & REPORTING PROGRAM (MMRP)

N/A

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MITIGATION, MONTORING AND REPORTING PROGRAM

MITIGATION MEASURES
PURSUANT TO THE ENVIRONMENTAL EVALUATION COMMITTEE
November 19, 2020
Second Imperial Geothermal Co. (Heber 2 Complex)
[Cup 19-0017]

(APN 054-250-031-000)

(CEQA – Mitigated Negative Declaration)

Pursuant to the review and recommendations of the Imperial County Environmental Evaluation Committee (EEC) on November 19, 2020, the following Mitigation Measures are hereby proposed for the project:

MM #	Mitigation Measure	Monitoring Responsibility	Timing	Verification (Date and Initials)
BIOLOGICAL RESOURCES				
BR-1	Prior to any construction activities commencing on site, contractors shall attend a Worker Environmental Awareness Program (WEAP) regarding sensitive biological resources potentially occurring within the BSA. The program shall be presented by a person knowledgeable about the biology of the covered species. At a minimum, the program shall cover the distribution of special-status species, general behavior and ecology of these species, their sensitivity to human activities, their legal protection, the penalties for violation of state and federal laws, reporting requirements, project mitigation measures, and measures to implement in the event that this species is found during construction. A fact sheet containing this information shall also be prepared and distributed. The program shall be presented to all members of the construction crew prior to the start of project construction activities. New employees shall receive formal, approved training prior to working onsite.	ICPDS	PRIOR TO CONSTUCTION	

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MM #	Mitigation Measure	Monitoring Responsibility	Timing	Verification (Date and Initials)
	Upon completion of the orientation, employees will sign a form stating that they attended the program and understand all protection measures. These forms shall be made available to CDFW upon request.			
BR-2	In accordance with the Staff Report on Burrowing Owl Mitigation (CDFW 2012), a preconstruction take avoidance survey shall be conducted (CDFW 2012). If the burrowing owl is absent, then no mitigation is required. If present, the following mitigation shall be implemented. If burrowing owls and their habitat can be protected in place on or adjacent to a project site, then disturbance impacts shall be minimized through the use of buffer zones, visual screens, or other measures in accordance with CDFW (2012). Occupied burrows shall be avoided during the breeding period from February 1 through August 31 (CDFW 2012). "Occupied" is defined as a burrow that shows sign of burrowing owl occupancy within the last 3 years. Occupied burrows shall also be avoided during the non-breeding season. Burrow exclusion is a technique of installing one-way doors in burrow openings during the non-breeding season to temporarily exclude burrowing owls, or permanently exclude burrowing owls and close burrows after verifying burrows are empty by site monitoring and scoping (CDFW 2012). Mitigation for permanent impacts to nesting, occupied, and satellite burrows and/or burrowing owl habitat is required such that the habitat acreage, number of burrows and burrowing owls impacted are replaced based on the burrowing owl life history information provided in Staff Report on Burrowing Owl Mitigation (CDFW 2012). Coordination with CDFW may be necessary for the development of site-specific avoidance and mitigation measures.	ICPDS	Survey prior to any construction activities. If species present, timing as indicated in mitigation measure and prior to any impact to the species	
BR-3	Protection of nesting birds would be required in compliance with the MBTA and to avoid impacts to nesting birds. To avoid impacts to nesting birds and to comply with the MBTA, clearing of vegetation should occur between non nesting (or non-breeding) season for birds (generally, September 1 to February 1). If this avoidance schedule is not feasible, the alternative is to carry out the clearing of vegetation associated with construction under the supervision of a qualified biologist. This shall entail a pre-construction nesting bird survey conducted by a qualified biologist within 14 days prior	.ICPDS	Survey prior to any construction activities. If species present, timing as	

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MM #	Mitigation Measure	Monitoring Responsibility	Timing	Verification (Date and Initials)
	to initiating ground disturbance activities. The survey shall consist of full coverage of the proposed disturbance limits and a 500 foot buffer. The buffer shall be determined by the biologist and will take into account the species nesting in the area and the habitat present. If no active nests are found, no additional measures are required. If "occupied" nests are found, the nest locations shall be mapped by the biologist, utilizing GPS equipment. The nesting bird species shall be documented and, to the degree feasible, the nesting stage (e.g., incubation of eggs, feeding of young, near fledging). The biologist shall establish a no disturbance buffer around each active nest. The buffer will be determined by the biologist based on the species present and surrounding habitat. No construction or ground disturbance activities shall be conducted within the buffer until the biologist has determined the nest is no longer active and has informed the construction supervisor that activities may resume.		indicated in mitigation measure and prior to any impact to the species	
BR-4	If pre-construction surveys determine either the presence of special status species or sensitive biological resources, a construction monitor may be needed during construction. If determined necessary, construction monitoring shall be conducted by a qualified biologist. The biologist shall be given authority to execute the following functions: • Establish construction exclusion zones and make recommendations for implementing erosion control measures in temporary impact areas. • Ensure all construction activities stay within the staked construction zone and do not go beyond the limits of disturbance. • Minimize trimming/removal of vegetation to within the Project impact area. • Restrict non-essential equipment to the existing roadways and/or disturbed areas to avoid disturbance to existing adjacent native vegetation. • Install and maintain appropriate erosion/sediment control measures, as needed, throughout the duration of work activities. During construction, biological monitors shall inspect and verify field conditions, as needed, to ensure that wildlife and vegetation adjacent to the BSA are not harmed. The biological monitor shall coordinate with the construction foreman and construction crew and shall have the authority to immediately stop any activity that has the potential to impact special-status species or remove vegetation not specified in this report.	ICPDS	Survey prior to any construction activities. If species present, timing as indicated in mitigation measure and prior to any impact to the species.	

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MM #	Mitigation Measure	Monitoring Responsibility	Timing	Verification (Date and Initials)
HAZARDS AND HAZARDOUS MATERIALS				
HZ-1-17	1. To minimize potential extremely dangerous condition to firefighters and hazardous material teams Imperial County Fire Department is requiring that a Drone be purchase for Imperial County Fire Department. The final cost, details, and equipment of the drone shall be determined prior the issuance of the building permit. Additionally, the following requirements will be conditioned in the proposed Conditional Use Permit. The drone usage will help reduce required monitoring and compliance impacts to a level of less than significant. 2. All isopentane storage tanks will be protected by approved automatic fire suppression equipment. All automatic fire suppression will be installed and maintained to the current adapted fire code and regulation. 3. An approved automatic fire detection system will be installed as per the California Fire Code. All fire detection systems will be installed and maintained to the current adapted fire code and regulations. 4. Fire department access roads and gates will be in accordance with the current adapted fire code and the facility will maintain a Knox Box for access on site. 5. Compliance with all required sections of the fire code. 6. Applicant will provide product containment areas(s) for both product and water run-off in case of fire applications and retained for removal. 7. Each tank will be equipped with an automated water suppression system. 8. Each tank will be equipped with two flame detectors and one gas detector (for a total of 6 flame detectors and 3 gas detectors for the three tanks). 9. In the case of an isopentane leak, the gas detector(s) will detect it immediately and send a notification to the operator at the control room (manned 24/7) in order to mobilize fixing the leak. 10. In case of a fire, the flame detector(s) will detect it and immediately start the automatic fire suppression system. 11. In case of a fire, there will also be a horn and strobe system that will turn on	ICPDS & FIRE DEPARTMENT & OES.	DURIING CONSTRUCTIO N PHASE OF PROJECT	

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MM #	Mitigation Measure	Monitoring Responsibility	Timing	Verification (Date and Initials)
	automatically to alert the plant employees. 12. Concrete containment areas for isopentene , 13. vessels rarely filled to 90% capacity, 14. isopentane safety- control measures, 15. A blast wall between currently operational isopentene tanks #4 & #5. 16. To minimize the potential for a cascading failure event of the proposed isopentane tanks and to limit potential impacts within the existing Heber 2 Complex fence line, the three proposed isopentane tanks shall be located as set forth in the attached figure 7. 17. Diking and impoundment of the proposed isopentane tanks shall be installed to minimize the magnitude and extent of a tank failure.			
Geology and Soils				
GS-1	Prior to approval of a grading or a building permit, a California certified civil/geotechnical engineer shall prepare a geotechnical investigation of the Project site that includes appropriate subsurface exploration, laboratory testing, and evaluation of potential geotechnical constraints to critical Project structures, including liquefaction, corrosion, seismic shaking and shrink swell evaluations. The report shall include specific recommendations to address issues identified in the geotechnical investigation of the Project site to meet State and County seismic building code requirements. An ICPDS approved third party environmental monitor shall be on site during geotechnical investigations.	ICPDS & Imperial County Department of Public Works	Prior to the issuance of grading/building permit	

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(Lead Monitoring Agency: Imperial County Planning & Development Services Department)

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COMMENTS

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**Admitted in Colorado*

August 31, 2020

VIA EMAIL AND OVERNIGHT MAIL

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Re: Comments on the Negative Declaration for the Heber 2 Geothermal Repower Project (SCH No. 2020069002; CUP No. 19-0017)

Dear Mr. Minnick and Mr. Black:

We are writing on behalf of California Unions for Reliable Energy ("CURE") to provide comments on the Negative Declaration ("IS/ND") prepared by Imperial County ("County"), pursuant to the California Environmental Quality Act ("CEQA"),[1] for the Heber 2 Geothermal Repower Project ("Project") proposed by Second Imperial Geothermal Company, a wholly owned subsidiary of ORMAT Nevada, Inc ("Applicant"). The Applicant seeks a Conditional Use Permit ("CUP") amendment for installation of two new water-cooled ORMAT Energy Converters ("OECs") to replace six old units, along with three 10,000-gallon isopentane above-ground storage tanks and additional pipes to connect the proposed facilities with the existing geothermal complex.[2] The CUP amendment application also proposes to extend the permitted life of the entire Heber 2 Complex (including the Goulds 2 and Heber South geothermal energy facilities) ("Complex") by 30 years, to 2049, and

[1] Pub. Resources Code §§ 21000 et seq.
[2] IS/ND, p. 8.

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states that the Project will refurbish the Complex's original nameplate capacity of 33 megawatts ("MW"). The Project is located on the 39.99-acre Assessor's Parcel Number 054-250-031 at 855 Dogwood Road in Heber. Project disturbance from developing the new facilities would occur on approximately 4 acres of the existing site.[3] The parcel also contains geothermal facilities for the Gould 2[4] and Heber South projects.

The Project site is located in unincorporated Imperial County in the community of Heber and zoned for General Agriculture, Geothermal Overlay Zone within the Heber Specific Plan Area, which is intended to allow for commercial, residential, industrial, renewable energy, and other mixed-use development.[5] The primary land use in the surrounding area is agriculture, with a solar energy facility to the west, a commercial aggregate/rock supplier to the south, and agriculture to the north and east of the site. The closest residences are in the town of Heber, approximately 3,500 feet to the northeast of the Project site.

Based on our review of the IS/ND, we conclude that it fails to meet the basic requirements of CEQA. The IS/ND fails to accurate describe the Project and fails to accurately describe the Project's existing baseline setting, thus significantly underestimating the Project's impacts. As a result, the IS/ND's conclusions regarding impacts on air quality, cumulative air quality, public health, water supply, biological resources, and impacts from hazardous materials are not supported by substantial evidence. Moreover, as explained in these comments, there is substantial evidence supporting a fair argument that the Project will result in potentially significant impacts on air quality, public health, hazardous materials, water supply, and biological resources which the IS/ND fails to disclose and mitigate. The Project is also inconsistent with inconsistent with the Imperial Integrated Regional Water Management Plan.

The County may not consider approving the Project until it prepares an Environmental Impact Report ("EIR") that adequately analyzes the Project's potentially significant impacts and incorporates all feasible mitigation measures to avoid or minimize these impacts to the greatest extent feasible.

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[3] *Id.*
[4] The IS/ND refers to this facility as the "Goulds 2" facility.
[5] Imperial County General Plan, October 2015, 18.

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We reviewed the IS/ND for the Project with the assistance of Phyllis Fox, Ph.D., PE and Shawn Smallwood, Ph.D.[6,7] Dr. Fox and Dr. Smallwood provide substantial evidence of potentially significant impacts that have not been adequately disclosed, analyzed, or mitigated. Their technical comments and curriculum vitae are attached hereto and are submitted to the County, in addition to the comments in this letter. Accordingly, the County must address and respond to their comments separately.[8]

I. STATEMENT OF INTEREST

CURE is a coalition of labor organizations with members who may be adversely affected by the potential public and worker health and safety hazards and environmental and public service impacts of the Project. The coalition includes Heber residents Jaime Cuevas, Delila and Efrain Guzman, Imperial County resident Eric Jones, and other members who live, recreate, work, and raise families in Imperial County and in communities near the Project site. Thus, CURE, its participating organizations, and their members stand to be directly affected by the Project's impacts.

Since its founding in 1997, CURE has been committed to building a strong economy and healthier environment and it works to construct, operate, and maintain conventional and renewable energy power plants and other industrial facilities throughout California. CURE supports the development of clean, renewable energy technology, including geothermal power generation, where properly analyzed and carefully planned to minimize impacts on public health and the environment. Geothermal projects should avoid adverse impacts to natural resources and public health, and should take all feasible steps to ensure that unavoidable impacts are mitigated to the maximum extent feasible. Only by maintaining the highest standards can energy development truly be sustainable.

The individual members of CURE, and the members of its affiliated labor organizations, would be directly affected by the Project and may also work constructing the Project itself. They would therefore be first in line to be exposed to

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[6] P. Fox, Comments on the Initial Study/Negative Declaration for the Heber 2 Geothermal Repower Project (August 31, 2020) (hereinafter, "Fox Comments"), **Exhibit A**.
[7] S. Smallwood, Comments RE: Heber 2 Geothermal Repower Project, **Exhibit B**.
[8] The Commenters reserve the right to supplement these comments at later hearings and proceedings related to this Project. Gov. Code § 65009(b); PRC § 21177(a); *Bakersfield Citizens for Local Control v. Bakersfield* (2004) 124 Cal. App. 4th 1184, 1199-1203; *see Galante Vineyards v. Monterey Water Dist.* (1997) 60 Cal. App. 4th 1109, 1121.

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any health and safety hazards that may be present on the Project site. They each have a personal stake in protecting the Project area from unnecessary, adverse environmental and public health and safety impacts.

CURE supports and encourages the sustainable development of California's energy and natural resources and has an interest in enforcing environmental laws that encourage sustainable development and a safe working environment. Environmentally detrimental projects can jeopardize future jobs by making it more difficult and more expensive for business and industry to expand in the region, and by making it less desirable for businesses to locate and people to live and recreate in the County. Continued degradation can, and has, caused construction moratoriums and other restrictions on growth that, in turn, reduces future employment opportunities.

Finally, the organizational members of CURE are concerned with projects that can result in serious environmental harm without providing countervailing economic benefits. CEQA provides a balancing process whereby economic benefits are weighed against significant impacts to the environment. It is in this spirit we offer these comments.

II. AN EIR MUST BE PREPARED

CEQA is designed to inform decision-makers and the public about the potential, significant environmental effects of a project.[9] "CEQA's fundamental goal [is] fostering informed decision-making."[10] "The purpose of CEQA is not to generate paper, but to compel government at all levels to make decisions with environmental consequences in mind."[11]

CEQA requires that an agency analyze the potential environmental impacts of its proposed actions in an EIR, except in certain limited circumstances.[12] The EIR is the very heart of CEQA.[13] The EIR acts as an "environmental 'alarm bell' whose purpose is to alert the public and its responsible officials to environmental changes before they have reached the ecological points of no return."[14] The EIR aids an agency in identifying, analyzing, disclosing, and, to the extent possible, avoiding

[9] 14 Cal. Code Regs. ("CEQA Guidelines") § 15002, subd. (a)(1).
[10] *Laurel Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal.3d 376, 402.
[11] *Bozung v. LAFCO* (1975) 13 Cal.3d 263, 283.
[12] See, e.g., Pub. Resources Code, § 21100.
[13] *Dunn-Edwards v. Bay Area Air Quality Management Dist.* (1992) 9 Cal.App.4th 644, 652.
[14] *Bakersfield Citizens for Local Control v. City of Bakersfield* (2004) 124 Cal.App.4th 1184, 1220.

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a project's significant environmental effects through implementing feasible mitigation measures.[15] The EIR also serves "to demonstrate to an apprehensive citizenry that the [agency] has analyzed and considered the ecological implications of its action."[16] Thus, an EIR "protects not only the environment but also informed self-government."[17]

An EIR is required if "there is substantial evidence, in light of the whole record before the lead agency, that the project may have a significant effect on the environment."[18] The EIR aids an agency in identifying, analyzing, disclosing, and, to the extent possible, avoiding a project's significant environmental effects through implementing feasible mitigation measures.[19] In very limited circumstances, an agency may avoid preparing an EIR by issuing a negative declaration, a written statement briefly indicating that a project will have no significant impact. Because "[t]he adoption of a negative declaration . . . has a terminal effect on the environmental review process" by allowing the agency to dispense with the duty to prepare an EIR, negative declarations are allowed only in cases where there is not even a "fair argument" that the project will have a significant environmental effect.[20] Under the fair argument standard, a lead agency "shall" prepare an EIR whenever substantial evidence in the whole record before the agency supports a fair argument that a project may have a significant effect on the environment.[21] The phrase "significant effect on the environment" is defined as "a substantial, or potentially substantial, adverse change in the environment."[22]In certain circumstances, a project with potentially significant impacts can be modified by the adoption of mitigation measures to reduce the impacts to a level of insignificance. In such cases, an agency may satisfy its CEQA obligation by preparing a mitigated

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[15] Pub. Resources Code § 21002.1(a); CEQA Guidelines § 15002(a), (f).
[16] *No Oil, Inc. v. City of Los Angeles* (1974) 13 Cal.3d 68, 86.
[17] *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553, 564.
[18] Pub. Resources Code, § 21080, subd. (d) (emphasis added); CEQA Guidelines, § 15064; see also *Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903, 927; *Mejia v. City of Los Angeles* (2005) 13 Cal.App.4th 322.
[19] Pub. Resources Code, § 21002.1, subd. (a); CEQA Guidelines, § 15002, subd. (a) & (f).
[20] *Citizens of Lake Murray v. San Diego* (1989) 129 Cal.App.3d 436, 440; Pub. Resources Code, §§ 21100, 21064.
[21] Pub. Res. Code §§21080(d), 21082.2(d); 14 Cal. Code Reg. §§ 15002(k)(3), 15064(f)(1), (h)(1); *Laurel Heights Improvement Assn. v. Regents of the Univ. of Cal.* (1993) 6 Cal.4th 1112, 1123; *No Oil, Inc. v. City of Los Angeles* (1974) 13 Cal.3d 68, 75, 82; *Stanislaus Audubon Society, Inc. v. County of Stanislaus* (1995) 33 Cal.App.4th 144, 150-151; *Quail Botanical Gardens Found., Inc. v. City of Encinitas* (1994) 29 Cal.App.4th 1597, 1601-1602.
[22] Pub. Resources Code, § 21068.

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negative declaration.[23] A mitigated negative declaration, however, is also subject to the fair argument standard. Thus, an MND is also inadequate, and an EIR is required, whenever substantial evidence in the record supports a "fair argument" that significant impacts may occur even with the imposition of mitigation measures.

The "fair argument" standard is an exceptionally "low threshold" favoring environmental review in an EIR rather than a negative declaration.[24] The "fair argument" standard requires preparation of an EIR, if any substantial evidence in the record indicates that a project may have an adverse environmental effect.[25] As a matter of law, substantial evidence includes both expert and lay opinion.[26] Even if other substantial evidence supports the opposite conclusion, the agency nevertheless must prepare an EIR.[27] Under the "fair argument," CEQA always resolves the benefit of the doubt in favor of the public and the environment.

III. THE IS/ND FAILS TO ADEQUATELY DESCRIBE THE PROJECT

California courts have repeatedly held that "an accurate, stable and finite project description is the *sine qua non* of an informative and legally sufficient [CEQA document]."[28] CEQA requires that a project be described with enough particularity that its impacts can be assessed.[29] As articulated by the court in *County of Inyo v. City of Los Angeles*, "a curtailed, enigmatic or unstable project description draws a red herring across the path of public input."[30] Without a complete project description, the environmental analysis under CEQA is impermissibly limited, thus minimizing the project's impacts and undermining meaningful public review.[31]

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[23] Pub. Resources Code, § 21064.5; CEQA Guidelines, § 15064, subd. (f)(2).
[24] *Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903, 928.
[25] CEQA Guidelines, § 15064, subd. (f)(1); *Pocket Protectors v. City of Sacramento, supra*, 124 Cal.App.4th at 931.
[26] Pub. Resources Code, § 21080, subd. (e)(1); CEQA Guidelines, § 15064, subd. (f)(5).
[27] *Arviv Enterprises v. South Valley Area Planning Comm.* (2002) 101 Cal.App.4th 1333, 1346; *Stanislaus Audubon v. County of Stanislaus* (1995) 33 Cal.App.4th 144, 150-151; *Quail Botanical Gardens v. City of Encinitas* (1994) 29 Cal.App.4th 1597.
[28] *Stopthemillenniumhollywood.com v. City of Los Angeles* (2019) 39 Cal.App.5th 1, 17; *Communities for a Better Environment v. City of Richmond* ("*CBE v. Richmond*") (2010) 184 Cal.App.4th 70, 85–89; *County of Inyo v. City of Los Angeles* (1977) 71 Cal.App.3d 185, 193.
[29] *Id.* at 192.
[30] *Id.* at 197-198.
[31] *See, e.g., Laurel Heights Improvement Assn. v. Regents of the University of California* (1988) 47 Cal.3d 376.

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A public agency may not segment a large project into two or more smaller projects in order to mask serious environmental consequences. CEQA prohibits such a "piecemeal" approach and requires review of a Project's impacts as a whole.[32] "Project" is defined as "the whole of an action," which has the potential to result in a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment.[33] CEQA mandates "that environmental considerations do not become submerged by chopping a large project into many little ones — each with a minimal potential impact on the environment — which cumulatively may have disastrous consequences."[34] Before undertaking a project, the lead agency must assess the environmental impacts of all reasonably foreseeable phases of a project.[35]

a. The IS/ND's Description of the Project's Construction Activities is Inadequate and Flawed

The IS/ND lacks a detailed and complete description of construction activities to take place during the initial decommissioning of the facility's existing components and installation of the Project's new OECs, storage tanks, pipes, and any other additions to the facility. Crucial details, such as a detailed construction schedule, a list of all the construction equipment that would be used, and the horsepower rating and engine tier for each piece of construction equipment, are omitted. Without these specifics, it is impossible for the public to properly evaluate the potential environmental and public health impacts of the Project.

The Project requires a new Authority to Construct ("ATC") from the Imperial County Air Pollution Control District ("ICAPCD") pursuant to ICAPCD Rule 207 for a modification to the Complex's existing air permit, PTO #2217.[36] The Applicant submitted an ATC Application to ICAPCD in November 2019.[37] The ATC Application states that "The existing OECs will be deconstructed and removed from

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[32] 14 Cal. Code Reg. § 15378, subd. (a); *Burbank- Glendale-Pasadena Airport Authority v. Hensler* (1991) 233 Cal.App.3d 577, 592.
[33] 14 Cal. Code Reg., § 15378.
[34] *Bozung v. LAFCO* (1975) 13 Cal.3d 263, 283-84; *City of Santee v. County of San Diego*, (1989) 214 Cal.App.3d 1438, 1452.
[35] *Laurel Heights Improvement Assoc. v. Regents of the Univ. of Calif.* (1988) 47 Cal.3d 376, 396-97, 253 Cal.Rptr. 426) (EIR held inadequate for failure to assess impacts of second phase of pharmacy school's occupancy of a new medical research facility).
[36] See **Exhibit C**, Heber 2 Application for Authority to Construct, PROJECT No. 346-2-1, November 2019 ("ATC Application").
[37] *Id.*

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the Facility within 5 years per County of Imperial requirements."[38] However, the ATC Application is not part of the IS/ND, and nothing in the IS/ND provides a clear timeline or description of the activities required to decommission the existing six 1992 OECs and replacing them with the two new OECs. The IS/ND vaguely states that the construction phase would last "approximately eight months,"[39] but does not meaningfully describe the Project's construction equipment, schedule, or provide any information about the Project's construction-related emissions.

Construction emissions must be estimated and compared to significance thresholds to determine if the emissions are significant. It is standard practice to use the CalEEMod model to estimate a project's construction emissions. This requires a detailed construction schedule, a list of all the construction equipment that would be used, and the horsepower rating and engine tier for each piece of construction equipment, among other inputs.[40] None of this information is in the files produced by the County in support of the IS. The IS only mentions in passing that a crane, trucks, excavators, compactors, water truck, and powered hand tools would be used,[41] but otherwise is silent on the full construction fleet.[42] Information supplied in response to PRAs indicate that "semi-truck trailers, flatbed trucks, excavators/bulldozers, forklifts, roller, and cranes would be used to deliver and place the proposed facilities on the Heber 2 Project Site."[43] However, more equipment would be required than mentioned due to site soil conditions.[44] Further, this general information cannot be used to estimate emissions because critical operating parameters that determine emissions are missing, including equipment horsepower ratings, engine tiers, engine loads, hours of operation, etc.

An EIR must be prepared to fully describe and analyze the Project's construction phase and emissions.

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[38] ATC Application at pdf 12.
[39] IS/ND, pp. 23, 28, 29, 30.
[40] See User's Guide for CalEEMod Version 2016.3.2; http://www.caleemod.com/.
[41] IS, pdf 17, 333.
[42] IS, pdf 17, 24.
[43] Memorandum from Catalyst Environmental Solutions Inc., Re: Heber 2 Project Description Information, July 6, 2020. Exhibit --.
[44] See, e.g., IS, pdf 162 ("The soils are highly corrosive to metals and contain sufficient sulfates and chlorides to require special concrete mixes and protection of embedded steel building components when concrete is place in contact with native soil…").

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b. The IS/ND Fails to Describe Emissions from Reclamation Activities

The IS/ND includes a Reclamation Plan Application, which explains that "the entire Heber 2 site would be dismantled and removed" at the end of the 30-year CUP extension.[45] The Application states that all wells would be abandoned, that the Heber 2 Complex site will be revegetated and "likely" returned to a natural state, and that reclamation activities will use approximately 20,000 gallons of water.[46] However, neither the IS/ND nor the Reclamation Plan Application describe the timeline for reclamation activities,[47] and neither contain any description or analysis of the construction emissions associated with dismantling and removing Project structures, which will include all 6 OECs, pipelines, buildings, above-ground well facilities, fences, and other on-site physical Project structures.

Site reclamation, which will involve deconstructing a much larger area (40 acres[48] compared to 4 acres for Project construction) and require much of the same equipment (backhoes, excavators, heavy trucks, compactors, water trucks, crane)[49] will have impacts similar to construction. Reclamation of the entire Heber 2 Complex site may result in potentially significant construction emissions from both on-site and off-site construction equipment, dust, and may release Valley Fever spores, exposing reclamation construction workers and off-site receptors to potentially significant health risks. None of these reclamation impacts are discussed in the IS/ND or Reclamation Plan.

An EIR must be prepared to fully describe and analyze the Project's reclamation phase.

c. The IS/ND's Numerous Errors Prohibit the Public from Fully Evaluating the Project's Impacts

The IS/ND fails as an informational document because of its numerous errors and confusing statements. "A project description that gives conflicting signals to

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[45] See IS/ND, Reclamation Plan Application, p. 8.
[46] *Id*. at pp. 6-8.
[47] The Application states that revegetation will take approximately 6 months, but omits any timeline for deconstruction and dismantling activities associated with site closure. See Application, Revegetation Plan, p. 1.
[48] IS/ND, pdf 54, 330, 343.
[49] IS/ND, pdf 33; Reclamation Plan Application, p. 5 ("Backhoes, excavators, heavy trucks, light vehicles, compactors, hand tools, welding equipment, water truck, crane.").

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decision makers and the public about the nature of the project is fundamentally inadequate and misleading."[50]

The IS/ND is rife with inconsistent, misleading, and confusing statements, making it impossible for the reader to assess the County's conclusions regarding the Project's environmental impacts. The IS/ND asserts, for example, that a records search for previous cultural and historic resource surveys was conducted and "did not identify any recorded historical resources on the Project site or immediate vicinity. (Appendix C)." Appendix C is listed as the Water Quality Management Plan and does not concern cultural resources.[51] There is no cultural resources study attached to the IS/ND.

In addition, the IS/ND draws several conclusions that are not supported by substantial evidence or ask the reader to ferret out information not provided in the document, including:

- The IS/ND states that "no water resources or sensitive communities are present on or near the Project Site." The reader is directed to see Figure 6 and Appendix A as evidence of this conclusion. Figure 6 is a photograph of the Project site showing a lot with geothermal facilities at the back of a dirt lot. It does not support any conclusion, other than that a facility of some kind exists at the place where the photo was taken. The dirt lot does not lead to the conclusion that no water resources or sensitive communities are present on or near the site. Appendix A, meanwhile, contains more photographs of the site, none of which serve as evidence of a lack of sensitive natural communities.[52]

- The IS/ND consistently refers to the "Heber 2 Geothermal Complex" as also including the Heber South and Gould 2 facilities. ORMAT also owns the Heber 1 complex, located east of the Project site on Assessor's Parcel No. 054-250-036-000. Some documents, including the SEC Form 10-K, refer to the "Heber complex," which in some cases appears to refer to both sites.[53]

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[50] *South of Market Community Action Network v. City and County of San Francisco* (2019) 33 Cal.App.5th 321, 332.
[51] IS/ND at PDF page 22.
[52] IS/ND at PDF pages 21; 15; 48-52.
[53] See, e.g., http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/21c08b55-9e75-424a-b5b0-d2831cafc0e4.pdf at 83.

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- The IS/ND misuses the term "complex," fails to disclose the baseline generation and future generation after the Project is completed, and incorrectly identifies the units that would be modified.[54]

IV. THE IS/ND FAILS TO ACCURATELY DESCRIBE THE PROJECT'S BASELINE CONDITIONS

Courts have repeatedly emphasized the importance of an adequate baseline description, "for without such a description, analysis of impacts, mitigation measures and project alternatives becomes impossible."[55] CEQA Guidelines section 15125, subdivision (a), provides:

> An EIR must include a description of the physical environmental conditions in the vicinity of the project, as they exist at the time the notice of preparation is published, or if no notice of preparation is published, at the time environmental analysis is commenced, from both a local and regional perspective. This environmental setting will normally constitute the baseline physical conditions by which a lead agency determines whether an impact is significant.

A. The IS/ND Fails to Accurately Describe the Project's Baseline Generating Capacity and Associated Impacts, as Well As Its Baseline Emissions

The IS/ND's description of the generating capacity of the Complex is misleading and inaccurate. As Dr. Fox explains, the Applicant's annual reports and filings with the SEC describe the Heber 2 Complex as consisting of six OECs at Heber 2 plus Goulds 2 and Heber South. Further, the asserted nameplate generation capacity of the "complex" in the IS of 33 MW appears to be wrong. The owner/operator of the Heber 2 Complex, for example, asserts that the generating capacity of the "Heber Complex" is 92 MW and "has been sustainably operating since 1985, consisting of Heber 1, Heber 2, Heber South, Gould 1, and Gould 2."[56] Elsewhere, the owner variously reports that the generating capacity of the "Heber Complex" is

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[54] Hazard Assessment, PDF page 297, describes the complex as having three facilities (H2, G2, and Heber South).
[55] *County of Amador v. El Dorado County Water Agency* (1999) 76 Cal.App.4th 931, 953–954.
[56] Fox Comments, pp. ____; Charlene Wardlow, Director of Business Development, Ormat, Ormat's Geothermal Projects in Imperial County, p. 14, Imperial Valley Renewable Energy Summit, March 11, 2016; http://ivres.ivedc.com/media/managed/031116_Ormat_presentation_at_IVRES.pdf.

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currently 81 MW[57,58] to 82 MW[59] and includes Heber 1 and 2 and the Goulds Project in the term "Heber Complex."[60]

Generation data from the CEC for the original Heber units show multiple years with electrical output around 320,000 MWh and a peak output of 326,153 MWh in 2003, the year after net capacity was restored to 44 MW (per Ormat's 2015 Application[61]). The 2019 output of 198,110 MWh suggests that the proposed action would increase generation by up to 128,043 MWh/year, or by 65%.
Because the 2002 upgrade only increased capacity to 44/47 of the original capacity, Dr. Fox concludes that the current proposal would increase output by an addition 47/44 over 2003 output, or 65% x 47/44 = 69% over 2019 output. Thus, Dr, Fox explains that the proposed action would increase generation and associated impacts, e.g., water use and emissions, by approximately 2/3.[62] These increases are not disclosed in the IS/ND, which supplies misleading and inaccurate statements regarding the Project's baseline generating capacity.

Furthermore, the increase in emissions from this Project must be based on baseline emissions, typically the average emissions in the years immediately preceding the start of environmental review.[63] The IS/ND asserts that the change in isopentane emissions is based on actual baseline emissions for the 2017 to 2018 period.[64] However, the ATC Application indicates that the IS/ND calculated the increase in isopentane emissions using the maximum reported quarterly emissions over the period 2017–2018 based only on the third quarter of 2018 of 117.5 lb/day facility total,[65] not average emissions for 2017 to 2018 as claimed in the IS/ND.[66] Baseline emissions must be based on the average emissions over the baseline

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[57] ORMAT, 2019 Annual Report, pdf 19; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.
[58] SEC, Form 10-K, p. 11, pdf 10, 27, December 31, 2019.
[59] U.S. Securities and Exchange Commission, Form 10-Q, Ormat Technologies, Inc., March 31, 2020, p. 41, pdf 36-37; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/bd1a8403-baa2-4834-9e2f-29ea970e033c.pdf.
[60] U.S. Securities and Exchange Commission, Form 10-K, Ormat Technologies, Inc., December 31, 2007, p. 9, 24-26; https://www.sec.gov/Archives/edgar/data/1296445/000095013608001172/file1.htm.
[61] Heber 1 CUP #04-0024—Request to Amend, pdf 7; http://www.icpds.com/CMS/Media/Heber-Geothermal-Company_Part2.pdf.
[62] Fox Comments, p. ___.
[63] See e.g. *Association of Irritated Residents v. Kern County Board of Supervisors* ("*AIR v. Kern County*") (2017) 17 Cal.App.5th 708, 728–729,
[64] IS, pdf 19 and Table 2, pdf 291.
[65] ATC Application, pdf 28.
[66] Compare ATC Application, pdf 28 with IS, pdf 291.

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period, not the maximum. The use of the maximum emissions spike from a single point in time two years ago is not an accurate or permissible measure of the facility's baseline emissions because it is not representative of existing conditions at the Project site. The IS/ND's reliance on an inflated baseline artificially reduces the air quality impacts that are measured against it, and is not supported by substantial evidence.

Finally, the IS/ND contains no estimate of baseline emissions or resulting increases in emissions from any supporting equipment. Dr. Fox's analysis of the CEC generation for the subject units indicates that the Project will increase generation by two-thirds or by a factor of 1.6.[67] Thus, emissions from all supporting equipment will nearly double emissions as compared to the actual baseline conditions at the site. The IS/ND fails to disclose this potentially significant impact due to its reliance on an improperly inflated baseline.

B. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site

The County failed to make a reasonable effort to describe baseline biological conditions at the Project site. As a result, the IS/ND contains inaccurate and unreliable baseline information about potential sensitive species to occur at the Project site. The IS/ND also overlooks critical aerial habitat for special status birds and bats, and lacks substantial evidence to support its "no impact" conclusion for biological resources.

The IS/ND relies on a single site visit made by a wildlife biologist on June 1st, 2019, at an unreported time of day and for an unreported time period.[68] The IS/ND does not describe the survey guidelines followed by the biologist, including whether they complied with applicable United States Fish and Wildlife Service ("USFWS") and California Department of Fish and Wildlife ("CDFW") guidelines for surveys of relevant species, such as burrowing owl or migratory birds. Based on this single survey, the biologist concluded that no wildlife, and no suitable habitat for any special-status wildlife, exists on site.[69]

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[67] Dr. Fox Comments, p. ___.
[68] See IS/ND, Biological Resources Clearance Memorandum ("Biological Memorandum") (June 3, 2019), p. 5.
[69] *Id.*

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The Biological Memorandum vaguely states that the consultants reviewed information from four other sources: Unites States Fish and Wildlife Service ("USFWS"); Information, Planning, and Consultation System ("IPaC System"); California Natural Diversity Database ("CNDDB"); and the California Native Plant Society ("CNPS").[70] However, as Dr. Smallwood explains, "no use was made of richly informative data sets on wildlife occurrences, such as eBird."[71] Dr. Smallwood explains that, when appropriate use of available information is made, and consideration given to the aerial portion of wildlife habitat, readily available evidence supports the conclusion that up to 45 special-status species of wildlife are likely occur at the Project site.[72] Dr. Smallwood further explained that 6 of the 45 species are special-status species – either threatened, endangered, or a candidate for listing.[73]

Dr. Smallwood also conducted his own visual research using Google Earth images of the Project site. His review of Project-site images showed four common ravens taking off from structures on the Project site.[74] As Dr. Smallwood explains, common ravens remove carcasses of collision victims faster than any other vertebrate scavenger; the fact that common ravens are readily detectable in Google Earth imagery demonstrates that the site is likely providing vertebrate scavengers with regular, reliable food resources, which means "the Project is likely already killing birds and bats."[75] The IS/ND does not provide any baseline information about collision mortality with existing Project structures at the Project site. Therefore, the IS/ND lacks substantial evidence to support the conclusion that no wildlife will be impacted by the Project.

Dr. Smallwood presents substantial evidence demonstrating that special-status wildlife are likely to be present at the Project site. While courts have upheld EIRs containing limited biological baseline surveys,[76] no such deference is afforded to agency's decision to dispense with an EIR and prepare a negative declaration.[77] In this case, substantial evidence supports a fair argument for the need to prepare

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[70] *Id*. at p. 4.
[71] Smallwood Comments, p. 1.
[72] *Id*.
[73] *Id*. at pp. 1-2.
[74] Smallwood Comments, p. 6.
[75] *Id*. at pp. 5-6.
[76] *North Coast Rivers Alliance v. Marin Mun. Water Dist*. (2013) 216 Cal. App. 4th 614, 644; *Association of irritated Residents v. County of Madera ("AIR v. Madera"*) (2003) 107 Cal. App. 4th 1383, 1396.
[77] Pub. Resources Code, § 21080, subd. (d); CEQA Guidelines, § 15064; see also *Pocket Protectors,* 124 Cal.App.4th at 927.

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an EIR to accurately describe the Project's baseline conditions for wildlife, and to accurately analyze the Project's impacts to wildlife from both direct mortality and interference with wildlife movement.

V. THE COUNTY HAS VIOLATED CEQA BY PIECEMEALING ENVIRONMENTAL REVIEW AND PERMITTING FOR THE EXPANSION OF THE HEBER GEOTHERMAL FACILITIES AS SEPARATE PROJECTS

A public agency may not segment a large project into two or more smaller projects in order to mask serious environmental consequences. CEQA prohibits such a "piecemeal" approach and requires review of a Project's impacts as a whole.[78] "Project" is defined as "the whole of an action," which has the potential to result in a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment.[79] CEQA mandates "that environmental considerations do not become submerged by chopping a large project into many little ones — each with a minimal potential impact on the environment — which cumulatively may have disastrous consequences."[80] Before undertaking a project, the lead agency must assess the environmental impacts of all reasonably foreseeable phases of a project.[81]

Courts have found improper piecemealing where a lead agency conducts separate CEQA reviews for related activities proposed by the same applicant in the same vicinity. In *Plan for Arcadia v. City Council of Arcadia*,[82] a developer submitted two applications for developments on a 400-acre property, first a 72-acre shopping center and then a parking lot to serve a racetrack on the property. A site plan showed that the owner had plans to redevelop the entire property.[83] Although both projects were exempt from CEQA because they predated CEQA's effective date, it was "clear" to the court that they were "related to each other and that in

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[78] 14 Cal. Code Reg. § 15378, subd. (a); *Burbank- Glendale-Pasadena Airport Authority v. Hensler* (1991) 233 Cal.App.3d 577, 592.
[79] 14 Cal. Code Reg., § 15378.
[80] *Bozung v. LAFCO* (1975) 13 Cal.3d 263, 283-84; *City of Santee v. County of San Diego*, (1989) 214 Cal.App.3d 1438, 1452.
[81] *Laurel Heights Improvement Assoc. v. Regents of the Univ. of Calif.* (1988) 47 Cal.3d 376, 396-97, 253 Cal.Rptr. 426) (EIR held inadequate for failure to assess impacts of second phase of pharmacy school's occupancy of a new medical research facility).
[82] (1974) 42 Cal.App.3d 712, 718, 721.
[83] *Id.* at 719.

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assessing their environmental impact they should be regarded as a single project under [CEQA]."[84]

In *Tuolumne,* the court articulated "general principles" for determining whether two actions are one CEQA project, including "how closely related the acts are to the overall objective of the project," and how closely related they are in *time*, *physical location*, and *the entity undertaking the action*.[85] The court rejected arguments that a shopping center and nearby road alignment were "separate and independent" projects, and held that (1) separate approvals do not sever the connections between two activities; (2) the broad definition of a CEQA "project" extends beyond situations where a future activity is "necessitated by" an earlier one (noting that when actions "actually will be taken," the appropriate inquiry is whether they are related to one another, i.e. they comprise the "whole of an action" or "coordinated endeavor"); and (3) the applicable standard is not always whether two actions "could be implemented independently of each other."[86]

The Project is one of a series of permitting actions undertaken by the County to authorize operation of the Heber 2 Complex. The IS/ND provides misleading information about the Heber facilities, describing the Project as a simple upgrade to the Complex and extension of existing 33 MW operations. However, the ATC Application, Security and Exchange Commission ("SEC") filings by the Applicant, and other publicly available information indicate that the Heber 2 Geothermal Complex consists of eight OECs that "…are operationally interconnected to each other as well as to Goulds 2 and Heber South" as follows:[87]

- Heber 2: 6 OECs
- Heber South: 1 OEC
- Goulds 2: 1 OEC

The six OECs at Heber 2 are not only operationally interconnected to each other as well as to Goulds 2 and Heber South, they also share facilities, including the vapor recovery unit, fire pump, emergency pump, cooling towers, a diesel generator, and storage tanks. There is also piping connecting the motive fluid

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[84] *Id.* at 723, 726.
[85] *Tuolumne County Citizens for Responsible Growth, Inc. v. City of Sonora* (2007) 155 Cal.App.4th 1214, 1226-1227 ("*Tuolumne*").
[86] *Id.* at 1228-1230 (citing 14 Cal. Code Reg. § 15378(c) and analyzing *Sierra Club v. W. Side Irr. Dist.* (2005) 128 Cal.App.4th 690, 698-700).
[87] ATC Application, Section 1.1, pdf 9 and Appendix B, pdf 28.

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between the units.[88,89] Thus, these units constitute a single facility, rather than three separate facilities, as described in the IS/ND. The total generating capacity of this "complex" has been reported over the years by their owner to be significantly higher than the 33 MW described in the IS[90] and the 58 MW described in the ATC Application.[91] The combined generating capacity of these eight units is variously reported in Applicant documents filed elsewhere as ranging from 58 MW[92] to 81 MW.[93] These eight units clearly constitute a single facility, the "Heber Complex," a term that is widely misused in the IS and supporting documents.

The IS/ND fails to analyze the impacts of the Project's proposed extension of permits for the Heber Complex as a whole. As a result, the IS/ND is fundamentally flawed, as it piecemeals operational changes to the facilities that have occurred over time, and which will be expanded with implementation of the Project. The County must prepare an EIR which analyzes the impacts of the entire Heber Complex.

VI. SUBSTANTIAL EVIDENCE SUPPORTS A FAIR ARGUMENT THAT THE PROJECT MAY HAVE SIGNIFICANT IMPACTS WHICH MUST BE ANALYZED IN AN EIR

CEQA contains a strong presumption in favor of requiring a lead agency to prepare an EIR. This presumption is reflected in the "fair argument" standard. Under that standard, a lead agency must prepare an EIR whenever substantial evidence in the whole record before the agency supports a fair argument that a project may have a significant effect on the environment, even if other substantial evidence supports the opposite conclusion.[94] CEQA requires a lead agency to assess a project's impacts on the environment.[95] Any significant impacts must be mitigated or avoided to the extent feasible.[96]

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[88] ATC Application, Table 1, p. 5, pdf 13.
[89] Heber 1 CUP #04-0024 – Request to Amend, May 7, 2015; http://www.icpds.com/CMS/Media/Heber-Geothermal-Company_Part2.pdf.
[90] IS, pdf 9.
[91] ATC Application, Table 1, p. 5, pdf 13: 10+$_{1223.6+14.52 = pdf}$ 9: 36 MW + 10 MW + 12 MW = 58 MW.
[92] ATC Application, pdf 28, Air Emission Calculations, Gross Power Column.
[93] ORMAT, 2019 Annual Report, pdf 9 (81 MW); http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/21c08b55-9e75-424a-b5b0-d2831cafc0e4.pdf.
[94] Pub. Res. Code § 21082.2; *Laurel Heights Improvement Ass'n v. Regents of the University of California* (1993) ("Laurel Heights II") 6 Cal.4th 1112, 1123; *No Oil, Inc. v. City of Los Angeles* (1974) 13 Cal.3d 68, 75, 82; Quail Botanical, supra, 29 Cal.App.4th 1597at 1602; Stanislaus, supra, 33 Cal.App.4th 144, 150-151.)
[95] Pub. Res. Code § 21002.1(a), 21061; 14 Cal. Code Reg. § 15125, subd. (d).
[96] Pub. Res. Code §§ 21002, 21002.1(b), 21081, 21080.5(d)(2)(i).
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To determine whether a project will have a significant impact, the lead agency must first identify the relevant "environment," and then determine whether the project will cause a "significant effect on the environment."[97] CEQA defines these terms as follows:

"Environment means the physical conditions which *exist* within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise, objects of historic or aesthetic significance."[98]

"Significant effect on the environment means a substantial, or potentially substantial, *adverse change* in the environment."[99]

Additional guidance is provided in section 15125 of the CEQA Guidelines, which provides that an environmental review document must describe the environment in the project's vicinity "as it exists before the commencement of the project . . . ."

A. There is a Fair Argument that Construction Emissions from the Project Could Have a Significant Impact on Public Health and the Environment

CEQA requires the County to analyze the Project's impacts by determining whether there would be an adverse impact as measured against the *existing* environment in the area. Because the description of construction activities was incomplete, any estimation of impacts from construction activities will necessarily be inaccurate.

According to Dr. Fox, it is standard practice to use the CalEEMod model to estimate a project's emissions from construction. This requires, however, a detailed construction schedule, a list of all the construction equipment that would be used, and the horsepower rating and engine tier for each piece of construction equipment, among other inputs.[100] As Dr. Fox points out, the IS/ND contains none of this information, nor does any of it appear to exist in any of the files provided by the County in support of its conclusions.[101]

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[97] Pub. Res. Code § 21002.1; 14 Cal. Code Reg. §§ 15063, 15064.
[98] Pub. Res. Code § 21060.5 (emphases added).
[99] Pub. Res. Code § 21068 (emphasis added).
[100] See User's Guide for CalEEMod Version 2016.3.2; http://www.caleemod.com/.
[101] Fox Comments, p. ___.

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Far from estimating imprecise impacts to air quality due to construction emissions, the IS/ND simply fails to estimate these impacts at all. Construction emissions are not calculated, air quality significance thresholds are not presented for them, existing ambient air quality data are not presented, and the impacts of construction emissions on ambient air quality are not disclosed. Instead of estimating construction emissions and comparing them to ICAPCD's significance thresholds, the IS/ND concludes, with no analysis at all, that all construction emissions are not significant: "Emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"[102]

Dr. Fox explains that impacts from "temporary" construction emissions are routinely found to be significant.[103] ICAPCD, in fact, states in its guidance on construction emissions that "[i]t is not uncommon for construction-related emissions, which are generally temporary in nature, to have a temporary adverse impact on air quality."[104] Construction activities like demolition, grading, excavation, cut-and-fill operations, trenching, soil compaction, land clearing and grubbing "can cause substantial increases in localized concentrations of [particulate matter.]"[105]

The IS/ND states, without evidentiary support, that any emissions from construction activities will be insignificant. As the document contains no estimate of such emissions, however, there is no basis for this conclusion. Dr. Fox, meanwhile, estimates that emissions of PM10 and NOx and their attendant impacts to health and the environment due to construction activity will indeed be significant.[106]

Imperial County is already in violation of ambient air quality standards for PM2.5, PM10, and ozone (federal 8-hour).[107] As Dr. Fox states, "Imperial County fails the American Lung Association's (ALA's) State of the Air annual rankings for Imperial County (grade F). The ALA concludes that 'If you live in Imperial County,

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[102] IS, pdf 19.
[103] Fox Comments, p. ___.
[104] Imperial County APCD, CEQA Air Quality Handbook, November 2007, Section 4.2, p. 11.
[105] *Id*.
[106] Dr. Fox comments, 16.
[107] U.S. EPA, California Nonattainment/Maintenance Status for Each County by Year for all Criteria Pollutants, May 31, 2020; https://www3.epa.gov/airquality/greenbook/anayo_ca.html.

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the air you breathe may put your health at risk.'"[108] Based on Dr. Fox's calculations of emissions from construction activity at the Project site, emissions will increase and "any increase in PM2.5, PM10, or ozone precursors (ROG, NOx) due to construction (and operation) of the Project is a per se significant air quality and public health impact as they contribute to an acknowledged significant health risk."[109] Because this impact would clearly be significant, mitigation measures are required. Because the IS/ND failed to even estimate emissions and their impacts, a Negative Declaration is inappropriate and an EIR must be prepared.

B. There is a Fair Argument that the Project Could Result in Significant Impacts to Public Health from Valley Fever

As pointed out by Dr. Fox in her comments, the Project site is located in an area that is endemic for Coccidioidomycosis (abbreviated as cocci), commonly known as Valley Fever. Coccidioidomycosis is an infectious disease caused by inhaling the spores of *Coccidioides ssp.*[110,111] Clinical manifestations range from influenza-like illness to progressive pulmonary disease and, in 1% of infections, potentially fatal disseminated disease.[112] When soil containing this fungus is disturbed by activities such as digging, vehicle use, construction, dust storms, or during earthquakes, the fungal spores become airborne.[113,114] Valley Fever outbreaks during construction in

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[108] American Lung Association, State of the Air, California: Imperial County; http://www.stateoftheair.org/city-rankings/states/california/imperial.html.
[109] Dr. Fox comments, 15.
[110] Two species of *Coccidioides* are known to cause Valley Fever: *C. immitis*, which is typically found in California, and *C. posadasii*, which is typically found outside California. See Centers for Disease Control, Coccidioidomycosis (Valley Fever), Information for Health Professionals; https://www.cdc.gov/fungal/diseases/coccidioidomycosis/health-professionals.html.
[111] D. R. Hospenthal, Coccidioidomycosis and Valley Fever, Medscape, Updated September 20, 2018; https://emedicine.medscape.com/article/215978-overview.
[112] Cummings et al., Point-Source Outbreak of Coccidioidomycosis in Construction Workers, *Epidemiology and Infection*, v. 138, no. 4, 2010, pp. 507-511, 2010 (Exhibit --).
[113] California Department of Public Health, Valley Fever Fact Sheet, January 2016; https://www.cdph.ca.gov/Programs/CID/DCDC/CDPH%20Document%20Library/ValleyFeverFactSheet.pdf. *See also* G. Sondermeyer Cooksey et al., Update on Coccidioidomycosis in California, pp. 20-21, Medical Board of California Newsletter, v. 141, Winter 2017; https://www.mbc.ca.gov/Download/Newsletters/newsletter-2017-01.pdf.
[114] Cummings et al. 2010 (Exhibit 14).

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California have been widely reported.[115,116,117,118,119,120] Spores raised during construction and/or wind storms,[121] which are common in the area, can result in significant worker and public health impacts. Imperial County is endemic for Valley Fever.[122] Valley Fever cases have increased significantly since the Heber 2 facility was constructed[123,124] in 1992,[125] including in Imperial County, where 42% of the cases occurred in El Centro.[126]

"Workers disturbing soil in areas where Valley Fever is common are at highest risk," with construction workers topping the list.[127] As the proposed site has the potential to contain Coccidioidomycosis spores and it is well known that they

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[115] Jason A. Wilken et al., Coccidioidomycosis among Workers Constructing Solar Power Farms, California, USA, 2011–2014, *Emerging Infectious Diseases*, v. 21, no. 11, November 2015; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4622237/.
[116] The Associated Press, Valley Fever Hits 28 at Calif. Solar Plant Sites, *The San Diego Union-Tribune*, May 1, 2013; http://www.sandiegouniontribune.com/sdut-valley-fever-hits-28-at-calif-solar-plant-sites-2013may01-story.html.
[117] G. L. Sondermeyer Cooksey et al., Dust Exposure and Coccidioidomycosis Prevention Among Solar Power Farm Construction Workers in California, *American Journal of Public Health*, August 2017 (Exhibit --).
[118] Rupal Das et al., Occupational Coccidioidomycosis in California, Outbreak Investigation, Respirator Recommendations, and Surveillance Findings, *Journal of Occupational and Environmental Medicine*, May 2012, vol. 54, no. 5, pp. 564-571 (Exhibit --).
[119] D. Pappagianis and the Coccidioidomycosis Serology Laboratory, Coccidioidomycosis in California State Correctional Institutions, *Annals of the New York Academy of Sciences*, v. 1111, pp. 103-111, 2007 (Exhibit --).
[120] K. C. Cummings et al., Point-source Outbreak of Coccidioidomycosis in Construction Workers, *Epidemiology and Infection*, v. 138, 2010, pp. 507-511 (Exhibit --).
[121] P. L. Williams, D. L. Sable, P. Mendez, and L. T. Smyth, Symptomatic Coccidioidomycosis Following a Severe Natural Dust Storm: An Outbreak at the Naval Air Station, Lemoore, Calif, *Chest*, pp. 566-70, 1979; https://pubmed.ncbi.nlm.nih.gov/498830/.
[122] California Department of Public Health, Valley Fever Fact Sheet; https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/Coccidioidomycosis.aspx#.
[123] Barbara Feder Ostrov and Harriet Blair Rowan, Valley Fever Cases Climb in California's Central Valley—and Beyond, December 17, 2019; https://khn.org/news/valley-fever-cases-climb-in-californias-central-valley-and-beyond/.
[124] CDC, Valley Fever (Coccidioidomycosis) Statistics; https://www.cdc.gov/fungal/diseases/coccidioidomycosis/statistics.html.
[125] IS, pdf 9, 11, 22, 27, 28, 40, 53, 73, etc. Other sources report 1985; https://en.wikipedia.org/wiki/List_of_power_stations_in_California.
[126] Stephen Munday, Imperial County Public Health, Overview of Coccidioidomycosis (Valley Fever), May 21, 2013, df 21, 24; http://imperial.granicus.com/MetaViewer.php?view_id=2&clip_id=455&meta_id=59137.
[127] Wilken 2015, pdf 19.

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can easily become airborne when soil is disturbed,[128] the Project construction site should be tested well in advance of construction to determine if spores are present. Accurate test methods have been developed and used in similar applications.[129,130] A study conducted in the Antelope Valley, slated for six solar ranches of varying sizes, concluded that soil analyses should be conducted before soil disturbance in endemic areas, noting: "Based on the findings of this study, we recommend that EIRs include soil analyses for *Coccidioides spp.* on land destined for construction of any type in endemic areas of the pathogen."[131] An Environmental Assessment for a solar project in a nearby area has required soil testing.[132]

Recommendations that go far beyond the conventional dust control measures included in the Applicant's CUP have been developed by the California Department of Public Health and other agencies. And on top of these, Dr. Fox recommends additional mitigation measures to protect construction worker health, including the following:

- Continuously wet the soil before and while digging or moving the earth. Landing zones for helicopters and areas where bulldozers, graders, or skid steers operate are examples where continuously wetting the soil is necessary.
- When digging a trench or fire line or performing other soil-disturbing tasks, position workers upwind when possible.
- Place overnight camps, especially sleeping quarters and dining halls, away from sources of dust such as roadways.

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[128] Colson et al. 2017, p. 451 ("A correlation between soil disturbances due to large-scale renewable energy construction projects, agricultural management practices and PM10 fugitive dust emission with increased incidence of coccidioidomycosis was clearly indicated by results of this study."), p. 456 ("One such danger is *Coccidioides spp.* arthroconidia becoming airborne when soil is disturbed and dust mitigation measures are inefficient or absent.").
[129] J. R. Bowers et al., Direct Detection of Coccidioides from Arizona Soils Using CocciENV, a Highly Sensitive and Specific Real-time PCR Assay, *Medical Mycology*, 2018 (Exhibit 18); and Proceedings of the 60th Annual Coccidioidomycosis Study Group Meeting, April 8–9, 2016, Fresno, CA; http://coccistudygroup.com/wp-content/uploads/2016/10/CSG-60th-Annual.pdf.
[130] Colson et al. 2017, pp. 439–458.
[131] Colson et al. 2017, p. 456.
[132] Final Environmental Assessment for Construction, Operation, and Decommissioning of a Solar Photovoltaic System at Marine Air Ground Task Force Training Command Marine Corps Air Ground Combat Center, Twentynine Palms, California, November 2015, Table ES-1, AQ-17; https://www.29palms.marines.mil/Portals/56/Docs/G4/NREA/Environmental%20Assessment%20Construction%20and%20Operation%20of%20Solar%20Photovoltaic%20System%20at%20MAGTFTC,%20MCAGCC%20(Final)%20November%202015.pdf.

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- Minimize the amount of digging by hand. Instead, use heavy equipment with the operator in an enclosed, air-conditioned, HEPA-filtered cab.

The IS/ND, however, is silent on this potentially significant impact. Further, the dust control measures included in the CUP are not adequate to control Valley Fever spores raised during Project construction. Indeed, Dr. Fox states, projects that have implemented similar conventional PM10 dust control measures have experienced fugitive dust issues and reported cases of Valley Fever.[133,134] The very existence of this potentially significant impact, as well as the mitigation measures that must be implemented to avoid it, requires the preparation of an EIR.

C. The IS/ND's Methods for Evaluating a Hazard Analysis and the Possibility of Accidents or Explosions at the Site Are Inadequate and Unsupported

Hazard analyses should be based on a worst-case scenario. While the IS/ND acknowledges that this the legal standard, it only evaluates hazards and potential accidents from the hypothetical scenario of a single tank accident, rather than considering an accident at an OEC, which contain more isopentane and would cause much more significant damage in an accident than one of the small tanks which the County included in the IS/ND's hazards assessment. As Dr. Fox points out, if one takes the IS/ND's analysis, given the new configuration of the tanks, an accident could cause worst-case hazard impacts that are up to five times higher than disclosed.[135]

Furthermore, the IS/ND failed to even evaluate the worst-case release scenario. The IS/ND acknowledges five possible release scenarios: flash fire, pool fire, boiling liquid expanding vapor explosion (BLEVE), vapor cloud explosion, and jet fire.[136] The IS selected a vapor cloud explosion as the "most appropriate consequence" with no explanation or justification whatsoever.[137] However, a

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[133] Herman K. Trabish, Green Tech Media, Construction Halted at First Solar's 230 MW Antelope Valley Site, April 22, 2013; http://www.greentechmedia.com/articles/read/Construction-Halted-At-First-Solars-230-MW-Antelope-Valley-Site.
[134] Julie Cart, 28 Solar Workers Sickened by Valley Fever in San Luis Obispo County, *Los Angeles Times*, May 1, 2013; http://articles.latimes.com/2013/may/01/local/la-me-ln-valley-fever-solar-sites-20130501.
[135] Dr. Fox comments, 47.
[136] IS, pdf 301: Hazard Assessment, p. 6.
[137] Ibid.

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BLEVE is the worst case release scenario for very flammable materials such as isopentane because it combines both the mechanical effects of an explosion and the thermal effects of a fire. Due to these dual effects, it is one of the most severe accidents that can happen and typically results in mortalities.[138] A BLEVE cannot be ruled out as a possible accident scenario, and would result in much greater impacts than the vapor cloud explosion evaluated in the IS/ND. An EIR is required to accurately evaluate and mitigate the Project's potentially significant hazardous materials impacts.

D. There is a Fair Argument that Extending the Life of the Project Could Result in Geologic Impacts

Though the IS/ND does not analyze or discuss geologic impacts of extending the life of the facilities at the site for 30 more years, it concludes that the "[d]evelopment of the proposed facilities would not result in the destabilization of any soils or geologic units that could cause a landslide, subsidence, or liquefaction."[139]

It is clear from the Geotechnical Report Update, however, that the Project site is located over a geothermal fluids reservoir where fluids extraction and reinjection are causing annual ground settlement of 1 to 2 inches.[140] These shifts can impact farming operations and other infrastructure at or near the surface, as stated in the 2019 SEC filing:

Another aspect of geothermal operations is the management and stabilization of subsurface impacts caused by fluid injection pressures of production and injection fluids to mitigate subsidence. In the case of the geothermal resource supplying the Heber complex, pressure drawdown in the center of the well field has caused some localized ground subsidence, while pressure in the peripheral area has caused localized ground inflation. Inflation and subsidence, if not controlled, can adversely affect farming operations and other infrastructure at or near the land surface. Cost of failing to stabilize site pressures in the Heber Complex area include repair and modification of gravity-based farm irrigation systems and municipal sewer piping and repair or replacement of a local road bridge spanning an irrigation canal.[141]

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[138] See Dr. Fox comments, 45–47.
[139] IS, Section VII: Geology and Soils, Sections VII(c) and (d), pdf 24.
[140] Mariana Eneva and others, Surface Deformation at the Heber Geothermal Field in Southern California, Proceedings, 44th Workshop on Geothermal Reservoir Engineering, February 11-13, 2019, p. 9, pdf 9.
[141] SEC, Form 10-K, p. 11, pdf 41, December 31, 2019.

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The presence of highly explosive isopentane makes the impacts from structural damage and accidents much more concerning. Both on-site personnel and off-site receptors are at risk of health impacts and mortality. An EIR must be prepared to adequately evaluate these risks.

E. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project

The IS/ND claims that there will be no significant impact to migratory bird species that are listed by the USFWS's IPaC to have the potential to occur in the vicinity of the Project site, based on its assertion that the site is devoid of vegetation or water resources and contains no suitable habitat.[142] Evidence of this assertion is allegedly found in Figure 6 and Appendix A, which show photographs of the site depicting geothermal facilities foregrounded by bare dirt lots.[143] These photos, however, do not support any conclusion other than that facilities of some kind exist at the place where the photos were taken. The bare ground does not lead to the conclusion that no water resources or sensitive communities are present on or near the site.

As pointed out in Mr. Smallwood's comment letter, birds "inhabit the lower atmosphere just as they necessarily inhabit terrestrial or aquatic environments."[144] The bare ground that the IS/ND's photos depict does not deter birds from flying over it. "Volant wildlife often fly over bare ground to migrate, disperse, forage, patrol home ranges, or to move from one habitat patch to another."[145]

Collisions with static structures such as those in the proposed Project, are known to be the cause of bird fatalities and wildlife fatality monitoring at several industrial solar projects, including some near the Project site, indicates an average collision and entrapment fatality rate of 17.4 birds per kilometer of security fencing.[146] By this measure, the Project's existing 1,615 meters of security fencing likely results in 28.1 birds killed per year. The Project's proposal to extend the life of the complex by 30 years is likely to result in 843 birds killed by the fence alone.[147]

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[142] IS/ND at PDF page 20–21.
[143] IS/ND at PDF pages 15, 48–52.
[144] Smallwood Comments, p. 4.
[145] *Id.*
[146] *Id.*
[147] *Id.*

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Using the collision fatality rate found at nearby solar projects of 91.4 birds per kilometer of generation tie-ins, Mr. Smallwood estimates that the Project's 1 kilometer of powerlines likely kills 91.4 birds per year, which would likely result in 2,742 birds over the proposed 30-year extension.[148] Acknowledging that it is more difficult to translate the solar projects' data on collisions with those sites' powerblocks to collisions with the proposed Project's energy converters and storage tanks, Mr. Smallwood adjusts his calculation of the collision rate using 65% of the volume of the solar powerblocks to accommodate for a potentially smaller volume at the Heber Complex. The according fatality rate predicts annual fatalities of 31 bats and 315 birds.[149] This is a potentially significant impact on biological resources, which could also result in illegal take of special status bird or bad species.

All told, if the life of the Project is extended 30 years, the existing and proposed structures could result in 13,050 birds and 930 bats. The IS/ND, however, concludes that the Project will have no impact on wildlife.

Mr. Smallwood's calculations provide substantial evidence demonstrating that there is a fair argument that the Project will result in significant impacts to wildlife, and that an EIR must be prepared to assess those potential impacts.

F. The IS/ND Fails to Disclose the Project's Construction or Operational GHG Emissions, and Relies on an Inapplicable Significance Threshold

The IS/ND fails to meaningfully describe or analyze the Project's construction and operational GHG emissions. With regard to construction emissions, the IS/ND simply states that the Project's construction equipment will "emit greenhouse gases," then concludes, with no analysis, that these emissions would be "minor," "temporary," and "well under the 10,000 C02e lb/day threshold established by AB 32."[150] With regard to operational emissions, the IS/ND states, with no supporting evidence, that long-term emissions from the Heber 2 Complex would "remain the same or very similar to the existing emissions profile."[151] The IS/ND makes no attempt to quantify or qualify the Project's GHG emissions in any manner authorized by the CEQA Guidelines.[152] The IS/ND therefore lacks any evidence to support its conclusion that the Project would have insignificant GHG impacts.

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[148] *Id.*
[149] *Id.*
[150] IS/ND, p. 23.
[151] IS/ND, p. 24.
[152] 14 Cal. Code Regs § 15064.4.

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The IS/ND also relies on an inapplicable GHG threshold to evaluate construction and operational GHG impacts. Under the CEQA Guidelines, a lead agency must analyze a project's impacts on GHG emissions.[153] The Guidelines allow for several approaches to this analysis, both qualitative and quantitative. The Guidelines explicitly mandate, however, that the "analysis should consider a timeframe that is appropriate for the project. The agency's analysis also must reasonably reflect evolving scientific knowledge and state regulatory schemes."[154]

The IS/ND relies on the AB 32 10,000 C02e lb/day threshold.[155] This significance threshold, however, is not applicable to the Project, because it was developed to comply with the state reduction target as it is embodied in AB 32,[156] which mandates that statewide greenhouse gas emissions be reduced to 1990 levels by the target year 2020.[157] In 2016, the state passed SB 32,[158] which codified a new statewide 2030 GHG emissions reduction target of 40% below 1990 levels. Following the new legislation, the California Air Resources Board ("CARB") adopted in December 2017 a new scoping plan to outline the strategy needed to achieve SB 32 GHG targets. These are the binding "state regulatory scheme" that the CEQA Guidelines require agencies to account for.

The AB 32 threshold applies only through 2020, and does not account for or include any numeric threshold for compliance with SB 32 or the scoping plan and are therefore not applicable to projects that will be built and operated beyond the AB 32 target year.[159] Because the Project's first fully operational year would be after 2020, and it would continue to operate many years beyond that, the County must analyze the Project for its compatibility with the state's mandated goals for, at the very least, the year 2030 and beyond.[160]

An EIR must be prepared to correct these substantial deficiencies in the County's analysis of the Project's GHG impacts.

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[153] 14 CCR §15064.4.
[154] 14 CCR §15064.4(b)
[155] IS/ND, p. 23.
[156] See, California Environmental Quality Act Air Quality Guidelines, Bay Area Air Quality Management District, May 2017, at p. D-27.
[157] California Air Resources Board, Assembly Bill 32 Overview; available at: https://www.arb.ca.gov/cc/ab32/ab32.htm, accessed April 3, 2019.
[158] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32
[159] See also *Cleveland National Forest Foundation v. San Diego Assn. of Governments* (2017) 3 Cal.5th 497.
[160] SWAPE Comments, p. 21.

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G. There is a Fair Argument that the Project Will Have Significant Impacts on Water Supply

The IS/ND asserts that "[n]o additional water will be required to support the proposed facilities … The existing Heber 2 facility will provide the water via existing permits."[161] As Dr. Fox explains, however, relative to baseline conditions, the Project will increase water use at the facility by 69% through use of its two new water-cooled energy converters.[162,163]

The Imperial Irrigation District ("IID"), which supplies Colorado River water for the Project, adopted the Imperial Integrated Regional Water Management Plan ("IRWMP") in 2012. The IRWMP finds that "[r]enewable energy projects that result in intensification of water use could have a negative effect on agricultural water supplies unless mitigated" and requires that "[t]o the extent that water is proposed for power plant cooling, the developer shall demonstrate that alternative water supply sources and alternative cooling technologies are unavailable, environmentally undesirable, or economically unsound."[164] The IS/ND contains no such demonstration and fails to even disclose that the Project will increase water use from the IID relative to baseline conditions.

Moreover, the Water Quality Control Plan (Basin Plan) for the Colorado River Basin Region[165] states that fresh inland waters should only be used for power plant cooling if other sources or other methods of cooling would be environmentally undesirable or economically unsound. This policy requires that power plant cooling water should come from, in order of priority: (1) wastewater being discharged to the ocean; (2) ocean water; (3) brackish water from natural sources or irrigation return

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[161] IS, Reclamation Plan Application, pdf 333.
[162] Dr. Fox explains in her comments at pages 8 and 59 that CEC generation data for selected years for the original Heber units shows that the proposed action would increase generation by up to 128,043 MWh/year, or 65%. An upgrade to the facility in 2002 increased capacity to 44/47 of the original capacity. The current proposal would increase the capacity to 47/44 over 2003 output, or 65% x 47/44 = 69% over 2019 output.
[163] Dr. Fox further explains that water-cooled geothermal binary power plants, such as the Heber units, have the highest water consumption rate per megawatt hour of any thermal power plant technology.
[164] Imperial Water Forum, Imperial Region Integrated Regional Water Management Plan, October 2012, Chapter 8, Reduce Water Demand – Increase Water Use Efficiency, p. 8-22; http://imperialirwmp.org/2013%20Updates/finalirwmp.html.
[165] Water Quality Control Plan for the Colorado River Basin Region, January 8, 2019; https://www.waterboards.ca.gov/coloradoriver/water_issues/programs/basin_planning/docs/bp032014/r7_bp2019fullbp.pdf.

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flow; (4) inland waste waters of low total dissolved solids; (5) other inland waters.[166] The IS is silent on this policy and its application to the Project's water use, thus failing as an informational document under CEQA. Irrigation return flows, for example, would be available from IID.

The existing CUP states that "If the amount of water available to Imperial County is reduced by the Central Arizona project, the right to the irrigation water for the five years granted herein may be terminated."[167] Ongoing drought conditions in the area supplying the IID water puts the Project's water supply at risk. Thus, the existing water supply is not only inadequate, it is also insecure. The IS/ND is silent on the availability and source of the increase in water required to operate the Project and alternative water supply sources in the event that IID water is inadequate.

The increase in water use will result in significant impacts not disclosed or mitigated in the IS/ND. This increase in water use is for cooling purposes, specifically for evaporation and blowdown in the Project's cooling towers.[168] Heber 1 is primarily a flash steam plant. The only significant water use is for cooling tower water makeup. The cooling system is an evaporative (wet) system, and all makeup water not supplied by condensate is provided by water from the IID canal. At Heber 2, the condensers are cooled by a closed-loop wet cooling tower system. Because all of the geothermal brine is returned to the resource aquifer, and none is used for steam production, there is no condensate to be recovered for other uses.[169] Thus, all of the cooling tower makeup water is supplied from the IID canal.[170]

The IID's Interim Water Supply Policy ("IWSP"), which provides a mechanism to address new water supply requests for proposed projects being developed within the IID service area, currently designates up to 25,000 AFY of IID's annual Colorado River water supply for non-agricultural projects within its service area.[171] The Project's proposed use of IID Colorado River water for power

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[166] Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling, p. 4, Principle #1. Adopted June 19, 1975, Resolution No. 75-58; https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1975/rs75_058.pdf.
[167] Imperial County, Agreement for Conditional Use Permit #06-0006, ORCAL/Heber Field Company, April 25, 2006, Document 2006-020097, pdf 14. Exhibit 14.
[168] Doering and Jordan, Heber KGRA, pdf 11-12.
[169] Dr. Fox Comments, p. 61.
[170] Ibid.
[171] IID, IID's Interim Water Supply Policy for Non-Agricultural Projects, adopted September 29, 2009, fee schedule revised 2015, p. 1; http://www.iid.com/home/showdocument?id=9599.

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plant cooling is inconsistent with the IRWMP. The County must disclose this inconsistency in an EIR. The County must also require the applicant to demonstrate that alternative water supply sources and alternative cooling technologies are unavailable, environmentally undesirable, or economically unsound prior to allowing the use of Colorado River water for the proposed Project.[172]

VII. THE IS/ND CONCEDES THAT MITIGATION IS REQUIRED

The IS/ND makes several references to measures that will be implemented during construction to reduce impacts on the environment. Control measures, for example, will allegedly be taken "to minimize the potential for construction fugitive dust and particulate matter releases," consistent with Imperial County 2019 PM10 and PM2.5 Plans.[173] The IS/ND further claims that "[t]hrough the application of these [unidentified] measures, the construction of the Project would limit visible dust emissions and particulate matter emissions to 20 percent opacity and/or 150 lb/day, and therefore, be in compliance with Imperial County's approach to minimizing these construction related emissions."[174]

The implementation of mitigation measures indicates that an IS/ND is the incorrect environmental analysis document for the Project. If mitigation measures are required to avoid significant impacts to the environment, a Mitigated Negative Declaration or an EIR must be prepared.

Furthermore, it is improper to defer the formulation of mitigation measures under CEQA. Courts have imposed several parameters for the adequacy of mitigation measures. First, the lead agency may not defer the formulation of mitigation measures until a future time unless there are specific performance standards capable of mitigating the project's impacts to a less than significant level. Deferral is impermissible where an agency simply requires a project applicant to obtain a report and then comply with any recommendations that may be made in

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[172] Dr. Fox explains in her Comments at pages 63–64 that other technologies, which consume much less water, are widely available and in use by the Applicant. Dry cooling, for example, is technologically feasible as demonstrated by some of Ormat's other operational geothermal binary OEC plants in the United States and all over the world. Not only would dry cooling eliminate the plant's water demand, it would also eliminate particulate matter emissions in an airshed that is designated as nonattainment for PM10.

[173] IS, pdf 19. "Emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"

[174] IS, pdf 19.

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the report.[175] Second, a public agency may not rely on mitigation measures of uncertain efficacy or feasibility. Third, "[m]itigation measures must be fully enforceable through permit conditions, agreements, or other legally binding instruments."[176] Fourth, mitigation measures that are vague or so undefined that it is impossible to evaluate their effectiveness are legally inadequate.

With respect to this Project, the IS/ND fails to satisfy the basic purposes of CEQA. The IS/ND failed to adequately disclose, investigate, and analyze the Project's potentially significant impacts, and in some places states that mitigation measures will be implemented—making an EIR the appropriate environmental review document—while at other times requiring no mitigation to reduce potential impacts to less than significant levels. Because the IS/ND lacks basic information regarding the Project's potentially significant impacts, the IS/ND's conclusion that the Project will have no significant impact on the environment is unsupported.[177] The County failed to gather the relevant data to support its findings and repeatedly and impermissibly deferred analysis and formulation of mitigation measures to future reports. Finally, the County's own evidence and that of experts provide substantial evidence showing that the Project may result in potentially significant impacts. Therefore, a fair argument can be made that the Project may cause significant impacts requiring the County to prepare an EIR.

A. The IS/ND Fails to Consider Feasible Mitigation to Reduce Potentially Significant impacts to Less than Significant Levels

Dr. Fox describes numerous readily available, feasible mitigation measures to reduce many of the Project's significant impacts to less than significant levels. The County should consider and implement these measures in a binding mitigation plan as part of an EIR.

1. Construction Mitigation

As Dr. Fox points out, the IS/ND's conclusions rely on mitigation of air quality impacts but the document contains no such control measures. The IS/ND contains no mitigation for "potential fugitive dust and particulate releases,"[178]

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[175] *Gentry v. City of Murrieta* (1995) 36 Cal.App.4th 1359, 1393; *Quail Botanical Gardens Foundation v. City of Encinitas* (1994) 29 Cal.App.4th 1597, 1604, fn. 5.
[176] 14 Cal. Code Reg. § 15126.4(a)(2).
[177] Pub. Res. Code § 21064.5.
[178] Ibid.

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which would contribute to existing violations of ambient air quality standards, a potentially significant impact. Further, construction emits other pollutants, including the ozone precursors ROG and NOx. As the area where the Project will be located is in violation of ozone ambient air quality standards, increases in ROG and NOx from construction equipment could contribute to an existing violation of the ozone standard, which is a significant impact. Thus, mitigation is required and an EIR must be prepared.

Dr. Fox agrees that construction ozone emissions are likely significant because the area where the Project is located currently violates ozone ambient air quality standards and construction would increase ozone precursor emissions. She explains, however, that shutting off equipment that is not in use—a mitigation measure recommended by the Application to Amend CUP 06-0006—will not mitigate this impact because idling emissions are a very small fraction of ozone precursor emissions. Thus, assuming ozone emissions are significant, and the IS/ND contains no estimate of ozone-precursor emissions, this proposed mitigation would do nothing to mitigate the significant impact. These emissions can be significantly reduced by requiring high tier (Tier 3 or 4) construction equipment and/or tailpipe controls such as catalytic converters.[179]

2. <u>Operational Mitigation</u>

As the facility will emit isopentane, which is a reactive organic gas (ROG) as well as other criteria pollutants, mitigation is required to avoid significant impacts.

The major source of ROG emissions is fugitive sources, such as pumps, valves, flanges, and connectors.[180] The ROG emission calculations in the ATC, relied upon in the IS/ND, assumed the use of the U.S. EPA's leak detection and repair (LDAR) program[181] to estimate ROG emissions from fugitive sources. The ROG emissions from fugitive sources can be mitigated by implementing an enhanced LDAR program and the use of leakless and low-leak technology,

[179] Dr. Fox Comments, p. 19.
[180] ATC, Table 4, pdf 18.
[181] U.S. Environmental Protection Agency, Leak Detection and Repair Compliance Assistance Guidance, A Best Practices Guide, October 2007; http://www2.epa.gov/sites/production/files/2014-02/documents/ldarguide.pdf.

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including:[182]

- Reduce the leak detection threshold from 10,000 ppmv to 500 ppmv for all components except pumps in the motive fluid system, where the threshold should be 2,000 ppmv.
- Leak minimization after detection must occur as soon as possible after detection and no later than 24 hours after leak discovery.
- Leak repair must occur as soon as possible after detection and no later than 7 days after leak discovery.
- All leak detection monitoring must be done with both a USEPA Method 21 portable analyzer and a new hand-held infrared camera.
- Leakless and low-leak technology must be used to prevent fugitive emissions of the motive fluid.
- Require monthly LDAR inspections.

Additional reduction of ROG emissions can be achieved by the following mitigation measures proposed by Ormat Nevada, Inc. for its Casa Diablo IV Geothermal Development Project in Mono County:[183]

a) Install vapor recovery devices estimated to return at least 99% of the motive fluid back to the system.

b) Use a maintenance vapor recovery unit during OEC unit maintenance activities to capture motive fluid that could otherwise be released.

c) Lower pressure of motive fluid system compared to motive fluid used at older existing plants, thus, less potential for fugitive leaks/emissions.

d) Place pentane-specific vapor sensors and flame detectors at strategic locations around the around the turbine, motive fluid pumps, and motive fluid storage tank and connection to power plant computer control system to quickly alert plant operators to any potentially hazardous situations, which would help to keep a check on significant leaks.

e) Perform leak checks, inspections, monitoring, and leak logging.

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[182] ESA, Casa Diablo IV Geothermal Power Plant Draft Supplemental Environmental Impact Report, August 2020, Chapter 3; https://files.ceqanet.opr.ca.gov/139190-6/attachment/uz9O5pnLE-zHa0ulN3BgkuisP8fXYGyhCgPux2Zx7m8nGPwgcghuwFJ4IZOvzQ67LT2cQOGEv1rTrdyV0.
[183] County of Imperial, East Brawley Geothermal, Final Environmental Impact Report, May 2012; ftp://ftp.co.imperial.ca.us/icpds/eir/east-brawley-geothermal/final/07minor-revisions-deir.pdf.
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Further, Dr. Fox explains, the ATC Application indicates VOC emissions would be offset, implying offsets are mitigation. The ATC Application therefore demonstrates that the Project's excess VOC emissions are significant and require mitigation. However, the IS/ND cannot rely on offsets to mitigate air quality impacts because they are not valid CEQA mitigation unless they reduce the emissions at the location where the impact occurs.[184] Emission reduction credits ("ERCs") are not an acceptable substitute for performing local air quality analyses and mitigating the local impacts themselves. A revised CEQA document should prohibit the use of offsets to mitigate air quality impacts, except those offsets that occur at the project site at the time of project startup. Instead, conventional mitigation is required to reduce the significant ROG emissions.

VIII. THE IS/ND FAILS TO PROPERLY EVALUATE POTENTIALLY SIGNIFICANT CUMULATIVE IMPACTS

An EIR must discuss significant "cumulative impacts."[185] This requirement flows from CEQA section 21083, which requires a finding that a project may have a significant effect on the environment if

> the possible effects of a project are individually limited but cumulatively considerable. . . . 'Cumulatively considerable' means that the incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.[186]

Cumulative impacts are defined as "two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts."[187] "[I]ndividual effects may be changes resulting from a single project or a number of separate projects."[188]

"The cumulative impact from several projects is the change in the environment which results from the incremental impact of the project when added to other closely related past, present, and reasonably foreseeable probable future projects. Cumulative impacts can result from individually minor but collectively

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[184] See Dr. Fox Comments, p. 32.
[185] CEQA Guidelines § 15130(a).
[186] Pub. Resources Code § 21083(b)(2).
[187] CEQA Guidelines § 15355(a).
[188] *Id.*

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significant projects taking place over a period of time."[189] A legally adequate "cumulative impacts analysis" views a particular project over time and in conjunction with other related past, present, and reasonably foreseeable probable future projects whose impacts might compound or interrelate with those of the project at hand. "Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time."[190]

As the court stated in *Communities for a Better Environment, supra,* 103 Cal.App.4th 98, 114:

> Cumulative impact analysis is necessary because the full environmental impact of a proposed project cannot be gauged in a vacuum. One of the most important environmental lessons that has been learned is that environmental damage often occurs incrementally from a variety of small sources. These sources appear insignificant when considered individually, but assume threatening dimensions when considered collectively with other sources with which they interact.

In this case, the IS/ND's cumulative impact analysis is inaccurate and not in accordance with CEQA for numerous reasons. Most troublesome is the IS/ND's failure to analyze the cumulative impacts of the Project when taken together with the other geothermal facilities at the Heber Complex.

V. THE PROJECT MAY REQUIRE A CEC LICENSE

Dr. Fox's comments illustrate why the Project may require a CEC license:[191]

The subject geothermal facility as described in its Application for an Authority to Construct permit consists of six ORMAT Energy Converters (OECs) at Heber 2 (36 MW) that are operationally interconnected to each other as well as to Goulds 2 (12 MW) and Heber South (12 MW) for a total generating capacity of 60 MW.[192] Other information discussed in [Fox Comment 1, pp. 1–3] indicates that the Heber 2 Complex has a generating capacity of 81-82 MW. The Project will restore generating capacity of the Heber 2 Complex to its original capacity of 92 MW, not 33 MW as asserted in the IS.

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[189] Communities for a Better Environment v. () 103 Cal.App.4th 98, 117.
[190] CEQA Guidelines § 15355(b).
[191] Dr. Fox Comments, pp. 67–70.
[192] Air Sciences Inc., Heber 2 Application for Authority to Construct, November 2019, Section 1.0, pdf 9, Exhibit 11.

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The CEC licenses all thermal power plants over 50 MW in California.[193] The CEC's listing of licensed facilities does not include the Heber Complex.[194] The discussion in Comment 1 indicates that the Heber Complex currently exceeds 50 MW. The Project will extend the life of the Heber Complex by 30 years, from 2019 to 2049.[195] Thus, the Project requires a license from the CEC.

The CEC may delegate siting authority over geothermal power plants and related facilities to county governments that have adopted geothermal elements into their general plan.[196] [Dr. Fox's] research identified a geothermal element in Imperial County's General Plan.[197] However, this element clearly states that all energy facilities are required to undergo review by the CEC as part of an Application for Certification. "The CEC and County of Imperial coordinate the permitting and siting of power plants and any necessary transmission lines."[198] Two tests are required to establish that the Heber Complex is a single facility.

First, the net generating capacity must equal or exceed 50 MW using the calculation method in California Code of Regulations, Title 20, Section 203. Under Section 203, the generating capacity of an electric generating facility is found by subtracting the minimum auxiliary load from the maximum gross rating of the plant's turbine generators. The IS and the record before the County does not contain the information required to make this determination. Thus, the IS fails as an informational document under CEQA.

However, the CEC lists the Heber Complex as a single plant, with four units that share the same identifier (T0033) and a capacity of 81.5 MW.[199] While the record does not contain the information required to make the Section 203 calculation, based on my experience, it is unlikely that the maximum gross rating

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[193] U.S. Department of Energy, California State Plant Commissioning Process—Application for Certification (7-CA-a); https://openei.org/wiki/RAPID/Roadmap/7-CA-a.
[194] California Energy Commission, Alphabetical List of Power Plant Projects; https://ww2.energy.ca.gov/sitingcases/alphabetical_cms.html.
[195] IS, pdf 9.
[196] U.S. Department of Energy, California State Plant Commissioning Process—Application for Certification (7-CA-a).
[197] Imperial County Planning and Development Services Department, Geothermal/Alternative Energy and Transmission: Element, County of Imperial General Plan, October 17, 2006, p. 29; http://www.icpds.com/CMS/Media/Geothermal-TransmissionElement-(2006).pdf.
[198] Ibid.
[199] CEC, Annual Generation – Plant Unit; https://ww2.energy.ca.gov/almanac/electricity_data/web_qfer/Annual_Generation-Plant_Unit_cms.php.

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minus the minimum auxiliary load would be less than 50 MW. Heber energy, for example, is purchased by SCPPA, who reports a net annual generation of 327 gwh and a 60% net capacity factor for the Heber Complex.[200] This corresponds to a net generating capacity of 62 MW, which exceeds 50 MW.

Second, one must establish the connectivity between the components of the Heber 2 Complex, which includes Gould 2 and Heber South.[201] This requires the consideration of four factors:

- sited on contiguous parcels,
- designed, installed, and operated by the same organization,
- have energy and environmental impacts greater than a jurisdictional 50 MW facility, and
- share utility services for water, electrical interconnection, natural gas lines, and/or road access.

All four of these tests are met by the Project.

First, the proposed development would occur entirely on a single 39.99-acre parcel, which also includes the other Heber Complex geothermal facilities, the Goulds 2 and Heber South projects.[202] The proposed Project site is within the existing Heber 2 power plant area. All proposed facilities would be located within the existing fence line and permit area.[203] Finally, the Project shares the same road

[200] Ormat Heber 1; http://scppa.org/page/Ormat-Heber-1.
[201] IS, pdf 9.Charlene Wardlow, Ormat's Geothermal Projects in Imperial County, Imperial Valley Renewable Energy Summit, March 11, 2016, Heber Facility Summary, p. 14; http://ivres.ivedc.com/media/managed/031116_Ormat_presentation_at_IVRES.pdf.
[202] IS, p. 10, 23 ("the proposed facilities would be located within the existing Heber 2 Complex site."), 39 ("The proposed development would occur entirely on the 39.99 Assessor's Parcel Number (APN) 054-250-031. This parcel also includes geothermal facilities for the Goulds 2 and Heber South projects.").
[203] IS, p. 39.

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access as the entire Heber 2 Complex on Dogwood Road,[204] the same fire and emergency access roads,[205] and shared pipelines.[206]

Second, Ormat will design, install, and operate the Heber Complex over the 30-year extension, from 2019 to 2049, as noted in numerous SEC filings and annual reported cited elsewhere in these comments.[207]

Third, the Project proposes to extend the life of the entire Heber 2 complex by an additional 30 years.[208] As demonstrated in [Dr. Fox's Comments], the environmental impacts of the operation of the entire Heber 2 Complex, a 92 MW facility,[209] are significant over the 30-year extension.

Fourth, the Heber Complex geothermal facilities all rely on the same support facilities: cooling towers, vapor recovery unit, emergency generator, fire pumps, and emergency pump.[210] Thus, the proposed 30-year extension of the lifetime of the Heber 2 Complex requires a license from the CEC.

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[204] IS, p. 8 (project location and location of entire Heber 2 Complex is 855 Dogwood Road, Heber, CA 92249), p. 30 ("Lone site access is provided via Dogwood Road.").
[205] IS, p. 24 (discussing fire department access roads and gates at Heber 2 Complex site); p. 31 (all proposed facilities would be constructed within the existing Heber 2 Complex site and not introduce any transportation hazards, design features, or incompatible uses with surrounding roadways); p. 33 ("The existing Heber 2 Emergency Response Plan addresses project construction and operations. The proposed work is within the existing footprint of ongoing geothermal activities in the Heber 2 plant site.").
[206] IS, p. 8 (Project will add additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex).
[207] See, for example, https://www.ormat.com/en/projects/all/main/?Country=USA&Seg=0&Tech=6 and the Ormat May 2020 10-Q report cited in Comment 2.1, which states: "Heber Complex (California). We are currently in the process of repowering the Heber 1 and Heber 2 power plants. We are planning to replace steam turbine and old OEC units with new advanced technology equipment that will add a net capacity of 11 MW. Following these enhancements, we expect the capacity of the complex to reach 92 MW. Permitting, engineering and procurement are ongoing as well as manufacturing and site construction. We expect commercial operation in the second half of 2021."
[208] IS, p. 8.
[209] The current capacity of the complex is 81 MW with a planned expansion to add 11 MW; https://www.ormat.com/en/projects/all/main/?Country=USA&Seg=0&Tech=6.
[210] ATC Application, p. 5, pdf 13, Table 1. Existing and Proposed Equipment at Heber 2, Heber South, and Goulds 2.

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IX. CONCLUSION

The IS/ND fails to meet the informational and public participation requirements of CEQA, because it improperly piecemeals environmental review, fails to analyze potentially significant impacts compared to the existing baseline, fails to evaluate the proposed Project and lacks evidence to support the County's environmental conclusions. CEQA requires that an EIR be prepared if there is substantial evidence supporting a fair argument that any aspect of a project may cause a significant effect on the environment, regardless of whether the overall effect of the project is adverse or beneficial.[211] As discussed in detail above, there is substantial evidence supporting a fair argument that the Project may result in significant adverse and unmitigated impacts that were not identified in the IS/ND. An EIR is required for the Project.

Thank you for your consideration of these comments. Please include them in the record of proceedings for the Project.

Sincerely,

Kendra D. Hartmann
Christina Caro

Attachments

KDH:acp

[211] CEQA Guidelines § 15063(b)(1).

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EXHIBIT A

EEC ORIGINAL PKG

Comments

on the

Initial Study

for the

Heber 2 Geothermal Repower Project

Heber, California

August 31, 2020

By

Phyllis Fox, PhD, PE

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1. INTRODUCTION

Second Imperial Geothermal Company (the "Applicant") is requesting a Conditional Use Permit (CUP) amendment to modify its facilities at the existing Heber 2 Geothermal Energy Complex located at 855 Dogwood Road, Heber, California, in Imperial County. Imperial County, the CEQA lead agency, has prepared an Initial Study (IS)[1] for this facility.

The IS describes the Project as consisting of two new water-cooled ORMAT Energy Converters (OECs) to replace six old OEC units, three new 10,000 gallon isopentane aboveground storage tanks; and pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex. The IS states that these modifications would "refurbish the Heber 2 Complex to its original nameplate capacity (33 megawatts) without expanding the existing facility beyond the current footprint…"[2] The IS further states that the permitted life of the entire Heber 2 Complex will be increased by 30 years, from 2019 to 2049.[3]

This description is incomplete, misleading, and inconsistent with information on the Project filed by the Applicant with other agencies. As discussed below, the Project will replace the six OEC units disclosed in the IS. These OEC units are part of the Heber 2 Complex, as stated in the IS. The Heber 2 Complex also includes the Goulds 2 and Heber South units in addition to the six existing OECs.[4] The Project will restore the total generation capacity of the Heber 2 Complex to its original capacity of 92 MW, not 33 MW as asserted in the IS. The owner/operator of the Heber 2 Complex, for example, asserts that the generating capacity of the "Heber Complex" is 92 MW,[5] close to the total generating capacity of 96 MW disclosed in the ATC.[6]

The capacity of the upgraded Complex is critical here because the CEQA lead agency for power generation facilities of 50 MW or greater is the California Energy

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[1] Imperial County, Initial Study & Environmental Analysis for Heber 2 Geothermal Repower Project (IS), Contained in Project Report, Heber 2 Geothermal CUP #19-0017, pdf 2, May 28, 2020; http://www.icpds.com/CMS/Media/2.-Heber-2-Geothermal-CUP19-0017-EEC-Pkg.pdf.

[2] IS, pdf 9.

[3] IS, pdf 9.

[4] IS, pdf 9: "The CUP amendment application also proposes to renew the permitted life of the entire Heber 2 Complex (including the Goulds 2 and Heber South geothermal energy facilities to 30 years (2019-2049)."

[5] Charlene Wardlow, Director of Business Development, Ormat, Ormat's Geothermal Projects in Imperial County, p. 14, Imperial Valley Renewable Energy Summit, March 11, 2016; http://ivres.ivedc.com/media/managed/031116_Ormat_presentation_at_IVRES.pdf.

[6] ATC, pdf 28, Air Emission Calculations, Gross Power Column.

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Commission (CEC), not Imperial County. The CEC has jurisdiction over all power generation facilities of 50 MW and larger, together with their supporting infrastructure. Imperial County is the wrong lead agency under CEQA for this Project.

The Project is described in an Application for an Authority to Construct (ATC)[7] Permit submitted to Imperial County Air Pollution Control District (ICAPCD) as replacing six existing two-level geothermal power generation units at Heber 2 with two new larger units.[8] The ATC Application asserts Heber 2 has a gross combined power output rating of 36 MW,[9] not 33 MW as claimed in the IS. The existing units will be deconstructed and removed from the Facility within five years per County of Imperial requirements.[10]

I reviewed the IS and supporting files supplied by the lead agency, Imperial County, as well as information submitted to other agencies. In my opinion, the IS is substantially deficient and does not fulfill its mandate as an informational document under CEQA to inform the public of potential impacts. My review and analysis of the IS indicate that:

- The Project description is fundamentally flawed.
- The IS and Conditional Use Permit Application recommend mitigation for construction impacts, requiring the preparation of an Environmental Impact Report (EIR).
- The IS fails as an informational document under CEQA for failing to evaluate impacts, including construction and air quality impacts, operational air quality impacts, cumulative air quality impacts, construction health risks, reclamation air quality impacts, and water use impacts, among others.
- Construction PM10 and NOx emissions are significant and unmitigated.
- Valley Fever impacts are significant and unmitigated.
- Operational ROG emissions are significant and unmitigated.
- Water use impacts are significant and unmitigated.
- The IS failed to disclose emissions relative to baseline operation of the entire facility, thus significantly underestimating emissions.
- Cumulative impacts were not evaluated.

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[7] ORMAT Nevada Inc., Application for Authority to Construction (ATC Application), November 2019 (Exhibit 3).

[8] Ibid, pdf 5, 8.

[9] ATC Application, p.1, pdf 9.

[10] ATC Application, Section 1.3, pdf 12.

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- Significant geologic impacts were not evaluated or disclosed.
- Risk of upset (hazards) impacts are significant and unmitigated.
- Imperial County is the wrong lead agency under CEQA. The facility requires a license from the California Energy Commission (CEC).

I have over 40 years of experience in the field of environmental engineering, including air emissions and air pollution control; greenhouse gas (GHG) emission inventory and control; water quality and water supply investigations; hazardous waste investigations; risk of upset modeling; environmental permitting; nuisance investigations (odor, noise); environmental impact reports (EIRs), including CEQA/NEPA documentation; risk assessments; and litigation support. I have MS and PhD degrees in environmental engineering from the University of California at Berkeley and am a licensed professional engineer in California. My resume is included in Exhibit 1 to these comments.

I have prepared comments, responses to comments and sections of CEQA and NEPA documents on air quality, greenhouse gas emissions, water supply, water quality, hazardous waste, public health, risk assessment, worker health and safety, odor, risk of upset, noise, land use, traffic, and other areas for well over 500 CEQA and NEPA documents. This work includes EIRs, EISs, Initial Studies (ISs), Negative Declarations (NDs), and Mitigated Negative Declarations (MNDs). My work has been specifically cited in two published CEQA opinions: *Berkeley Keep Jets Over the Bay Committee, City of San Leandro, and City of Alameda et al. v. Board of Port Commissioners* (2001) 111 Cal. Rptr. 2d 598, and *Communities for a Better Environment v. South Coast Air Quality Management Dist.* (2010) 48 Cal. 4th 310; and has supported the record in many other CEQA and NEPA cases. I have also presented expert testimony in many California Energy Commission (CEC) cases and before the hearing boards of numerous air districts across the United States.

2. PROJECT DESCRIPTION IS INACCURATE

The Project description in the IS is inaccurate and incomplete. The Application for an Authority to Construct (ATC) permit for the Project, Security and Exchange Commission (SEC) filings, and other publicly available information discussed below indicate that the Heber 2 Geothermal Complex consists of six ORMAT Energy Converters (OECs) that "are operationally interconnected to each other as well as to Goulds 2 and Heber South" as follows:[11]

- Heber 2: 6 OECs
- Heber South: 1 OEC

[11] ATC Application, Section 1.1, pdf 9 and Appendix B, pdf 28.

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- Goulds 2: 1 OEC

The combined generating capacity of these eight units is variously reported in Applicant documents filed elsewhere as ranging from 58 MW[12] to 81 MW.[13] These eight units constitute a single facility, the "Heber Complex," a term that is widely misused in the IS and supporting documents.

The six OECs at Heber 2 are not only operationally interconnected to each other, as well as to Goulds 2 and Heber South, they also share facilities, including the vapor recovery unit, fire pump, emergency pump, cooling towers, a diesel generator, and storage tanks. There is also piping connecting the motive fluid between the units.[14,15] Thus, these units constitute a facility, rather than three separate facilities. The total generating capacity of this "complex" has been reported over the years by its owner to be significantly higher than the 33 MW disclosed in the IS[16] and the 58 MW disclosed in the ATC Application.[17]

Thus, the IS is fundamentally flawed for at least three major reasons. First, it piecemeals operational changes to the facility. The Project is just one part of an overall upgrade of these eight units. Second, the IS only addresses a subset of the changes at the facility. The Project, for example, also requires the repair and enhancement of existing wells and drilling of new wells.[18] Third, Imperial County is the wrong CEQA lead agency. Power generating facilities of 50 MW or greater fall under the jurisdiction of the CEC. Comment 11. My review of the CEC's database of licensed facilities[19] indicates this facility is not listed. Third, the Project description in the IS is incomplete, inconsistent with information filed elsewhere by the Applicant, and littered with errors, rendering an accurate environmental analysis based on the IS as impossible.

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[12] ATC Application, pdf 28, Air Emission Calculations, Gross Power Column.

[13] ORMAT, 2019 Annual Report, pdf 9 (81 MW); http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/21c08b55-9e75-424a-b5b0-d2831cafc0e4.pdf.

[14] ATC Application, Table 1, p. 5, pdf 13.

[15] Heber 1 CUP #04-0024 – Request to Amend, May 7, 2015; http://www.icpds.com/CMS/Media/Heber-Geothermal-Company_Part2.pdf.

[16] IS, pdf 9.

[17] ATC Application, Table 1, p. 5, pdf 13: 36 MW + 10 MW + 12 MW = 58 MW.

[18] SEC, U.S. Securities and Exchange Commission (SEC), Ormat Technologies, Inc., Form 10-K, pdf 46, p. 60, December 31, 2019; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/21c08b55-9e75-424a-b5b0-d2831cafc0e4.pdf.

[19] California Energy Commission, Alphabetical List of Power Plant Projects; https://ww2.energy.ca.gov/sitingcases/alphabetical_cms.html.

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After considerable research, described in further detail below, I conclude that the Project is an 11 MW addition to the Heber Complex to restore its capacity to 92 MW. However, reaching this conclusion required significant research, including information filed by the Applicant elsewhere, information that should have been disclosed by the Applicant and included in the IS, ATC, CUP Application and other documents before the County. The following sections describe the information I reviewed to reach this conclusion.

2.1. Generating Capacity of the "Complex"

The IS misuses the term "complex," fails to disclose the baseline generation and future generation after the Project is completed, and incorrectly identifies the units that would be modified. This information is essential to estimate air quality and other impacts. The files I reviewed indicate that the information in the IS is misleading, incomplete, full of errors and omissions and inconsistent with information filed by the Applicant elsewhere. Impacts cannot be identified without a complete and accurate project description, which is missing from the IS. Thus, the IS fails as an informational document under CEQA.

The IS[20] states that the purpose of the Project is to allow the existing "Heber 2 Complex" to return to its nameplate energy generation capacity of 33 MW,[21] by replacing six old units dating from 1992.[22] The IS also states that the Heber 2 Complex currently generates less than 33 MW.[23] These two assertions are wrong.

The term "complex" is incorrectly used in the IS because, as discussed in Comment 2, "complex" refers to eight connected generating units (OECs), with a total generating capacity that ranges from 58 MW[24] to 81 MW,[25] not 33 MW as asserted in the IS.

The ATC, for example describes the facility as follows:[26] "The six OECs at Heber 2 are operationally interconnected to each other as well as to Goulds 2 and Heber South.

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[20] IS, pdf 9.

[21] IS, pdf 22, 29, 53, 54, 362.

[22] IS, pdf 9.

[23] IS, pdf 53, 361.

[24] ATC Application, pdf 28 (Heber 2 = 36 MW; Gould 2 = 10 MW; Heber South = 12 MW).

[25] ORMAT Technologies, Inc. 2019 Annual Report, pdf 19; https://s1.q4cdn.com/231465352/files/doc_financials/2019/ar/Ormat-2019-Annual-Report.pdf.

[26] ATC, Section 1.1, pdf 9.

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The VRMU and MF storage tanks are shared by all the units and there is piping connecting the MF circuits between the units."

The Conditional Use Permit (CUP) application similarly describes the subject facilities as follows: "This application also proposes to extend the permitted life of the entire Heber 2 Complex (including the related Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049)."[27]

The Applicant's annual reports and filings with the SEC similarly describe the Heber 2 Complex as consisting of six OECs at Heber 2, plus Goulds 2 and Heber South. Further, the asserted nameplate generation capacity of the "complex" in the IS of 33 MW appears to be wrong. The owner/operator of the Heber 2 Complex, for example, asserts that the generating capacity of the "Heber Complex" is 92 MW and "has been sustainably operating since 1985, consisting of Heber 1, Heber 2, Heber South, Gould 1, and Gould 2".[28] Elsewhere, the owner variously reports that the generating capacity of the "Heber Complex" is currently 81 MW[29,30] to 82 MW[31] and includes Heber 1 and 2 and the Goulds Project in the term "Heber Complex".[32] See, for example:[33]

Project Name	Size(MW)	Technology	Resource Cooling	Customer	PPA Expiration
Heber Complex (3)	81	Geothermal dual flash and binary systems using a water cooled system	1°F per year	SCPPA	Heber 1 — 2025 Heber 2 — 2023 Heber South — 2031

[1] PPA = power purchase agreement

This applicant information is consistent with information on file with the CEC, which identifies the following units at Heber with a total output of 81.5 MW:[34]

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[27] CUP, p. 2.

[28] Charlene Wardlow, Director of Business Development, Ormat, Ormat's Geothermal Projects in Imperial County, p. 14, Imperial Valley Renewable Energy Summit, March 11, 2016; http://ivres.ivedc.com/media/managed/031116_Ormat_presentation_at_IVRES.pdf.

[29] ORMAT, 2019 Annual Report, pdf 19; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.

[30] SEC, Form 10-K, p. 11, pdf 10, 27, December 31, 2019.

[31] U.S. Securities and Exchange Commission, Form 10-Q, Ormat Technologies, Inc., March 31, 2020, p. 41, pdf 36-37; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/bd1a8403-baa2-4834-9e2f-29ea970e033c.pdf.

[32] U.S. Securities and Exchange Commission, Form 10-K, Ormat Technologies, Inc., December 31, 2007, p. 9, 24-26; https://www.sec.gov/Archives/edgar/data/1296445/000095013608001172/file1.htm.

[33] U.S. SEC, Form 10-K, December 31, 2019, p. 34, pdf 27.

[34] California Energy Commission (CEC), Annual Generation—Plant Unit, Facility ID # T0033; http://www.icpds.com/CMS/Media/Heber-Geothermal-Company_Part2.pdf.

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- Heber Geothermal Company 1, online 8/1/1985, 52 MW
- Heber Geothermal Company GEN2, online 6/11/2006, 3.5 MW
- Heber Geothermal Company GEN3, online 6/11/2006, 7 MW
- Heber Geothermal Company GEN4, online 3/8/2018, 19 MW

These units are referred to as the "Heber Complex" and currently have a combined generating capacity of 81.5 MW.[35]

The Ormat annual report indicates that the Project will add 11 MW to the Heber Complex, raising its total output to 92 MW.[36] Recent (e.g., September 30, 2019,[37] March 31, 2020[38]) Ormat SEC Form 10-Q filings[39] similarly state:

> *Heber Complex (California).* We are currently in the process of repowering the Heber 1 and Heber 2 power plants. We are planning to replace steam turbine and old equipment with new advanced technology equipment that will add a net capacity of 11 MW. Following these enhancements, we expect the capacity of the complex to reach 92 MW. Permitting, engineering and procurement are ongoing. Manufacturing of equipment is planned to commence in the fourth quarter 2019. We expect commercial operation in early 2021.

The addition of 11 MW to reach the original design capacity of 92 MW is consistent with the CEC position that the facility currently has 81.5 MW (81.5+11 MW = 92.5 MW).

Thus, it appears that the Project is an 11 MW addition to the Heber Complex to restore its capacity to 92 MW. If the 11 MW addition is designed to return the Complex to its design capacity, the 11 additional megawatts will increase all impacts relative to baseline conditions by at least a factor of 1.13 (92/81.5 = 1.13) and likely more, depending on the increase relative to "baseline" operational conditions in a representative two-year period prior to the start of environmental review. The record that I reviewed, supplied in response to PRAs, does not include the information required to establish baseline generation. Thus, the IS and supporting files supplied by Imperial County fail as information resources under CEQA.

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[35] See also CEC, Geothermal Electric Generation, Heber Geothermal Co. capacity = 81.5 MW; gross MWh = 441,041 MWh; https://ww2.energy.ca.gov/almanac/renewables_data/geothermal/index_cms.php.

[36] ORMAT Annual Report, pdf 46.

[37] Ormat Technologies, Inc., Form 10-Q, U.S. Securities & Exchange Commission, September 30, 2019, p. 52, pdf 53; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/94e40060-5286-4b4f-bc1c-c6549e04d4cf.pdf.

[38] Ormat Technologies, Inc., Form 10-Q, U.S. Securities & Exchange Commission, March 31, 2020, pp. 40-41, pdf 36-37; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/bd1a8403-baa2-4834-9e2f-29ea970e033c.pdf.

[39] Ormat Technologies, Inc., Form 10-Q, U.S. Securities & Exchange Commission, September 30, 2019, p. 52; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/94e40060-5286-4b4f-bc1c-c6549e04d4cf.pdf.

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2.2. Baseline Heber Complex Generation

Due to the significant confusion in the Project description and the absence of any baseline data, I examined CEC operating data for the Heber units for the past five years.[40] The actual operating data indicate that if the facility is really only a 33-MW net facility, as asserted in the IS, then it has been operating at a capacity factor of more than 100% in most years, clearly not requiring an upgrade. However, it is more likely that the IS simply incorrectly referred to the units that would be upgraded as the "Heber Complex."

These multiple values for Project capacity make it impossible to reach any legally defensible conclusions about the nature of the proposed project. If (and **only** if) the proposed changes are only to the original 1986 project, and not to any other part of the Heber Complex, then it is possible to draw some conclusions about the proposed Project's impact on Heber generation.

The spreadsheet in Exhibit 2 shows CEC generation data for selected years for the original Heber units. Data before 2001 were not easily available. The spreadsheet shows multiple years with electrical output around 320,000 MWh and a peak output of 326,153 MWh in 2003, the year after net capacity was restored to 44 MW (per Ormat's 2015 Application[41]). The 2019 output of 198,110 MWh suggests that the proposed action would increase generation by up to 128,043 MWh/year, or by 65%.

Because the 2002 upgrade only increased capacity to 44/47 of the original capacity, the current proposal would increase output by an additional 47/44 over 2003 output, or 65% x 47/44 = 69% over 2019 output. Thus, the proposed action would increase generation and associated impacts (e.g., water use and emissions), by approximately 2/3. These increases are not disclosed in the IS. Comment 2.

In sum, it is evident that the term "complex" is incorrectly used in the IS, that the Project is piecemealed, and that the facility that is being modified should be licensed by the CEC, not evaluated in an IS issued by Imperial County.

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[40] Heber Geothermal Company (T0033) data from CEC QFER reports, where xx = 19, 18, 17, 16, or 15, for the years, e.g., 2019, 2019, 2017, 2016, and 2015; https://ww2.energy.ca.gov/almanac/electricity_data/web_qfer/Annual_Generation-Plant_Unit_cms.php?goSort=plant_table.plantName&year=20xx.

[41] Heber 1 CUP #04-0024—Request to Amend, pdf 7; http://www.icpds.com/CMS/Media/Heber-Geothermal-Company_Part2.pdf.

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3. CONSTRUCTION

3.1. Construction Emissions Were Not Estimated

Construction emissions must be estimated and compared to significance thresholds to determine if the emissions are significant. It is standard practice to use the CalEEMod model to estimate a project's construction emissions. This requires a detailed construction schedule, a list of all the construction equipment that would be used, and the horsepower rating and engine tier for each piece of construction equipment, among other inputs.[42] None of this information is in the files produced by the County in support of the IS. The IS only mentions in passing that a crane, trucks, excavators, compactors, water truck, and powered hand tools would be used,[43] but otherwise is silent on the full construction fleet.[44] Information supplied in response to PRAs indicate that "semi-truck trailers, flatbed trucks, excavators/bulldozers, forklifts, roller, and cranes would be used to deliver and place the proposed facilities on the Heber 2 Project Site."[45] However, more equipment would be required than mentioned due to site soil conditions.[46] Further, this general information cannot be used to estimate emissions because critical operating parameters that determine emissions are missing, including equipment horsepower ratings, engine tiers, engine loads, hours of operation, etc. Thus, the IS fails as an informational document under CEQA.

In fact, the IS does not contain any analysis of the impact of Project construction emissions on air quality. Construction emissions are not estimated. Rather, they are only generally, incoherently, and very briefly discussed in two IS subsections.

They are first discussed in IS Section III(b)(b). This section addresses cumulative emissions ("Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment…"), not Project emissions. Second, they are discussed in Section III(b)(c), which addresses health impacts ("Expose sensitive receptors to substantial pollutants [*sic*] concentration.").[47] Neither of these IS sections

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[42] See User's Guide for CalEEMod Version 2016.3.2; http://www.caleemod.com/.

[43] IS, pdf 17, 333.

[44] IS, pdf 17, 24.

[45] Memorandum from Catalyst Environmental Solutions Inc., Re: Heber 2 Project Description Information, July 6, 2020 (Exhibit 4).

[46] See, e.g., IS, pdf 162 ("The soils are highly corrosive to metals and contain sufficient sulfates and chlorides to require special concrete mixes and protection of embedded steel building components when concrete is place in contact with native soil…").

[47] IS, pdf 19.

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directly addresses Project construction emissions, which are confusingly and briefly discussed in each of these sections in spite of the section heads.

Construction emissions are not calculated, air quality significance thresholds are not presented for them, existing ambient air quality data are not presented, and the impacts of construction emissions on ambient air quality are not disclosed. Instead of estimating construction emissions and comparing them to Imperial County Air Pollution Control District's (ICAPCD's) significance thresholds, the standard CEQA approach, the IS concludes with no analysis at all that all construction emissions are not significant: "Emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"[48]

This failure to evaluate construction impacts not only violates CEQA but also the ICAPCD guidance on construction emissions, which states:[49]

> It is not uncommon for construction related emissions, which are generally temporary in nature, to have a temporary adverse impact on air quality. Construction, by its very nature may produce a variety of emissions however particulate matter (PM_{10}) is the pollutant of greatest concern. Past experience has shown that the emissions from construction can cause substantial increases in localized concentrations of PM_{10}. The most common activities associated with construction involve site preparation, earthmoving activities and general construction. These activities include, but are not limited to: demolition, grading, excavation, cut and fill operations, trenching, soil compaction, land clearing, grubbing and the addition of improvements such as roadway surfaces, structures and facilities. These common construction activities generate emissions from:
>
> 1. Fuel combustion from mobile heavy-duty diesel and gasoline powered equipment.
> 2. Portable auxiliary equipment
> 3. Worker commuter trips
> 4. Fugitive dust from soil disturbance.

Site reclamation, which will involve a much larger area (40 acres[50] compared to 4 acres for Project construction) and require much of the same equipment (backhoes, excavators, heavy trucks, compactors, water trucks, crane)[51] will have impacts similar to construction. Reclamation impacts are not discussed in the IS. Thus, the IS fails as an informational document under CEQA. In addition to this failure, there are numerous problems with the IS's superficial treatment of construction impacts.

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[48] IS, pdf 19.

[49] Imperial County APCD, CEQA Air Quality Handbook, November 2007, Section 4.2, p. 11.

[50] IS, pdf 54, 330, 343.

[51] IS, pdf 33.

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3.2. Temporary Emissions Are Often Significant

The IS seeks to minimize the potential significance of construction emissions by asserting they are "temporary."[52] Construction, by its very nature, is "temporary." I have worked on hundreds of similar projects with "temporary" construction emissions that were estimated and found to be significant.[53] "Temporary" is not a valid basis for concluding that construction emissions are not significant because construction is always temporary. "Temporary" construction and other emissions are commonly estimated and often found to be significant in CEQA documents, as clearly explained in the local air district's CEQA guidelines.

3.3. Construction Impacts Are Not Analyzed

Construction impacts are typically analyzed in two ways. First, emissions are estimated and compared to CEQA significance thresholds. Second, if a threshold is exceeded, or the area where the Project is located is not in compliance with ambient air quality standards (i.e., nonattainment), the emissions are modeled to estimate ambient concentrations. The IS fails to include either analysis.

3.3.1. Construction Significance Thresholds

ICAPCD's guidance states that construction emissions must be estimated and compared to significance thresholds:[54]

> The emissions from construction activities, such as fugitive PM_{10} and exhaust emissions from construction equipment, must be quantified and identified in an EIR or a Comprehensive Air Quality Analysis Report. Table 4 below is intended to serve as a guide for project developers and interested parties in determining the recommended type of mitigation measures.

Table 4, Thresholds of Significance for Construction Activities

Pollutant	Thresholds
PM_{10}	150 lbs/day
ROG	75 lbs/day
NOx	100 lbs/day
CO	550 lbs/day

The IS does not recognize these thresholds or contain any estimate of construction emissions to compare to these thresholds. Instead, the IS confusingly asserts that "if an individual project generates construction or operational emissions

[52] IS, pdf 19.

[53] See, for example, Digging Up Trouble: The Health Risks of Construction Pollution in California, 2006; https://www.ucsusa.org/sites/default/files/2019-10/digging-up-trouble.pdf.

[54] Imperial County APCD, CEQA Air Quality Handbook, Table 4, pdf 19.

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that exceed the ICAPCD's recommended daily thresholds for project-specific impacts, that project would also cause a cumulatively considerable increase in emissions…."[55] However, the IS does not contain any project-specific construction emissions or significance thresholds for them.

Rather, IS Section 3(a) asserts that "[e]missions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"[56] However, as the IS contains no estimate of construction emissions, there is no basis for concluding that they do not exceed thresholds and thus are not significant. My analysis in Comment – indicates that construction PM10 and NOx emissions are significant.

3.3.2. Construction Emissions Contribute to Existing Violations of Ambient Air Quality Standards

The area where the Project is located is in violation of ambient air quality standards for PM2.5, PM10, and ozone (federal 8-hour).[57] Short-term exposure to particle pollution (PM2.5, PM10) can kill.[58] Ozone, often called "smog," is harmful to breathe because it aggressively attacks lung tissue.[59] Imperial County fails the American Lung Association's (ALA's) State of the Air annual rankings for Imperial County (grade F). The ALA concludes that "If you live in Imperial County, the air you breathe may put your health at risk."[60] See Figures 1 to 4.

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[55] IS, pdf 19.

[56] IS, pdf 19.

[57] U.S. EPA, California Nonattainment/Maintenance Status for Each County by Year for all Criteria Pollutants, May 31, 2020; https://www3.epa.gov/airquality/greenbook/anayo_ca.html.

[58] American Lung Association (ALA), What Can Particles Do to Your Health?, https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/particle-pollution.

[59] American Lung Association, What is Ozone; https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/ozone.

[60] American Lung Association, State of the Air, California: Imperial County; http://www.stateoftheair.org/city-rankings/states/california/imperial.html.

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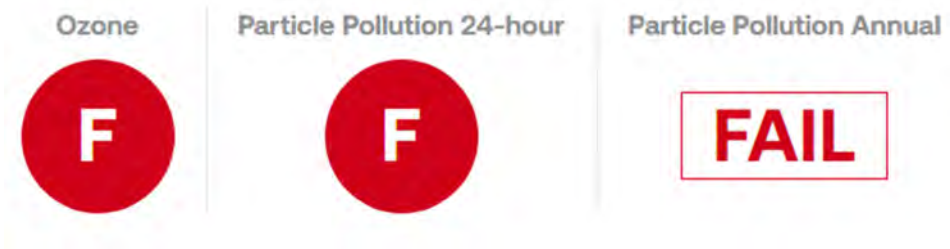
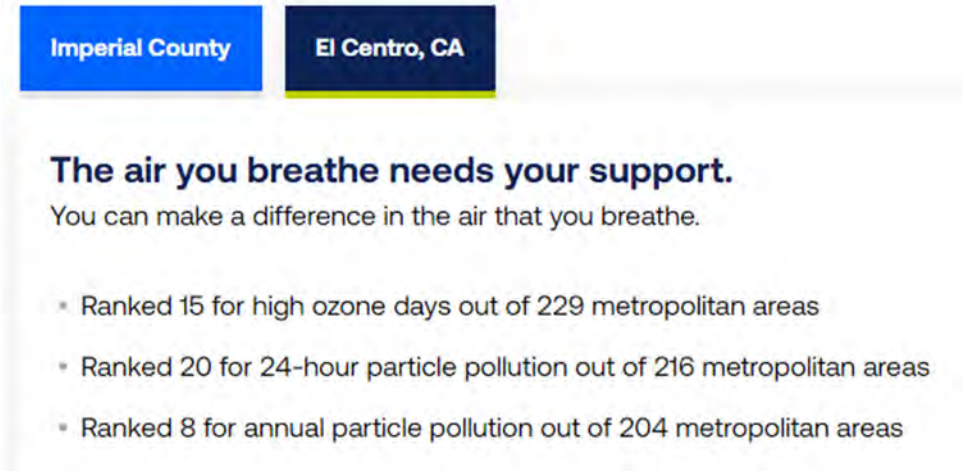
Figure 1: American Lung Association State of the Air Ranking, Imperial County[61]



El Centro, 6 miles north of the Project, ranks among the worst out of 229 metropolitan areas that were evaluated for ozone and particulate pollution:

Figure 2: El Centro, California, Ozone and Particulate Ranking[62]



Imperial County has large numbers of people at risk from elevated ozone and particulate pollution:

[61] Ibid.

[62] Ibid.

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Figure 3: Populations at Risk in El Centro[63]

Groups at Risk	El Centro, CA
Total Population:	181,827
Pediatric Asthma:	3,195
Adult Asthma:	11,043
COPD:	5,862
Lung Cancer:	70
Cardiovascular Disease:	8,440
Ever Smoker:	42,924
Children Under 18:	51,765
Adults 65 & Over:	23,580

Further, short-term (24-hour) particulate pollution, such as generated by construction, is on the rise in Imperial County:[64]

Figure 4: Number of Days That Exceed Annual and 24-hour PM10 Ambient Air Quality Standards in Imperial County[65]



For all of these reasons, any increase in PM2.5, PM10, or ozone precursors (ROG, NOx) due to construction (and operation) of the Project is a per se significant air quality and public health impact as they contribute to an acknowledged significant health risk.

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[63] http://www.stateoftheair.org/city-rankings/compare-your-air.html?msa1=El%20Centro,%20CA&msa2=Los%20Angeles-Long%20Beach,%20CA.

[64] Ibid.

[65] Ibid.

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Particulate matter (PM2.5, PM10) and ozone precursors (ROG, NOx) are emitted in significant amounts during construction. ROG is also emitted during Project operation. The impact of construction and operational emissions on ambient air quality (PM2.5, PM10, ozone) can only be determined by estimating the emissions, comparing them to adopted significance thresholds and/or using air dispersion models to estimate ambient concentrations to determine if ambient air quality standards will be violated.

The files I reviewed do not contain any analysis at all of construction emissions. The IS and supporting files contain no information to demonstrate that construction emissions would not contribute significantly to an existing regional nonattainment condition, nor does it set forth any criteria for making this determination. The IS and supporting documents do not contain the information required to estimate emissions—neither construction emissions nor any air dispersion modeling. Instead, the IS concludes that construction impacts are not significant with no support whatsoever, despite the well-known air quality problems in the Project area, summarized in Figures 1 to 4. Thus, the IS fails as an informational document under CEQA.

Any increase in a pollutant that contributes to existing violations of ambient air quality standards or creates a new violation, for example, is a per se significant impact, absent a demonstration to the contrary. Construction will emit PM2.5, PM10, ROG, and NOx, which all contribute to existing violations of ambient air quality standards in the Project area. Thus, ambient air quality impacts of construction are significant unless analyses demonstrate the contrary and/or mitigation is imposed. The IS contains no analysis of construction air quality impacts or demonstration that they are not significant.

Construction equipment emits ROG and NOx, which are not mentioned in the IS construction discussion. These chemicals are ozone precursors and are converted into ozone in the atmosphere. The IS admits, and I agree, that Imperial County where the Project is located is in violation of ambient ozone standards (nonattainment).[66] This acknowledgement should have triggered an analysis to determine if construction emissions would contribute to violations of ambient ozone standards. It did not.

As to ozone construction impacts, the IS concludes with no analysis, buried in a section on "sensitive receptors," that "the temporary and relatively low amount of ozone emissions from the construction equipment would result in a less than significant cumulative effect to the existing nonattainment status of the ICAPCD."[67] The IS

[66] IS, pdf 19. See also footnote 56.

[67] IS, pdf 19.

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contains no support for this conclusion, which would require an estimate of construction ozone precursors (NOx, ROG) and/or air quality modeling.

The "sensitive receptor" section then states that construction equipment would be turned off when not in use to limit "ozone emissions" from idling construction equipment.[68] A requirement to turn construction equipment off to limit ozone emissions is a mitigation measure, which requires preparation of an EIR.

Regardless, idling emissions are a tiny fraction of ozone-precursor emissions from construction equipment and would do nothing to mitigate significant construction ozone precursor impacts. The major source of ozone precursor emissions is engine exhaust when construction equipment is operating, not idling.

In my opinion, the undisclosed ROG and/or NOx emissions are significant for two reasons. First, the area where the Project is located currently violates the federal 8-hour ozone standard. As noted above, the APA rated the area where the Project is located as an F for ozone. Increases in ozone precursors from both Project construction and operation would contribute to these violations. Second, as demonstrated below, ROG and NOx construction emissions could exceed the ICAPCD's significance thresholds of 75 lb/day for ROG and 100 lb/day for NOx without enforceable mitigation. No mitigation is proposed for ROG and NOx in the IS. Thus, in my opinion, an Initial Study is not appropriate for this Project. Because mitigation is required, an EIR must be prepared.

3.3.3. Construction Mitigation

The IS asserts that Section 2.1.7 lists air quality control measures that would be implemented during construction "to minimize the potential for construction fugitive dust and particulate matter releases," consistent with Imperial County 2019 PM10 and PM2.5 Plans.[69] The IS asserts that "control measures would be in line with the Imperial County 2018 PM10 Plan and Imperial County 2018 PM2.5 Plan …. and therefore, be in compliance with Imperial County's approach to minimizing these construction-related emissions."[70]

Elsewhere, the IS concludes, with no analysis whatsoever, that "[t]hrough the application of these [unidentified] measures, the construction of the Project would limit visible dust emissions and particulate matter emissions to 20 percent opacity and/or

[68] IS, pdf 19.

[69] IS, pdf 19. "Emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"

[70] IS, pdf 19.

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150 lb/day, and therefore, be in compliance with Imperial County's approach to minimizing these construction related emissions."[71] This conclusion is unsupported and incorrect. There are major problems with these assertions as to impacts and mitigation.

First, if air quality control measures must be implemented during construction, as asserted in these cited sections of the IS, an Initial Study is the wrong CEQA document. An EIR must be prepared if a Project results in significant impacts.

Second, the cited mitigation in Section 2.1.7 is missing from the IS. Section 2.1.7 of the IS is captioned "Record Keeping and Internal Reporting." It does not contain any air quality control measures. Instead, it is a subsection of "Non-Structural BMPS" to minimize the probability of pollution from stormwater discharge.[72] It has nothing to do with air quality. Section 2.1.7 in the IS states as follows:[73]

> *2.1.7 Record Keeping and Internal Reporting*
>
> **All inspection, sampling, maintenance, corrective action records, and any other information that is a part of this plan are maintained at the facility office. All records are maintained for a period of at least three (3) years.**

These are not air quality control measures for construction PM10 and PM2.5 emissions. I did not find any air quality control measures anywhere in the IS, in any section, even though the IS's conclusions rely on mitigation. Thus, the IS contains no mitigation for "potential fugitive dust and particulate releases,"[74] which would contribute to existing violations of ambient air quality standards, a potentially significant impact. If mitigation is required, and my analyses below indicate that it is, an EIR must be prepared.

The Application to Amend CUP No. 06-0006 for the Project does contain construction mitigation for particulate matter, suggesting the Applicant expects construction PM10 and PM2.5 emissions to be significant, contrary to the IS's conclusions. The CUP Application proposes the following construction mitigation:[75]

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[71] IS, pdf 19.

[72] IS, Section 2.1, pdf 77.

[73] IS, pdf 79.

[74] Ibid.

[75] IS, Application to Amend Conditional Use Permit No. 06-0028, August 13, 2009, pdf 358. See pdf 364 for construction mitigation.

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- The Project would comply with the Imperial County Air Pollution Control District (ICAPCD) Regulation VIII (Fugitive Dust Control), the Imperial County 2018 PM10 Plan, and the Imperial County 2018 PM2.5 Plan.
- Project equipment and worker vehicles would be turned off when not in use and not left idling to minimize unnecessary emissions.
- Water would be applied to the development site and during site preparation and construction to control fugitive dust.
- Earth moving work would be completed in phases (as necessary) to minimize the amount of disturbed area at one time.
- Construction vehicles and heavy equipment that use non-surfaced facility roads/areas will be restricted to 5 mph to control fugitive dust.
- During windy conditions, barriers would be constructed and/or additional watering is conducted to minimize wind-blown fugitive dust.
- Vehicle access would be restricted to the disturbance area via signage/fencing.
- Equipment would be operated according to best practices and maintained according to design specifications.

The IS cannot rely on these measures to mitigate what are evidentially considered to be significant impacts because an IS by definition is prepared for projects that have no significant impacts and thus require no mitigation. The fact that the Applicant has proposed mitigation in the CUP Application for the Project evaluated in the IS indicates that there is an expectation that construction PM2.5 and PM10 emissions are significant. Thus, an IS is the wrong CEQA document. An EIR must be prepared and circulated for review.

Third, Section 3(a) of the IS asserts "As discussed in Section 2.1.7, air quality measures would be implemented during construction … to minimize the potential for fugitive dust and particulate matter releases."[76] The IS does not identify any air quality construction mitigation measures. As noted above, if mitigation is required, an IS is the wrong CEQA document. Further, as noted above, Section 2.1.7 does not exist. Finally, what does "minimize" mean in the referenced CEQA cumulative impact context? How can you conclude cumulative emissions are not significant, even if minimized, without estimating the emissions and either comparing them to a significance threshold or modeling them to determine if they violate ambient air quality standards? You cannot.

Fourth, the IS asserts that the applicable controls (which are never identified in the IS itself) "would be in line with the Imperial County 2018 PM10 Plan and the Imperial County 2018 PM2.5 Plan."[77] However, the IS fails to identify the applicable controls (which were mistakenly asserted to be in Section 2.1.7) or provide a specific citation to the PM10 and PM2.5 plans where these controls can be found. The PM10[78]

[76] IS, pdf 19.

[77] IS, pdf 19.

[78] Imperial County APCD, Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter, Adopted October 23, 2018, October 23, 2018; https://apcd.imperialcounty.org/wp-content/uploads/2020/01/2018PM10PlanBoardPacket.pdf.

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and PM2.5[79] plans submitted in response to a PRA only require controls at nonresidential construction sites greater than or equal to 5 acres.[80] The subject site is a nonresidential 4-acre site.[81] Thus, if construction PM10 and PM2.5 impacts are significant, these plans do not require a control plan for them.

Fifth, even if Section 2.1.7 did exist, the only control measures that the IS asserts it contains are for PM10 and PM2.5. Construction emits other pollutants, including the ozone precursors ROG and NOx. As the area where the Project will be located is in violation of ozone ambient air quality standards, increases in ROG and NOx from construction equipment could contribute to an existing violation of the ozone standard, which is a significant impact. See Comment 3.3.2. The IS does not discuss this issue, thus failing as an informational document under CEQA.

Sixth, the IS then wraps up the construction air quality discussion with an unsupported conclusion on ozone, asserting that the Project will:[82]

> be in compliance with Imperial County's approach to minimizing these construction-related emissions. Ozone, which is formed by a complex series of chemical reactions and the precursors of which stem from the use of fuel-combusting equipment (e.g., backhoes, trucks), would also be limited to the construction phase of the Project. To limit the amount ozone emissions from construction equipment, vehicles and equipment would be turned off when not in use and not left idling to minimize unnecessary emissions. The temporary and relatively low amount of ozone emissions from the construction equipment would result in a less than significant cumulative effect to the existing nonattainment statusof the ICAPCD.

By proposing mitigation, the IS is conceding that Project and cumulative ozone impacts are significant, requiring the preparation of an EIR. I agree that construction ozone emissions are likely significant because the area where the Project is located currently violates ozone ambient air quality standards and construction would increase ozone precursor emissions. Thus, mitigation is required for this impact and an EIR must be prepared. Regardless, shutting off equipment that is not in use will not mitigate this impact because idling emissions are a very small fraction of ozone precursor emissions. Thus, assuming ozone emissions are significant, and the IS contains no estimate of ozone-precursor emissions, this proposed mitigation would do nothing to mitigate the significant impact. These emissions can be significantly reduced by requiring high tier (Tier 3 or 4) construction equipment and/or tailpipe controls such as catalytic converters. Comment 3.4.

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[79] Imperial County APCD, Imperial County 2018 Annual Particulate Matter Less than 2.5 Microns in Diameter State Implementation Plan, April 2018; https://ww3.arb.ca.gov/planning/sip/planarea/imperial/final_2018_ic_pm25_sip.pdf.

[80] PM10 Plan, pdf 39 (dust control plan only required for construction sites greater than or equal to 5 acres for nonresidential projects), PM2.5 Plan, pdf 169.

[81] IS, pdf 40, 54, 74.

[82] IS, pdf 19.

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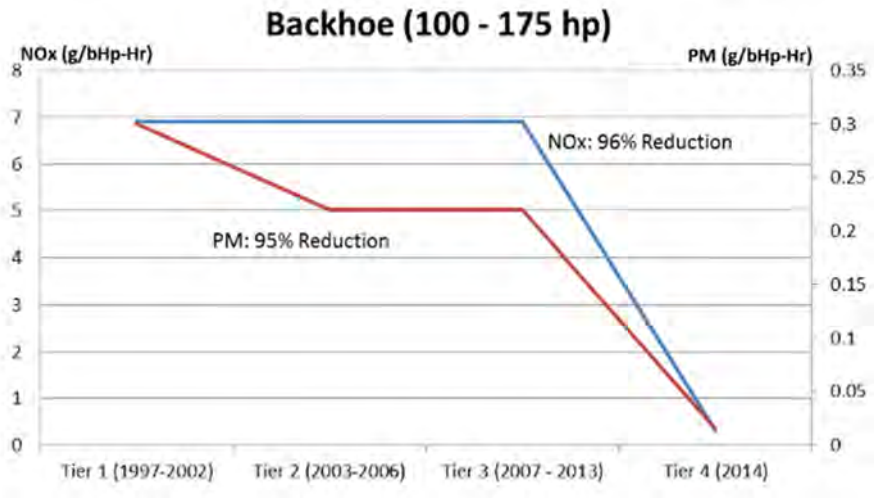
In sum, the IS failed to estimate construction emissions and failed to evaluate construction ambient air quality impacts, thus failing as an informational document under CEQA. Without estimating any emissions, the IS asserts mitigation is required, but it failed to disclose the mitigation, which is found in the CUP for the Project. In either case, requiring mitigation for an unquantified significant impact requires the preparation of an EIR. In the next section, I estimate that construction PM10 and NOx emissions are significant, confirming that mitigation is required. Thus, an EIR must be prepared for the Project.

3.4. Construction NOx Emissions Are Significant

The principal mitigation for NOx and ROG emissions from construction equipment is the design of the engine. The amount of pollution from construction equipment is categorized using a system of "engine tiers." The higher the tier, the lower the emissions.[83] For example, for a typical backhoe, the emissions of NOx and PM in grams per brake horsepower hour (g/bHp-Hr) as a function of engine tier are shown in Figure 5.[84]

Figure 5: PM and NOx Emission by Tier for a Backhoe[85]



This figure shows that NOx exhaust emissions would be about 35 (7/0.2) times higher if all Tier 1 construction equipment were used instead of Tier 4 equipment. Similarly, this figure shows that PM exhaust emissions would be about 15 (0.3/0.02) times higher if all Tier 1 equipment were used instead of Tier 4 equipment. It is

[83] See, eg., DieselNet, Emission Standards: Nonroad Diesel Engines; https://dieselnet.com/standards/us/nonroad.php.

[84] See also EPA, Nonroad Compression-Ignition Engines: Exhaust Emission Standards.

[85] Ibid.

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standard practice to disclose the construction fleet (type/number of equipment) and construction equipment engine tier in CEQA documents. This IS fails to identify the specific pieces of construction equipment and their tier, thus failing as an informational document under CEQA.

The off-road construction equipment that would be required to build the Project and thus the engine tier of this equipment must be known to estimate construction emissions. The IS indicates that site preparation would include excavation and compaction, listing as examples of required equipment: semi-truck trailers, flatbed trucks, forklifts, excavators/bulldozers, a roller, and cranes.[86]

Without specific requirements for the engine "tier" of all construction equipment that will be used to build the Project, the applicant is free to use the cheapest, highest emitting, Tier 1 equipment to build the Project. Tier 1 construction equipment would emit over 7 times more NOx and 15 times more PM10 than the most efficient Tier 4 construction equipment. The applicant has a significant financial incentive to use lower tier, higher polluting equipment as it is much cheaper than the newer, better controlled construction equipment. Thus, unmitigated increases in NOx, ROG, and PM10 from construction equipment could exceed the ICAPCD's CEQA significance thresholds.

Construction NOx emissions could exceed 100 lb/day if Tier 1 equipment were used. For example, assuming four 300-hp pieces of construction equipment operating simultaneously (dump truck, excavator, bulldozer, crane), the NOx emissions would be 148 lb/day,[87] which exceeds the ICAPCD's significance threshold of 100 lb/day and is thus a significant construction air quality impact. There is nothing in the IS to prevent the applicant from selecting Tier 1 equipment.

The significant NOx and PM10 emissions from construction equipment can be controlled by requiring the use of Tier 3 to 4 construction equipment or by retrofitting older Tier 1 to 2 equipment with similarly effective emissions controls, such as exhaust selective catalytic reduction (SCR) and particulate traps. See also construction PM10 mitigation in Comment 3.6.

The significant NOx and diesel particulate matter (DPM) emissions from construction equipment can be mitigated using the same mitigation measures required

[86] IS, pdf 29, 363.

[87] NOx emissions = 4(7 g/bhp-hr)(300 bhp)(8 hr/day)/(454 g/lb) = **148 lb/day.**

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by the County for the East Brawley Geothermal project[88] during all construction activities:

a) Use alternative-fueled or catalyst-equipped diesel construction equipment, including all off-road and portable diesel-powered equipment.

b) Minimize idling time either by shutting equipment off when not in use or reducing the time of idling.

c) Limit, to the extent feasible, the hours of operation of heavy-duty equipment and/or the amount of equipment in use.

d) Replace fossil-fueled equipment with electrically driven equivalents (provided they are not run via a portable generator set).

e) Utilize construction and well drilling equipment that meets or exceeds Tier 2 California Emission Standards for Off-Road Compression-Ignition Engines as specified in the California Code of Regulations.

f) Provide for on-site meals for construction workers by arranging a lunch wagon to visit the construction site.

g) Suspend construction activities when the Imperial County Air Pollution Control District issues a Health Advisory Alert pursuant to District Rule 608.

h) Require the construction contractor to ensure that construction equipment is properly maintained.

3.5. Construction PM10 Emissions Are Significant

The produced documents indicate that the Project would disturb 4 acres. Particulate matter emissions (PM10, PM2.5) can be estimated from the EPA emission factor for construction activity of 1.2 tons per acre per month of total suspended particulate (TSP) emissions per day (lb/day).[89] Studies indicate that on average, PM10 accounts for 34% to 52% of the TSP when watering is used for dust control.[90] Thus,

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[88] County of Imperial, East Brawley Geothermal, Final Environmental Impact Report, May 2012, pp. 4.0-20 and 4.0-21, See Board of Supervisors Agenda, Item #23; http://imperial.granicus.com/player/clip/356?view_id=2&meta_id=43881&redirect=true.

[89] AP-42, Section 13.2.3 Heavy Construction Operations, pdf 1; https://www3.epa.gov/ttn/chief/ap42/ch13/final/c13s02-3.pdf.

[90] Ingrid P.S. Araujo, Dayana B. Costa, and Rita J.B. de Moraes, Identification and Characterization of Particulate Matter Concentrations at Construction Job Sites, *Sustainability*, v. 6, pp. 7666-7688, 2014, Table 5, https://ideas.repec.org/a/gam/jsusta/v6y2014i11p7666-7688d41878.html.

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earthmoving activities could generate up to 166 lb/day of PM10,[91] exceeding the significance threshold of 150 lb/day.

In addition to PM10 from fugitive dust, PM10 would also be generated by construction equipment. Assuming that Tier 1 construction equipment would be used, PM10 exhaust emissions would be an additional 6 lb/day.[92]

Thus, total PM10 emissions would be 172 lb/day, which exceeds the significance threshold of 150 lb/day. Therefore, construction PM10 emissions are significant and unmitigated. Mitigation is thus required, requiring the preparation of an EIR for the Project.

The CUP identifies some proposed methods to control PM10 emissions. However, these controls are not required by the Negative Declaration as CEQA mitigation and are therefore not enforceable. The proposed controls are also not adequate to reduce the Project's significant PM10 impact to a less than significant level. There are numerous other feasible PM10 control methods that should be required for this Project.

The following summarizes frequently recommended measures to control emissions of DPM from construction that were not identified in the DEIR and that have been required in other CEQA documents and recommended by various air pollution control districts (e.g., BAAQMD[93]) and other public agencies. The following is a partial list:

- Maintain all construction equipment in proper tune according to manufacturer's specifications and use an ASE-certified mechanic to check the equipment and determine it to be running in proper condition before it is operated (CalAm IS/MND;[94] Chevron FEIR[95]).
- Diesel-powered equipment shall be replaced by gasoline-powered equipment whenever feasible (CalAm IS/MND, Chevron FEIR).

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[91] Earthmoving TSP emissions = (1.2 ton TSP/acre-mo)(2000 lb/ton)(4 acres)/(30 day/mo) =**320 lb TSP/day.** Assuming 52% of the TSD is PM10, PM10 emissions = (320 lb/day)(0.52) = **166 lb/day.**

[92] PM10 emissions = 4(0.3g/bhp-hr)(300 bhp)(8 hr/day)/(454 g/lb) = **6.3 lb/day.**

[93] BAAQMD, CEQA Guidelines, Updated May 2017, Tables 8-2 and 8-2.

[94] SWCA Environmental Consultants, Draft Initial Study and Mitigated Negative Declaration for the California American Water Slant Test Well Project, Prepared for City of Marina, May 2014 (CalAm IS/MND).

[95] Chevron Refinery Modernization Project EIR, March 2014, Chapter 4.8, Greenhouse Gases, https://s3.amazonaws.com/chevron/Volume+1_DEIR_r1.pdf and Chapter 5, Mitigation Measure Monitoring and Reporting Program, https://s3.amazonaws.com/chevron/Final+EIR/5_MMRP.pdf.

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- The engine size of construction equipment shall be the minimum practical size (CalAm IS/MND).
- Catalytic converters shall be installed on gasoline-powered equipment (CalAm IS/MND).
- Signs shall be posted in designated queuing areas and job sites to remind drivers and operators of the idling limit (CalAm IS/MND, Chevron FEIR).
- Diesel equipment idling shall not be permitted within 1,000 feet of sensitive receptors (CalAm IS/MND).
- Engine size of construction equipment shall be the minimum practical size (CalAm IS/MND).
- Construction worker trips shall be minimized by providing options for carpooling and for lunch on site (CalAm IS/MND, Chevron FEIR).
- Use alternative diesel fuels, such as renewable diesel, Aquazole fuel, Clean Fuels Technology (water emulsified diesel fuel), or O2 diesel ethanol-diesel fuel (O2 Diesel) in existing engines (Monterey County General Plan EIR). [96]
- Modify engines with ARB verified retrofits.
- Repower engines with Tier 4 final diesel technology.[97]
- Convert part of the construction truck fleet to natural gas.[98]
- Use new or rebuilt equipment.
- Use diesel-electric and hybrid construction equipment.[99]

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[96] Monterey County General Plan EIR, Section 6.4.3.3, p. 6-14 ("The EIRs prepared for the desalination plants are expected to require that construction equipment use alternative fuels or other means to reduce their emissions of ozone precursors. Although, depending upon the intensity of construction, there is the potential for a significant impact on air quality from ozone precursors."); https://www.co.monterey.ca.us/home/showdocument?id=44010. See also Union of Concerned Scientists, Digging Up Trouble: The Health Risks of Construction Pollution in California, November 2006, pp. 23-24; https://www.ucsusa.org/sites/default/files/2019-10/digging-up-trouble.pdf.

[97] Union of Concerned Scientists, November 2009, p. 23.

[98] This is a mitigation measure used by PG&E to offset NOx emissions from its Otay Mesa Generating Project. See: GreenBiz, Natural Gas Trucks to Offset Power Plant Emissions, September 12, 2000, http://www.greenbiz.com/news/2000/09/12/natural-gas-trucks-offset-power-plant-emissions.

[99] Tom Jackson, How 3 Diesel-Electric and Hybrid Construction Machines are Waging War on Wasted Energy, *Equipment World*, June 1, 2014, http://www.equipmentworld.com/diesel-electric-and-other-hybrid-construction-equipment-are-waging-war-on-wasted-energy/; Kenneth J. Korane, Hybrid Drives for Construction Equipment, Machine Design, July 7, 2009, http://machinedesign.com/sustainable-engineering/hybrid-drives-construction-equipment; Caterpillar's D7E Electric Drive Redefines Dozer Productivity, http://www.constructionequipment.com/caterpillars-d7e-electric-drive-redefines-dozer-productivity.

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- Use low rolling resistance tires on long-haul class 8 tractor-trailers.[100]
- Use idle reduction technology, defined as a device that is installed on the vehicle that automatically reduces main engine idling and/or is designed to provide services (e.g., heat, air conditioning, and/or electricity) to the vehicle or equipment that would otherwise require the operation of the main drive engine while the vehicle or equipment is temporarily parked or is stationary.[101]
- Implement EPA's National Clean Diesel Program.[102,103,104]
- Require that all construction equipment, diesel trucks, and generators be equipped with Best Available Control Technology for emission reductions of PM (BAAQMD).

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[100] EPA, Verified Technologies for SmartWay and Clean Diesel, Learn About Low Rolling Resistance (LRR) New and Retread Tire Technologies, https://www.epa.gov/verified-diesel-tech/learn-about-low-rolling-resistance-lrr-new-and-retread-tire-technologies; EPA, Verified Technologies for SmartWay and Clean Diesel, SmartWay Verified List for Low Rolling Resistance (LRR) New and Retread Tire Technologies, https://www.epa.gov/verified-diesel-tech/smartway-verified-list-low-rolling-resistance-lrr-new-and-retread-tire.

[101] EPA Names Idle Reduction Systems Eligible for Federal Tax Exemptions, March 2009; http://www.greenfleetmagazine.com/channel/green-operations/article/story/2009/03/epa-names-idle-reduction-systems-eligible-for-federal-excise-tax-exemptions-grn.aspx. See also: Idle Reduction, Wikipedia, https://en.wikipedia.org/wiki/Idle_reduction and Diesel Emissions Reduction Program (DERA): Technologies, Fleets and Project Information, Working Draft Version 1.0; https://nepis.epa.gov/Exe/ZyNET.exe/P100CVIS.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000003%5CP100CVIS.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

[102] Northeast Diesel Collaborative, Best Practices for Clean Diesel Construction: Successful Implementation of Equipment Specifications to Minimize Diesel Pollution, August 2012; https://www.northeastdiesel.org/pdf/construction/BestPractices4CleanDieselConstructionAug2012.pdf.

[103] U.S. EPA, Cleaner Diesels: Low-Cost Ways to Reduce Emissions from Construction Equipment, March 2007; https://nepis.epa.gov/Exe/ZyNET.exe/P1009QEO.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000024%5CP1009QEO.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

[104] NEDC Model Contract Specification, April 2008; https://www.epa.gov/sites/production/files/2015-09/documents/nedc-model-contract-sepcification.pdf.

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- Require that all contractors use equipment that meets CARB's most recent certification standard for off-road heavy-duty diesel engines.[105]
- Solicit bids that include these measures.

3.6. Well Drilling Emissions

Information filed by the Applicant in other fora indicate that new wells must be drilled to support the Project. The IS is silent on the need to drill new wells. Well drilling, flow testing, well venting, steam stacking, and fugitive sources such as valves and pumps can result in substantial emissions of air pollutants including diesel exhaust emissions from drill rigs and hydrogen sulfide ("H_2S").[106]

Hydrogen sulfide is an extremely hazardous gas with a "rotten egg" smell and pronounced health effects. Depending on the concentrations and length of exposure, health effects vary from irritation of eyes, nose, throat, or respiratory system to shock, convulsions, inability to breathe, and, in extreme cases, death.[107] Further, California has an ambient air quality standard on H_2S of 0.03 ppm for a one-hour average.[108] The IS failed to acknowledge this standard and failed to determine whether the Project's emissions would violate the standard.

The H_2S emissions, which typically result in significant odor and health impacts, can be controlled using liquid redox methods, reinjection, Selectox, Dow-Spec RT-2, BIOX, and other similar methods.[109]

3.7. Project Construction May Have Begun Without Required Permits

Under CEQA, environmental review must be completed before the start of construction. Documents filed by the Applicant with the SEC indicate that Project construction may have started in 2019 and is ongoing:[110]

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[105] BAAQMD, CEQA Guidelines, Updated May 2017, Table 8-3, Measure 13.

[106] See, for example, Acurex Corp., Assessment of H2S Control Technologies for Geothermal Power Plants, February 1980; https://www.osti.gov/servlets/purl/5226737.

[107] *See*, for example, Occupational Safety and Health Administration, OSHA Quick Card, Hydrogen Sulfide (H_2S); https://www.osha.gov/OshDoc/data_Hurricane_Facts/hydrogen_sulfide.pdf.

[108] CARB, Hydrogen Sulfide & Health; https://ww2.arb.ca.gov/resources/hydrogen-sulfide-and-health.

[109] Esteban Rodriguez, William Scott Harvey, and Einar Jon Abjornsson, Review of H_2S Abatement Methods in Geothermal Plants, Proceedings, Thirty-Eighth Workshop on Geothermal Reservoir Engineering, February 24-26, 2014; https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2014/Rodriguez.pdf.

[110] SEC, Form 10-K, Ormat Technologies, Inc., December 31, 2019, pdf 24.

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During fiscal year 2019, in the Electricity segment, we focused on the commencement of operations at Tungsten solar in Nevada and we began with construction of Heber Complex enhancement as well as with enhancement work in some of our operating power plants. During fiscal year 2018, we focused on

In the section of this SEC filing, in a subsection labeled "Projects Released for Construction", the summary table describes the work at the Heber Complex as: "Permitting, Engineering and procurement ongoing. Manufacturing and **construction commenced**."[111] See:

Project Name	Expected Size (MW)	Technology	Customer	Expected COD	Current Condition
Heber Complex	11	Geothermal air-cooled binary system	SCE and SCPPA	Early 2021	Permitting, Engineering and procurement ongoing. Manufacturing and construction commenced.

The SEC 10-Q filing similarly states "We are currently in the process of repowering the Heber 1 and Heber 2 power plants. We are planning to replace steam turbine and old OE units with new advanced technology equipment that will add a net capacity of 11 MW. Following these enhancements, we expect the capacity of the complex to reach 92 MW. Permitting, engineering and procurement are ongoing as well as manufacturing and site construction. We expect commercial operation in the second half of 2021."[112] The 92 MW is consistent with the original design capacity of the Heber Complex.

The Ormat 2019 annual report similarly reports that construction has commenced: "During fiscal year 2019, in the Electricity segment, we focused on the commencement of operations at Tungsten solar in Nevada and we began with construction of Heber Complex enhancement as well as with enhancement work in some of our operating power plants."[113] Elsewhere, the annual report states: "Permitting, Engineering and procurement ongoing. Manufacturing and construction commenced."[114]

If the Applicant's statements in its SEC filings are correct, then it appears the Applicant has begun prematurely constructing the Project without obtaining necessary land use permits.

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[111] SEC, Form 10-K, Ormat Technologies, Inc., December 31, 2019, pdf 30 (emphasis added);

[112] U.S. Securities and Exchange Commission, Form 10-Q, Ormat Technologies, Inc., March 31, 2020, p. 41, pdf 36-37; http://d18rn0p25nwr6d.cloudfront.net/CIK-0001296445/bd1a8403-baa2-4834-9e2f-29ea970e033c.pdf.

[113] ORMAT, 2019 Annual Report, p. 31, pdf 39.

[114] ORMAT, 2019 Annual Report, p. 38, pdf 46.

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4. OPERATIONAL AIR QUALITY IMPACTS

The facility will emit isopentane, which is a reactive organic gas (ROG) as well as other criteria pollutants, discussed below.

4.1. Isopentane Emissions

An accurate estimate of isopentane is very important because it is a reactive organic gas (ROG) and thus contributes to ozone in the atmosphere. As explained in Comment 3.3.2, the area where the Project is located violates ambient air quality standards for ozone. The Project will emit isopentane, a ROG precursor, from storage tanks during maintenance operations and from fugitive components. Fugitive emissions occur due to leaks from seals, flanges, pumps, valves, and other components.[115] The IS estimated 10.4 lbs/day of isopentane from maintenance and 54.1 lb/day from fugitive sources for a total of 64.5 lb/day.[116] The IS uses the ATC calculations to estimate the increase in ROG emissions from the Project, which are significant when correctly estimated.

The operational air quality analysis is presented in an appendix to the IS.[117] This appendix states that isopentane emissions are related to the size and complexity of the system. The new system would be smaller (111,000 gallons new vs. 120,000 gallons existing) and have decreased complexity with fewer seals, flanges, pumps, valves, etc. To account for the smaller size, the air quality analysis asserts that it scaled actual worst-case quarterly average daily emissions from 2017 to 2018 (111,000/120,000) to arrive at Project daily emissions. To account for the decreased complexity, the air quality analysis adjusted maintenance and fugitive emissions by 50%. Based on these assumptions, the IS finds a decrease in daily ROG (isopentane) emissions, and thus a less than significant impact.[118]

The IS does not include the supporting calculations for these emission estimates, which are complex. Thus, the IS fails as an informational document under CEQA. In my opinion, the emissions are underestimated and likely will increase, not decrease, for several reasons.

First, average daily emissions are calculated based on quarterly emission reports for maintenance, purging (minor), and fugitives. This is not a reasonable approach

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[115] ATC, pdf 15.

[116] ATC, Table 4, pdf 18.

[117] IS, pdf 287: Joel Firebaugh, Air Sciences Inc., Air Quality Analysis Summary for the Ormat Heber 2 Geothermal Repower Project, August 12, 2019 (Air Quality Appendix).

[118] IS, pdf 19 and 291.

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because maintenance emissions do not occur over an entire quarter, while fugitive emissions do. If the maintenance emissions occurred over a single day, for example, ROG emissions could exceed the daily ROG significance threshold of 55 lb/day.[119] The ATC, for example, explains:[120]

> Due to maintenance activities that occur during the 1st and 4th quarters annually, isopentane emissions have the potential to exceed 137 pounds per day on average for those quarters. ORMAT purchases VOC emissions offsets on an annual basis as required by ICAPCD Rule 207 C.2.a.

As the ROG significance threshold is 55 lb/day, 137 lb/day of ROG emissions are significant, requiring mitigation. The IS is silent as to this significant ROG impact.

Second, the IS assumes without any support that maintenance and fugitive emissions would be reduced by 50% compared to the existing facility emissions.[121] The IS and ATC do not identify any method(s) to assure that this reduction is enforceable and thus would be achieved in practice.

Third, the IS calculated a change in annual isopentane emissions of -3.1 ton/yr,[122] again asserting it is based on the period 2017 to 2018. However, the ATC Application indicates that the actual baseline emissions used in the IS are the maximum for 2017 of 14.9 tons/yr. The average 2017–2018 isopentane emissions are 11.4 ton/yr, resulting in an increase in annual ROG emissions of 0.4 ton/yr.

Fourth, the IS assumes without any support that maintenance and fugitive emissions would be reduced by 50% compared to the existing facility emissions.[123] The IS and ATC do not identify any method(s) to assure that this reduction is enforceable and thus would be achieved in practice. The IS therefore lacks substantial evidence to support this conclusion.

Fifth, the IS asserts that the change in isopentane emissions is based on actual baseline emissions for the 2017 to 2018 period.[124] However, the ATC Application, which was obtained through a PRA and was not part of the IS, indicates that the IS calculated the increase in isopentane emissions using the maximum reported quarterly emissions over the period 2017–2018 based only on the third quarter of 2018 of 117.5 lb/day

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[119] ICAPCD, CEQA Air Quality Handbook, November 2007, Table 1, p. 9.

[120] ATC, Section 2.0, p. 6, pdf 14.

[121] IS, pdf 290.

[122] IS, pdf 19. The ATC Application, Table 5, pdf 18 reports the change in permitted emissions:) [(202 lb/day – 218 lb/day)][(365 day/yr)/(2000 lb/ton)] = **-2.92 ton/yr**.

[123] IS, pdf 290.

[124] IS, pdf 19 and Table 2, pdf 291.

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facility total,[125] not average emissions for 2017 to 2018 as claimed in the IS.[126] Baseline emissions must be based on the average emissions over the baseline period, not the maximum. The use of the maximum artificially reduces the impact.

If the average quarterly emissions for 2017–2018 are used, 62.6 lb/day, the increase in isopentane would be 1.9 lb/day. Assuming arguendo that the IS is correct and instead of the maximum baseline emissions, the minimum quarterly baseline emissions are used, 0 lb/day in the first and second quarter of 2018, the increase would be 64.5 lb/day.[127] In fact, the ATC Application reports worst-case isopentane emissions after proposed changes of 64.5 lb/day.[128] Table 1. Thus, ROG emissions are significant.

Table 1: Estimated Worst-Case Isopentane Emissions After Proposed Changes

Emission Category	MF Volume After Changes (gallons)	Emission Factor (lbs/day/1,000 gal)	Emission Reduction Due to Reduced Complexity	Isopentane Emissions (lbs/day)	Isopentane Emissions (tons/year)
Maintenance	111,000	0.19	50%	10.4	1.9
Purging	111,000	2.8×10^{-5}	0%	0.0	0.0
Fugitive	171,000 (includes tanks)	0.63	50%	54.1	9.9
Facility Total				64.5	11.8

Finally, the ATC Application asserts that estimated uncontrolled ROG emissions would be 202 lbs/day:[129]

16. Estimated Emissions	Uncontrolled lbs/day	Controlled lbs/day
For largest single pollutant	VOC 202 lbs/day	

As the IS and the ATC do not include any controls for ROG emissions and the ICAPCD significance threshold for ROG[130] is 55 lb/day,[131] ROG emissions on any day that exceeds this threshold are significant because the ozone standard that the area violates is based on an 8-hour average. Thus, the Project has the potential to significantly increase ROG emissions on some days, requiring an EIR.

[125] ATC Application, pdf 28.

[126] Compare ATC Application, pdf 28 with IS, pdf 291.

[127] Increase in isopentane emissions = 62.6 + 1.9 = 64.5 lb/day.

[128] ATC Application, Table 4, p. 10, pdf 19.

[129] ATC Application, pdf 5.

[130] Isopentane is a reactive organic gas, or ROG.

[131] ICAPCD, Table 1, pdf 9.

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In sum, ROG emissions are significant and must be mitigated. The major source of ROG emissions is fugitive sources, such as pumps, valves, flanges, and connectors.[132] The ROG emission calculations in the ATC, relied upon in the IS, assumed the use of the U.S. EPA's leak detection and repair (LDAR) program[133] to estimate ROG emissions from fugitive sources. The ROG emissions from fugitive sources can be mitigated by implementing an enhanced LDAR program and the use of leakless and low-leak technology, including:[134]

- Reduce the leak detection threshold from 10,000 ppmv to 500 ppmv for all components except pumps in the motive fluid system, where the threshold should be 2,000 ppmv.
- Leak minimization after detection must occur as soon as possible after detection and no later than 24 hours after leak discovery.
- Leak repair must occur as soon as possible after detection and no later than 7 days after leak discovery.
- All leak detection monitoring must be done with both a USEPA Method 21 portable analyzer and a new hand-held infrared camera.
- Leakless and low-leak technology must be used to prevent fugitive emissions of the motive fluid.
- Require monthly LDAR inspections.

Additional reduction of ROG emissions can be achieved by the following mitigation measures proposed by Ormat Nevada, Inc. for its Casa Diablo IV Geothermal Development Project in Mono County:[135]

a) Install vapor recovery devices estimated to return at least 99% of the motive fluid back to the system.

b) Use a maintenance vapor recovery unit during OEC unit maintenance activities to capture motive fluid that could otherwise be released.

c) Lower pressure of motive fluid system compared to motive fluid used at older existing plants, thus, less potential for fugitive leaks/emissions.

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[132] ATC, Table 4, pdf 18.

[133] U.S. Environmental Protection Agency, Leak Detection and Repair Compliance Assistance Guidance, A Best Practices Guide, October 2007; http://www2.epa.gov/sites/production/files/2014-02/documents/ldarguide.pdf.

[134] ESA, Casa Diablo IV Geothermal Power Plant Draft Supplemental Environmental Impact Report, August 2020, Chapter 3; https://files.ceqanet.opr.ca.gov/139190-6/attachment/uz9O5pnLE-zHa0ulN3BgkuisP8fXYGyhCgPux2Zx7m8nGPwgcghuwFJ4IZOvzQ67LT2cQOGEv1rTrdyV0.

[135] County of Imperial, East Brawley Geothermal, Final Environmental Impact Report, May 2012; Exhibit 14.

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d) Place pentane-specific vapor sensors and flame detectors at strategic locations around the around the turbine, motive fluid pumps, and motive fluid storage tank and connection to power plant computer control system to quickly alert plant operators to any potentially hazardous situations, which would help to keep a check on significant leaks.

e) Perform leak checks, inspections, monitoring, and leak logging.

The ATC Application, cited *supra*, indicates VOC emissions would be offset, implying offsets are mitigation. The ATC Application therefore demonstrates that the Project's excess VOC emissions are significant and require mitigation. However, for several reasons the IS cannot rely on offsets to mitigate air quality impacts because they are not valid CEQA mitigation unless they reduce the emissions at the location where the impact occurs.

First, historically banked ERCs are part of the CEQA baseline. The emission reductions are already accounted for in the ambient air quality at the project site at the time of project proposal. Increases in emissions from the Project will increase emissions relative to the existing baseline. Thus, purchasing ERCs would not reduce, offset, or mitigate increases in Project emissions, as the reductions occurred historically, before the Project was conceived and are part of the baseline.

Second, historically banked ERCs are legally distinct from emission reductions required under CEQA to mitigate new increases in emissions. Thus, the ERC concept is not consistent with the CEQA mandate to mitigate actual impacts on local receptors. The emissions of VOCs will increase in the area where the new Project emissions are released. The impact of this increased pollution on local sensitive receptors must be evaluated under CEQA and mitigated at the time and place that it occurs.

On a common sense level, it is not logical to assume that ERCs, which frequently have been banked decades ago and at locations that are hundreds of miles from the project site, will do anything to mitigate impacts from local emission increases, especially in a region plagued with serious and ongoing air quality violations. Instead, this approach aggravates the exposure of residents to extraordinarily unhealthy ozone in the local area.

Therefore, the use of ERCs is not valid mitigation under CEQA. ERCs are not an acceptable substitute for performing local air quality analyses and mitigating the local impacts themselves. A revised CEQA document should prohibit the use of offsets to mitigate air quality impacts, except those offsets that occur at the project site at the time of project startup. Instead, conventional mitigation is required to reduce the significant ROG emissions.

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4.2. Emissions from Other Equipment and Units

The IS only estimates the change in ROG emissions for maintenance, purging, and fugitive components (valves, flanges, etc.) for the OEC units' emissions. The facility includes other equipment that emits pollutants, including four cooling towers, a vapor recovery unit, a diesel generator, and a fire pump.[136] These all variously emit ROG, NOx, PM10, PM2.5, and HAPs. Because the facility is at the end of its useful life and is being repowered, it is reasonable to assume that the Heber 2 facility and all of this supporting equipment has not been operating at its design capacity in the baseline.

The increase in emissions from this Project must be based on baseline emissions; typically, the average emissions in the two years preceding the start of environmental review. The IS contains no estimate of baseline emissions or resulting increases in emissions from any of this supporting equipment. Thus, it fails as an informational document under CEQA.

The baseline would depend on the amount of electricity generated by the units that are being retired or the baseline generation. In any given year, the actual power generation, and thus emissions from supporting equipment, may differ from the Project's design capacity, due to age, operational issues, or other factors. The IS and supporting files are silent on power generation from the units that are being retired, which would directly determine baseline emissions for supporting equipment. The Project is replacing six 36-MW units, for a total of 216 MW. Thus, the IS fails as an informational document under CEQA.

My analysis of the CEC generation for the subject units indicates that the Project will increase generation by two thirds or by a factor of 1.6. Thus, emissions from all supporting equipment will nearly double. The IS fails as an informational document under CEQA for failing to disclose the increase in generation and its impact on emissions from supporting equipment.

Additionally, neither the IS nor the ATC permit application discusses why the Project would require three new 10,000-gallon isopentane storage tanks even though the operating capacity of the new OECs is less than the operating capacity of the existing Heber 2 units, the units are more efficient, and the generating capacity only increases by about 2 MW gross. These tanks would in part be required to accommodate the significant increase in generation.

Another explanation would be that the Project may debottleneck production at the Goulds and Heber South facilities. The six OECs at Heber 2 are operationally

[136] IS, pdf 289; ATC Application, Table 1, pdf 13.

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interconnected to each other, as well as to Gould 2 and Heber South.[137] This would increase emissions. This explanation cannot be ruled out due to the inadequate Project description. In fact, the hazard assessment characterizes the Project as "part of the facility's expansion project…"[138] Thus, the IS fails as an informational document under CEQA.

5. CUMULATIVE AIR QUALITY IMPACTS

The IS concluded that all cumulative impacts were less than significant, without identifying any cumulative projects or conducting any analyses.[139] "Cumulatively considerable" under CEQA means that "the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects."[140] When the incremental effect of a project is cumulatively considerable, the lead agency must evaluate cumulative impacts in an EIR.[141]

The plain language of this section of CEQA (i.e., "the effects of past projects, the effects of other current projects, and the effects of probable future projects") requires the identification of other projects that will be constructed and/or operating over the same time period as the subject project and the analysis of these projects together with the Project being reviewed. Thus, cumulative impacts can be determined by identifying past projects, other current projects, and probable future projects and their impacts. The IS concluded that all cumulative impacts were less than significant without identifying any cumulative projects or conducting any cumulative impact analyses. Thus, the IS fails as an informational document under CEQA.

The IS includes a section captioned "Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard."[142] However, this section does not present any cumulative emissions or even discuss cumulative impacts.

First, the IS asserts that the Project would reduce VOC emissions (VOC = ROG). However, as discussed in Comments 2.2 and 4.1, this is incorrect due to the use of an invalid baseline assumption. The Project will increase VOC emissions.

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[137] ATC Application, pdf 9.

[138] IS, pdf 299, 314 (Heber 2 expansion project).

[139] IS, pdf 19.

[140] CEQA Guidelines §15064(h)(1).

[141] CEQA Guidelines §15064.

[142] IS, pdf 19.

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Second, the IS asserts that because VOC emissions will be reduced, the "Project would not … contribute to an existing air quality violation." This is incorrect because, even assuming it would not contribute to a ROG violation, the Project will also emit NOx, PM10, PM2.5 and other criteria pollutants from increases in the operation of support equipment. Comment 4.2.

Third, the IS asserts that "emissions from construction equipment would be temporary and not exceed any air quality thresholds or significantly contribute to an existing regional nonattainment condition…"[143] However, the IS contains no estimate of construction emissions, so there is no basis for concluding they are not cumulatively significant. My analysis in Comment – indicates that construction PM10 emissions are significant. Thus, under the IS's reasoning, cumulative construction PM10 emissions are also significant.

Fourth, the IS next asserts that air quality control measures "would be in line with the Imperial County 2018 PM10 Plan and Imperial County 2018 PM2.5 Plan …. and therefore, be in compliance with Imperial County's approach to minimizing these construction-related emissions."[144] However, the IS itself fails to identify a single PM control measure and fails to provide a specific citation to the PM10[145] and PM2.5 plans[146] where these controls can be found. The PM10[147] and PM2.5 plans[148] that I found only require controls at nonresidential construction sites greater than or equal to 5 acres. The subject site is a nonresidential 4-acre site. Thus, these plans do not apply. Regardless, compliance with control plans has nothing to do with cumulative impacts.

In sum, the IS fails to identify any cumulative projects and fails to estimate cumulative emissions and impacts. There are projects in the general area that would cumulatively contribute to air quality impacts, including the Valencia Solar Project and

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[143] IS, pdf 19.

[144] IS, pdf 19.

[145] Imperial County APCD, Board Agenda Fact Sheet, 2018 PM10 Plan, October 23, 2018; https://apcd.imperialcounty.org/wp-content/uploads/2020/01/2018PM10PlanBoardPacket.pdf.

[146] Imperial County APCD, Imperial County 2018 Annual Particulate Matter Less than 2.5 Microns in Diameter State Implementation Plan, April 2018, Rule 801 encompassed in this Plan only requires a dust control plan for nonresidential sites of 5 acres or greater. The subject site is 4 acres; https://ww3.arb.ca.gov/planning/sip/planarea/imperial/final_2018_ic_pm25_sip.pdf.

[147] Ibid., pdf 39 (dust control plan only required for construction sites greater than or equal to 5 acres for nonresidential projects), 169.

[148] Rule 801, Sec. E.1.c.

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Le Conte Battery Energy Storage facility, among others.[149] Thus, the IS fails as an informational document under CEQA.

6. HEALTH IMPACTS

The IS contains a subsection under air quality captioned "Expose sensitive receptors to substantial pollutants concentrations."[150] Normally, a section with this title in a CEQA document would discuss construction and operational health risks (cancer, acute and chronic impacts), not ambient air quality, which is a separate impact area.

6.1. The IS Did Not Evaluate Construction Health Risks

A health risk assessment is commonly conducted to determine if a Project's construction and/or operational hazardous air pollutant (HAP) emissions would cause a significant health impact.[151] The health risk assessment is based on pollutants other than conventional air quality pollutants, e.g., ROG, NOx, PM10, PM2.5, CO, and SO_2.

Construction equipment emits diesel particulate matter (DPM), which is a HAP.[152] If Tier 1 equipment is used (Comment 3.5), DPM emissions could be very high. Nothing in the IS would prevent the use of Tier 1 equipment. Construction workers, workers at the existing Heber facility, and nearby residents will be exposed to DPM during construction.

However, despite its caption, this section does not discuss health impacts to these sensitive receptors from HAP emissions. Instead, it discusses cumulative air quality impacts without ever estimating Project air quality impacts, the starting point for a cumulative analysis. The IS contains no analysis whatsoever of health impacts or cumulative air quality impacts, thus failing as an informational document under CEQA.

Instead of discussing health impacts to sensitive receptors, this section asserts with no support that "if an individual project generates construction or operational emissions that exceed the ICAPCD's recommended daily thresholds for project-specific impacts, that project would also cause a cumulatively considerable increase in emissions…."[153] However, these thresholds are for Project air quality impacts, not

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[149] See: http://www.icpds.com/?pid=2854.

[150] IS, pdf 19.

[151] Office of Environmental Health Hazard Assessment (OEHHA), Risk Assessment Guidelines: Guidance Manual for Preparation of Health Risk Assessment, February 2015; https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf.

[152] Cal/EPA OEHHA and American Lung Association of California, Health Effects of Diesel Exhaust; https://oehha.ca.gov/media/downloads/calenviroscreen/indicators/diesel4-02.pdf.

[153] IS, pdf 19.

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public health impacts or even cumulative impacts. The thresholds for public health impacts are cancer risk in cases per million exposed and acute and chronic hazard indices, metrics that are not reported in the IS.[154]

This mislabeled section continues: "As discussed in Section 2.1.7, air quality measures would be implemented during construction … to minimize the potential for fugitive dust and particulate matter releases."[155] However, as noted in Comment 3.3.3, Section 2.1.7 does not exist. Further, if an impact requires mitigation, an IS is the wrong CEQA document. Mitigation to minimize an impact requires the preparation of an EIR.

Further, what does "minimize" mean in the CEQA cumulative impact context? How can you conclude cumulative emissions, regardless of whether they are HAPs or conventional air pollutants (e.g., ROG, NOx), are not significant without estimating the Project and cumulative project emissions and either comparing them to a significance threshold or modeling them to determine if they violate ambient air quality standards? You cannot.

The IS then concludes, again with no analysis whatsoever, that "through the application of these [unidentified] measures, the construction of the Project would limit visible dust emissions and particulate matter emissions to 20 percent opacity and/or 150 lb/day, and therefore, be in compliance with Imperial County's approach to minimizing these construction related emissions."[156]

This conclusion is unsupported and incorrect. Further, it has nothing to do with the caption of this subsection, "expose sensitive receptors to substantial pollutants concentrations." The IS failed to estimate "visible dust emissions" and thus has no basis for concluding that these emissions would be less than 150 lb/day or meet any opacity limit.

The IS then wraps up this section with an unsupported conclusion on ozone, asserting that the Project will "be in compliance with Imperial County's approach to minimizing these construction-related emissions…. To limit the amount of ozone emissions from construction equipment, vehicles and equipment would be turned off when not in use and not left idling…. The temporary and relatively low amount of

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[154] Office of Environmental Health Hazard Assessment (OEHHA), Risk Assessment Guidelines: Guidance Manual for Preparation of Health Risk Assessment, February 2015; https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf.

[155] IS, pdf 19.

[156] IS, pdf 19.

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ozone emissions from the construction equipment would result in a less than significant cumulative impact."[157]

In my opinion, construction ozone emissions are likely significant because the area where the Project is located currently violates ozone ambient air quality standards and construction would increase ozone precursor emissions. Thus, by proposing mitigation, the IS is conceding that cumulative ozone impacts are significant, requiring the preparation of an EIR.

In sum, this section is a jumbled mess that has nothing to do with the section title. Despite the caption, this section and the entire IS fails to estimate construction HAPs, primarily DPM (typically measured as PM2.5) and does not contain a health risk assessment. Instead, the "expose sensitive receptor" section discusses unrelated issues, which are not supported. Thus, the IS fails as an informational document under CEQA.

6.2. Hydrogen Sulfide

The entire plan area overlays a geothermal fluids reservoir. Geothermal fluids extraction and reinjection has caused annual ground surface settlement that is not uniform.[158] Geothermal fluids contain high concentrations of hydrogen sulfide (H_2S),[159] which is an extremely hazardous gas with pronounced health effects. Depending on the concentrations and length of exposure, health effects vary from irritation of eyes, nose, throat, or respiratory system to shock, convulsions, inability to breathe, and, in extreme cases, death.[160]

If construction occurs in an area where surface settlement has occurred, construction workers could experience significant adverse health impacts from escaping H_2S.

Further, workers performing routine duties can be exposed to significant levels of H_2S. Occupational health and safety issues during construction and decommissioning of geothermal power generation projects are common but were not addressed in the IS. Environmental, Health, and Safety Guidelines note as follows:[161]

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[157] IS, pdf 19.

[158] IS, Geotechnical Report Update, pdf 96.

[159] See, for example, ATC Application, pdf 14.

[160] See, for example, Occupational Safety and Health Administration, OSHA Quick Card, Hydrogen Sulfide (H_2S); https://www.osha.gov/Publications/hydrogen_sulfide.html.

[161] International Finance Corporation and World Bank Group, Environmental, Health, and Safety Guidelines: Geothermal Power Generation, April 30, 2007; https://www.ifc.org/wps/wcm/connect/

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Geothermal Gases

Occupational exposure to geothermal gases, mainly hydrogen sulfide gas, may occur during non-routine release of geothermal fluids (for example, pipeline failures) and maintenance work in confined spaces such as pipelines, turbines, and condensers.

Where there is a potential for exposure to hazardous levels of hydrogen sulfide, geothermal power facilities should consider the following management measures:

- Installation of hydrogen sulfide monitoring and warning systems. The number and location of monitors should be determined based on an assessment of plant locations prone to hydrogen sulfide emission and occupational exposure;[8]
- Development of a contingency plan for hydrogen sulfide release events, including all necessary aspects from evacuation to resumption of normal operations;
- Provision of facility emergency response teams, and workers in locations with high risk of exposure, with personal hydrogen sulfide monitors, self-contained breathing apparatus and emergency oxygen supplies, and training in their safe and effective use;
- Provision of adequate ventilation of occupied buildings to avoid accumulation of hydrogen sulfide gas;
- Development and implementation of a confined space entry program for areas designated as 'Confined Spaces' (see below);
- Providing workers with a fact sheet or other readily available information about the chemical composition of liquid and gaseous phases with an explanation of potential implications for human health and safety.

afad6488-c478-45d8-bd2e-dc2f86b7e18a/Final%2B-%2BGeothermal%2BPower%2BGeneration.pdf?MOD=AJPERES&CVID=jkD2Ay-&id=1323161975166.

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None of these measures is incorporated into the Project, potentially exposing workers to dangerous conditions.

Further, the facility itself emits H_2S, reported as 0.5 lb/hr in the ATC Application.[162] Thus, workers at the facility, as well as others in the vicinity, including nearby workers or motorist on adjacent roadways, could be exposed to H_2S, resulting in both odor impacts and health impacts. The IS is silent on this issue, failing as an informational document under CEQA.

Hydrogen sulfide has well-established eye irritation, respiratory, neurological, and reproductive and development effects. It also can result in death at high exposure, such as may occur during accidental releases. The health effects of H_2S increase sharply with dose, ranging from a rotten egg smell (0.13–0.15 ppm), to respiratory, eye, and throat irritation (100 ppm), to olfactory nerve paralysis (150 ppm), and coma (1000 ppm). Exposure to high concentrations can be extremely hazardous and lead to immediate collapse or death. Most deaths have occurred in industrial settings.[163,164]

California has an ambient air quality standard for H_2S of 0.03 ppm (30 ppb or 42 $\mu g/m^3$) for one hour, which was adopted in 1969.[165] This standard is not adequate to protect exposed parties from chronic health effects because OEHHA's chronic Reference Exposure Level (REL) is 8 ppb, or a factor of nearly four lower.[166] The IS failed to identify this standard or determine if Project construction would cause or contribute to violations of the standard or result in chronic health impacts among the construction work force.

Further, H_2S is highly odiferous and can be detected at subparts per billion levels. Guidelines recommend installation of an H_2S gas monitoring network and

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[162] ATC Application, Section 2.0, pdf 14.

[163] E. Lim and others, Effect of Environmental Exposure to Hydrogen Sulfide on Central Nervous System and Respiratory Function: A Systematic Review of Human Studies, *International Journal of Occupational and Environmental Health*, v. 22, no. 1, January 2016, pp. 80–90; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4894269/.

[164] Health Canada, Draft Screening Assessment Hydrogen Sulfide (H_2S), Sodium Sulfide (Na(SH)) and Sodium Sulfide (Na_2S), September 2017; http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=2C9C9061-1.

[165] James Collins and David Lewis, Hydrogen Sulfide: Evaluation of Current California Air Quality Standards with Respect to Protection of Children, September 1, 2000; https://ww3.arb.ca.gov/ch/ceh/aqstandards/oehhah2scontractorreport091200.pdf.

[166] *Id.*, p. 18.

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emergency planning involving community input to allow for effective response to monitoring system warnings.[167]

The IS is silent on H_2S health effects and odor impacts, thus failing as an informational document under CEQA.

7. VALLEY FEVER

The Project site is located in an area that is endemic for Coccidioidomycosis (abbreviated as cocci), commonly known as Valley Fever. Coccidioidomycosis is an infectious disease caused by inhaling the spores of *Coccidioides ssp.*[168,169] Clinical manifestations range from influenza-like illness to progressive pulmonary disease and, in 1% of infections, potentially fatal disseminated disease.[170] When soil containing this fungus is disturbed by activities such as digging, vehicle use, construction, dust storms, or during earthquakes, the fungal spores become airborne.[171,172] Valley Fever outbreaks

[167] International Finance Corporation and World Bank Group, 2007, pp. 6-7.

[168] Two species of *Coccidioides* are known to cause Valley Fever: *C. immitis*, which is typically found in California, and *C. posadasii*, which is typically found outside California. See Centers for Disease Control, Coccidioidomycosis (Valley Fever), Information for Health Professionals; https://www.cdc.gov/fungal/diseases/coccidioidomycosis/health-professionals.html.

[169] D. R. Hospenthal, Coccidioidomycosis and Valley Fever, Medscape, Updated September 20, 2018; https://emedicine.medscape.com/article/215978-overview.

[170] Cummings et al., Point-Source Outbreak of Coccidioidomycosis in Construction Workers, *Epidemiology and Infection*, v. 138, no. 4, 2010, pp. 507-511, 2010 (Exhibit 5).

[171] California Department of Public Health, Valley Fever Fact Sheet, January 2016; https://www.cdph.ca.gov/Programs/CID/DCDC/CDPH%20Document%20Library/ValleyFeverFactSheet.pdf. *See also* G. Sondermeyer Cooksey et al., Update on Coccidioidomycosis in California, pp. 20-21, Medical Board of California Newsletter, v. 141, Winter 2017; https://www.mbc.ca.gov/Download/Newsletters/newsletter-2017-01.pdf.

[172] Cummings et al. 2010 (Exhibit 5).

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during construction in California have been widely reported.[173,174,175,176,177,178] Spores raised during construction and/or wind storms,[179] which are common in the area, can result in significant worker and public health impacts. Imperial County is endemic for Valley Fever.[180] Valley Fever cases have increased significantly since the Heber 2 facility was constructed[181,182] in 1992,[183] including in Imperial County, where 42% of the cases occurred in El Centro.[184]

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[173] Jason A. Wilken et al., Coccidioidomycosis among Workers Constructing Solar Power Farms, California, USA, 2011–2014, *Emerging Infectious Diseases*, v. 21, no. 11, November 2015; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4622237/.

[174] The Associated Press, Valley Fever Hits 28 at Calif. Solar Plant Sites, *The San Diego Union-Tribune*, May 1, 2013; http://www.sandiegouniontribune.com/sdut-valley-fever-hits-28-at-calif-solar-plant-sites-2013may01-story.html.

[175] G. L. Sondermeyer Cooksey et al., Dust Exposure and Coccidioidomycosis Prevention Among Solar Power Farm Construction Workers in California, *American Journal of Public Health*, August 2017 (Exhibit 6).

[176] Rupal Das et al., Occupational Coccidioidomycosis in California, Outbreak Investigation, Respirator Recommendations, and Surveillance Findings, *Journal of Occupational and Environmental Medicine*, May 2012, vol. 54, no. 5, pp. 564-571 (Exhibit 7).

[177] D. Pappagianis and the Coccidioidomycosis Serology Laboratory, Coccidioidomycosis in California State Correctional Institutions, *Annals of the New York Academy of Sciences*, v. 1111, pp. 103-111, 2007 (Exhibit 8).

[178] K. C. Cummings et al., Point-source Outbreak of Coccidioidomycosis in Construction Workers, *Epidemiology and Infection*, v. 138, 2010, pp. 507-511 (Exhibit 5).

[179] P. L. Williams, D. L. Sable, P. Mendez, and L. T. Smyth, Symptomatic Coccidioidomycosis Following a Severe Natural Dust Storm: An Outbreak at the Naval Air Station, Lemoore, Calif, *Chest*, pp. 566-70, 1979; https://pubmed.ncbi.nlm.nih.gov/498830/.

[180] California Department of Public Health, Valley Fever Fact Sheet; https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/Coccidioidomycosis.aspx#.

[181] Barbara Feder Ostrov and Harriet Blair Rowan, Valley Fever Cases Climb in California's Central Valley—and Beyond, December 17, 2019; https://khn.org/news/valley-fever-cases-climb-in-californias-central-valley-and-beyond/.

[182] CDC, Valley Fever (Coccidioidomycosis) Statistics; https://www.cdc.gov/fungal/diseases/coccidioidomycosis/statistics.html.

[183] IS, pdf 9, 11, 22, 27, 28, 40, 53, 73, etc. Other sources report 1985; https://en.wikipedia.org/wiki/List_of_power_stations_in_California.

[184] Stephen Munday, Imperial County Public Health, Overview of Coccidioidomycosis (Valley Fever), May 21, 2013; pdf 21, 24; http://imperial.granicus.com/MetaViewer.php?view_id=2&clip_id=455&meta_id=59137.

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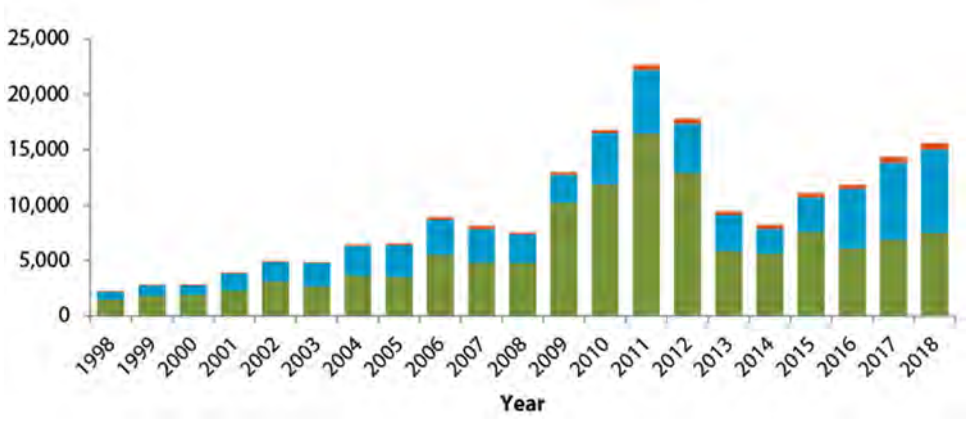
Figure 6: Number of Reported Valley Fever Cases[185]



The IS is silent on this significant impact, thus failing as an informational document under CEQA. Further, the existence of this potentially significant impact requires the preparation of an EIR.

"Workers disturbing soil in areas where Valley Fever is common are at highest risk," with construction workers topping the list.[186] As the proposed site has the potential to contain Coccidioidomycosis spores and it is well known that they can easily become airborne when soil is disturbed,[187] the Project construction site should be tested well in advance of construction to determine if spores are present. Accurate test methods have been developed and used in similar applications.[188,189] A study conducted in the Antelope Valley, slated for six solar ranches of varying sizes, concluded that soil analyses should be conducted before soil disturbance in endemic areas, noting: "Based on the findings of this study, we recommend that EIRs include soil analyses for *Coccidioides spp.* on land destined for construction of any type in

[185] Ibid.

[186] Wilken et al. 2015, pdf 19.

[187] Colson et al. 2017, p. 451 ("A correlation between soil disturbances due to large-scale renewable energy construction projects, agricultural management practices and PM10 fugitive dust emission with increased incidence of coccidioidomycosis was clearly indicated by results of this study."), p. 456 ("One such danger is *Coccidioides spp.* arthroconidia becoming airborne when soil is disturbed and dust mitigation measures are inefficient or absent.").

[188] J. R. Bowers et al., Direct Detection of Coccidioides from Arizona Soils Using CocciENV, a Highly Sensitive and Specific Real-time PCR Assay, *Medical Mycology*, 2018 (Exhibit 9); and Proceedings of the 60th Annual Coccidioidomycosis Study Group Meeting, April 8–9, 2016, Fresno, CA; http://coccistudygroup.com/wp-content/uploads/2016/10/CSG-60th-Annual.pdf.

[189] Colson et al. 2017, pp. 439–458.

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endemic areas of the pathogen."[190] An Environmental Assessment for a solar project in a nearby area has required soil testing.[191]

In response to an outbreak of Valley Fever in construction workers in 2007 at a construction site for a solar facility within San Luis Obispo County, its Public Health Department, in conjunction with the California Department of Public Health,[192] developed recommendations to limit exposure to Valley Fever based on scientific information from the published literature. The recommended measures go far beyond the conventional dust control measures included in the CUP.[193] They include the following measures that are not required by the IS's mitigation measures:

1. Train all employees on the following issues:
    - The soils in Imperial County may contain cocci spores;
    - Inhaling cocci spores may cause Valley Fever;
    - How to recognize symptoms of Valley Fever; these symptoms resemble common viral infections, and may include fatigue, cough, chest pain, fever, rash, headache, and body and joint ache;
    - Work with a medical professional with expertise in cocci as you develop your training program and consult information on public health department websites;
    - Workers must promptly report suspected symptoms of work-related Valley Fever to a supervisor;
    - Workers are entitled to receive prompt medical care if they suspect symptoms of work-related Valley Fever. Workers should inform the health care provider that they may have been exposed to cocci;
    - To protect themselves, workers should use control measures as outlined here.

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[190] Colson et al. 2017, p. 456.

[191] Final Environmental Assessment for Construction, Operation, and Decommissioning of a Solar Photovoltaic System at Marine Air Ground Task Force Training Command Marine Corps Air Ground Combat Center, Twentynine Palms, California, November 2015, Table ES-1, AQ-17; https://www.29palms.marines.mil/Portals/56/Docs/G4/NREA/Environmental%20Assessment%20Construction%20and%20Operation%20of%20Solar%20Photovoltaic%20System%20at%20MAGTFTC,%20MCAGCC%20(Final)%20November%202015.pdf.

[192] CDPH June 2013, pp. 4-6. See also Wilken et al., 2015, and Sondermeyer Cooksey et al. (Exhibit 6).

[193] IS, pdf 364 in the attached CUP lists construction mitigation.

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2. Control dust exposure:

   - Consult with local Air Pollution Control District Compliance Assistance programs and with California Occupational Safety and Health Administration ("Cal/OSHA") compliance program regarding meeting the requirements of dust control plans and for specific methods of dust control. These methods may include wetting the soil continuously while working it and ensuring that the wetting process does not raise dust or adversely affect the construction process.
   - Provide high-efficiency particulate ("HEP")-filtered, air-conditioned enclosed cabs on heavy equipment. Train workers on proper use of cabs, such as turning on air conditioning prior to using the equipment and keeping windows closed.
   - Provide communication methods, such as 2-way radios, for use in enclosed cabs.
   - Employees should be medically evaluated, fit-tested, and properly trained on the use of the respirators, and a full respiratory protection program in accordance with the applicable Cal/OSHA Respiratory Protection Standard (8 CCR 5144) should be in place.
   - Provide National Institute for Occupational Safety and Health (NIOSH)-approved respirators for workers with a prior history of Valley Fever.
   - Half-face respirators equipped with N-100 or P-100 filters should be used during digging. Employees should wear respirators when working near earth moving machinery.
   - Prohibit eating and smoking at the worksite, and provide separate, clean eating areas with handwashing facilities.
   - Avoid outdoor construction operations during unusually windy conditions or in dust storms.
   - Consider limiting outdoor construction during the Fall to essential jobs only, as the risk of cocci infection is higher during this season.

3. Prevent transport of cocci outside endemic areas:

   - Thoroughly clean equipment, vehicles, and other items before they are moved off-site to other work locations.

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- Provide workers with coveralls daily, lockers (or other systems for keeping work and street clothing and shoes separate), daily changing and showering facilities.
- Clothing should be changed after work every day, preferably at the work site.
- Train workers to recognize that cocci may be transported offsite on contaminated equipment, clothing, and shoes; alternatively, consider installing boot-washing facilities.
- Post warnings onsite and consider limiting access to visitors, especially those without adequate training and respiratory protection.

4. Improve medical surveillance for employees:
    - Employees should have prompt access to medical care, including suspected work-related illnesses and injuries.
    - Work with a medical professional to develop a protocol to medically evaluate employees who have symptoms of Valley Fever.
    - Consider preferentially contracting with 1-2 clinics in the area and communicate with the health care providers in those clinics to ensure that providers are aware that Valley Fever has been reported in the area. This will increase the likelihood that ill workers will receive prompt, proper and consistent medical care.
    - Respirator clearance should include medical evaluation for all new employees, annual reevaluation for changes in medical status, and annual training, and fit-testing.
    - Skin testing is not recommended for evaluation of Valley Fever. [194]
    - If an employee is diagnosed with Valley Fever, a physician must determine if the employee should be taken off work, when they may return to work, and what type of work activities they may perform.

In a more recent Valley Fever outbreak among solar plant construction workers in Monterey County, public health officials conducted a site visit to the solar farm to observe and interview workers and employers about work practices, dust control, and

[194] Short-term skin tests that produce results within 48 hours are now available. See Kerry Klein, NPR for Central California, New Valley Fever Skin Test Shows Promise, But Obstacles Remain, November 21, 2016; http://kvpr.org/post/new-valley-fever-skin-test-shows-promise-obstacles-remain.

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use of protective equipment; review training materials; and discuss prevention strategies. The visit confirmed dust control issues, serious lapses in use of respiratory protection, insufficient Coccidioidomycosis employee training, and no system for tracking or reporting illness. Thus, in November 2017, the CDPH issued prevention recommendations before the start of the second construction phase, which was scheduled to continue through the end of 2018. Recommendations for employers included:[195]

(1) reducing dust exposure by ensuring ample and efficient water truck capacity to wet soil;

(2) using only heavy equipment with enclosed cabs and temperature-controlled, high efficiency particulate air–filtered air;

(3) providing clean coveralls daily to employees who disturb soil;

(4) implementing a mandatory respiratory protection program (8 CCR §5144, Respiratory Protection: https://www.dir.ca.gov/title8/5144.html) that specifically requires National Institute for Occupational Safety and Health–approved respirators be worn while performing or in the near vicinity of job activities that create airborne dust;

(5) developing effective Valley Fever training for all employees, including ways to reduce exposure, how to recognize symptoms, and where to seek care; and

(6) tracking and reporting of all suspected Valley Fever illnesses that occur at the worksite to the Imperial County Public Health Department.

The study concluded that prevention methods need to be better incorporated into the planning and monitoring of construction projects in areas with endemic *Coccidioides* (e.g., by involving public health practitioners in pre-project reviews). Specifically, the following was recommended: "Outdoor workers in these areas should be trained by employers about the potential for infection, how to limit dust exposure, how to recognize symptoms, where to seek care, and how to ask a health care provider to assess them for coccidioidomycosis. Clinicians should inquire about occupational history and should suspect coccidioidomycosis in patients who are outdoor workers in areas with endemic *Coccidioides* and who have a clinically compatible illness."[196]

Similarly, the California Department of Public Health (CDPH) recently summarized recommendations to control Valley Fever, including:[197]

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[195] Law et al., 2018.

[196] *Ibid.*

[197] See, *e.g.*, 8/21/18 CDPH; Wilken 2015.

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- Minimize soil disturbance through job design (e.g., avoid digging, reduce grading, maintain vegetation, install wiring in aboveground trays instead of belowground trenches);
- Limit dust generation and exposure;
- Protect operators with enclosed cabs (air conditioned with HEPA air filtration, windows closed & 2-way radio for communication, wet-clean inside cabs);
- Maintain effective cab pressurization and filtration (positive pressure, tight door seals, gaskets, holes sealed up, replace clogged filters, provide cooling & heating);
- Get employees respirator-ready;
- Use respirators with N95 or P100 (HEPA) filters;
- Develop respiratory protection program (program coordinator, medical clearance, fit testing, training, written policy on when to use respirators);
- Plan to take action when dust cannot be controlled (rules for work stoppage, monitor conditions, move indoors or into HEPA-filtered A/C, don respirators quickly);
- Valley Fever prevention training (train all supervisors, employees, & subcontractors);
- Training content to include Valley Fever awareness, symptoms, groups at greater risk, how to prevent exposure, what to do if you have symptoms;
- Preventing "take-home" dust (provide clean area to wash up, require change of clothing, provide boot cleaning stations, wet-clean tools and equipment); and
- Train workers on what to do if they're sick (inform supervisors, get medical evaluation, file workers' compensation claim).

In addition to the above-discussed measures, I recommend the following mitigation measures to protect construction workers, on-site workers at the existing geothermal facilities, and off-site sensitive receptors:

- Continuously wet the soil before and while digging or moving the earth. Landing zones for helicopters and areas where bulldozers, graders, or skid steers operate are examples where continuously wetting the soil is necessary.
- When digging a trench or fire line or performing other soil-disturbing tasks, position workers upwind when possible.

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- Place overnight camps, especially sleeping quarters and dining halls, away from sources of dust such as roadways.
- Minimize the amount of digging by hand. Instead, use heavy equipment with the operator in an enclosed, air-conditioned, HEPA-filtered cab.

In sum, construction mitigation measures in the IS (included in the attached CUP) are not adequate to control Valley Fever spores raised during Project construction. Projects that have implemented similar conventional PM10 dust control measures have experienced fugitive dust issues and reported cases of Valley Fever.[198,199]

All of the above health-protective measures recommended by the San Luis Obispo County Public Health Department, Monterey County Health Department, and the California Department of Public Health are feasible for the Project and must be required in a dust control plan included in an EIR that evaluates and mitigates the risk to construction workers, on-site workers, nearby residents, and passengers on public roads from contacting Valley Fever. Many of these measures have been required by the County of Monterey in other EIRs.[200] They are also required in the EIR for the California High-Speed Train.[201] Even if all of the above measures are adopted, CEQA review is required to analyze whether these measures are adequate to reduce this significant impact to a level below significance.

8. HAZARDS

The IS contains an asserted "worst-case analysis" for the failure of one isopentane storage tank (vapor cloud explosion) with an endpoint distance of 0.3 miles for an overpressure of 1 psi. The IS also contains an alternative release scenario for a truck transfer hose uncoupling from the isopentane storage tank during loading operations with an endpoint distance of 0.1 miles for an overpressure of 1 psi.[202]

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[198] Herman K. Trabish, Green Tech Media, Construction Halted at First Solar's 230 MW Antelope Valley Site, April 22, 2013; http://www.greentechmedia.com/articles/read/Construction-Halted-At-First-Solars-230-MW-Antelope-Valley-Site.

[199] Julie Cart, 28 Solar Workers Sickened by Valley Fever in San Luis Obispo County, *Los Angeles Times*, May 1, 2013; http://articles.latimes.com/2013/may/01/local/la-me-ln-valley-fever-solar-sites-20130501.

[200] County of Monterey, California Flats Solar Project Final Environmental Impact Report, December 2014; https://www.co.monterey.ca.us/home/showdocument?id=48244.

[201] California High-Speed Rail Authority and U.S. Department of Transportation, California High-Speed Train Project Environmental Impact Report/Environmental Impact Statement, Fresno to Bakersfield, Mitigation Monitoring and Enforcement Program Amendments, September 2015.

[202] IS, Hazard Assessment for Heber 2 Expansion Project, pdf 293.

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The chemical released from the tank and transfer hose is isopentane (also called methyl butane or 2-methylbutane), which is an extremely volatile and highly flammable liquid at room temperature and pressure. The normal boiling point is just a few degrees above room temperature.[203] It will readily boil and evaporate on a warm day. Isopentane is used to drive turbines in geothermal power production, including the Project.

The IS concludes that impacts from accidents involving isopentane use and storage are not significant because the nearest sensitive receptors to the Project site are residences about 3,500 feet (0.66 mi) to the northeast.[204] The scenarios evaluated in the IS are not worst-case scenarios, as demonstrated below.

8.1. The Wrong Release Scenario Was Selected

Under applicable regulations,[205] a hazard analysis should be based on a worst-case scenario. The IS Hazard Assessment acknowledges this but failed to evaluate a worst-case scenario. Instead, it asserts:[206]

> *Normally, to develop the worst-case scenario, the covered process is reviewed, and a suitable worst-case release analysis is identified through a review of vessels and storage tanks to determine the single vessel with the largest quantity of the regulated substance. However, in this particular Hazard Assessment, the worst-case scenario instead analyzes a release from one of the three new 10,000 gallon isopentane storage vessels. This updated Hazard Assessment was performed to account for the modifications made to Heber 2 as part of the facility's expansion project, thus an exclusive examination of the new 10,000 gallon storage vessels was performed rather than a review of the entire facility.*

However, this is not a reasonable worst-case scenario under existing regulations for this Project. The new facilities are linked to existing facilities and are not standalone. Thus, the entire facility must be considered. The worst-case scenario is a single scenario (for toxics or flammables) that results in the maximum potential distance from the facility where people or the environment may be adversely impacted. This assessment requires that the entire isopentane inventory be taken into account when determining the maximum potential distance, not just the inventory from one of the three new tanks picked out of thin air. Thus, the IS fails as an informational document under CEQA.

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[203] Wikipedia, Isopentane; https://en.wikipedia.org/wiki/Isopentane.

[204] IS, pdf 20, 26, 29, 363.

[205] Federal EPA regulations at 40 CFR §68.20 to §68.42 and California EPA regulations at 19 CCR §2750.1 to §2750.9.

[206] IS, Hazard Assessment, pp. 3-4, pdf 298-299.

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Isopentane is present in two sources, the Ormat Energy Converters and storage tanks.[207] The Project will increase OEC isopentane from 150,000 gallons to 171,000 gallons or by 21,000 gallons[208] and tank OEC storage from 20,000 gallons to 50,000 gallons, increasing on-site isopentane from 171,000 gallons to 221,000 gallons. Thus, at a minimum, the IS should have evaluated a release of 51,000 gallons of isopentane, rather than a release of 10,000 gallons from a single tank.

The IS only evaluates a tank accident but failed to evaluate an accident at an OEC. The Project will reduce the total number of geothermal power units from eight to four.[209] Thus, an accident involving an OEC after the Project is complete will result in much more significant impacts than an accident involving one of the smaller units because each individual OEC will contain more isopentane. The IS is silent on these issues, failing as an informational document under CEQA.

Further, as the three new tanks will be sited side by side and adjacent to two existing 10,000-gallon isopentane tanks,[210] an accident involving any one of these tanks would very likely trigger a similar accident at adjacent tanks. Thus, assuming the IS's analysis, the worst-case hazard impacts are up to five times higher (5 tanks/1 tank = 5) than disclosed. In other words, rather than extending just 0.66 miles from the tanks, the impact would extend 5 x 0.66 = 3.3 miles from the site, which would encompass all of the city of Heber and portions of El Centro.

Further, the IS failed to evaluate the worst-case release scenario. The IS acknowledges five possible release scenarios: flash fire, pool fire, boiling liquid expanding vapor explosion (BLEVE), vapor cloud explosion, and jet fire.[211] The IS selected a vapor cloud explosion as the "most appropriate consequence" with no explanation or justification whatsoever.[212] However, a BLEVE is the worst case release scenario for very flammable materials such as isopentane because it combines both the mechanical effects of an explosion and the thermal effects of a fire. Due to these dual effects, it is one of the most severe accidents that can happen and typically results in mortalities. See for example, the summary in Table 2.

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[207] ATC Application, pdf 16.

[208] IS, pdf 289-290.

[209] ATC Application, pdf 17.

[210] IS, pdf 54 and 79 (3 new and 2 existing 10,000 gal tanks); Air Sciences Inc., Heber 2 Application for Authority to Construct (ATC Application), November 2019, Figure 2, pdf 11 (Exhibit 10).

[211] IS, pdf 301: Hazard Assessment, p. 6.

[212] Ibid.

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Table 2: BLEVE Accidents Occurring Between 1980 and 2004[213]

Date	Place	Material	Cause	Fatalities
1980	Los Angeles, USA	Gasoline	Tanker, road accident	2
1980	Rotterdam, The Netherlands	LPG	External fire in a bus station	-
1981	Montonas, México	Chlorine	Derailment, impact, fire	29
1982	Spencer, USA	Water	Overheating	7
1982	Louisiana, USA	Vinyl chloride	Derailment, impact, fire	0
1982	Taft, USA	Acroleine	Runaway reaction	0
1982	Tyne and Wear, UK	LPG	Tank, external fire	-
1983	Reserve, USA	Chlorobutadiene	Runaway reaction	3
1983	Houston, USA	Methyl bromide	Overfilling	2
1983	Murdock, USA	Propane	Derailment, impact, fire	0
1984	Romeoville, USA	Propane	Weld failure	15
1984	Cleveland, USA	LPG	External fire on vessel	0
1984	Mexico City	LPG	Leak and fire in storage park	500
1985	Priolo, Italy	Ethylene	Leak, jet fire on tanks	0
1985	Pine Bluff, USA	Ethylene, ethylene oxide	Derailment, impact, fire	0
1986	Kennedy S C, USA	Hydrogen	Fire	7
1987	Cairns, Australia	LPG	Human error (hose disconnected), fire	0
1988	Philadelphia, USA	Gasoline	Tanker, road accident	0
1988	Kings Ripton, UK	LPG	Human error (hose): leak while filling vessel, fire	0
1989	Alma Ata, Mongolia	LPG?	Train collision, fire	5
1990	St. Peters, Australia	LPG	Tank, external fire	-
1991	Lyon, France	Propane	External fire on small vessel	-
1995	La Plata, Argentina	Propane	Overfilling (human error)	2
1996	Paese, Italy	Propane	Human error while unloading a tanker, release, fire	0
1998	Albert City, USA	Propane	Car breakes pipes, fire	2
1998	Xian, China	LPG	Leak, fire on storage park	11
1999	Dortyol, Turkey	LPG	Human error	-
1999	KamenaVourla, Greece	LPG	Road accident, leak, fire	4
2000	Downey, USA	Propane	Leak, fire	-

A BLEVE is an explosion caused by the rupture of a vessel containing a pressurized liquid that has reached a temperature above its boiling point. As the normal boiling point of isopentane is just a few degrees above room temperature, this condition can be reasonably expected to occur. It can occur, for example, when a sudden drop in pressure inside a vessel causes violent boiling of the liquid, which rapidly releases large amounts of vapor. The pressure of this vapor can be extremely high, causing a significant wave of overpressure (explosion) that may completely destroy the tank and eject fragments over the surrounding areas, resulting in injury

[213] Joaquim Casal (Ed.), Evaluation of the Effects and Consequences of Major Accidents in Industrial Plants, Industrial Safety Series, Vol. 8, Table 5-1 (Exhibit 11).

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from shrapnel, explosion, and fire radiation. If the vessel's integrity is compromised, the loss of pressure and dropping boiling point can cause the liquid to quickly convert to gas and expand extremely rapidly. If the gas is also combustible, as is isopentane, further damage can be caused by fire.

The IS should have evaluated a BLEVE, which cannot be ruled out as a possible accident scenario. A BLEVE would result in much greater impacts than the vapor cloud explosion evaluated in the IS. The IS is silent on BLEVE impacts—a fatal omission, rendering the IS invalid under CEQA. I did not have the time or resources to redo the IS's work. However, the results of a similar study in which various release scenarios for a butane storage facility (63 million pounds of butane[214]) were evaluated shows that the impact radius for the BLEVE cases are substantially higher (up to 68 times) than the impact radius for the vapor cloud explosion cases evaluated in the IS.[215] Table 3.

Table 3: Summary of Release Scenarios, Amerigas Storage Facility[216]

Release Description	Wind Speed (m/s)	Air Temperature (°F)	Release Rate (lb/min.)	Impact Radius (miles)
Vapor Cloud Explosion	3.0	77.0	7,790	<0.1
Vapor Cloud Explosion	3.0	77.0	1,000	<0.1
Pool Fire	3.0	77.0	500	0.4
Pool Fire	3.0	77.0	7,790	1.7
Vapor Cloud Explosion	1.5	77.0	Instantaneous	3.2
Vapor Cloud Explosion	1.5	77.0	Instantaneous	4.0
BLEVE	3.0	77.0	Instantaneous	5.2
BLEVE	3.0	77.0	Instantaneous	6.8

Assuming a 68 times higher impact radius, an explosion at the Project's storage tank facility could extend 20 miles from the tanks,[217] impacting all of the city of Heber and much of the cities of El Centro and Calexico. The literature, for example, reports an accident that occurred in a 15,000-barrel spherical tank containing 500,000 gallons of mixed pentane and hexane that caught fire at a Texas refinery. Over an hour after the original fire started, the top of the tank ruptured violently and the storage tank BLEVEd and ignited two adjacent tanks 450 and 550 feet from the BLEVEd tank. Nineteen

[214] Isobutane is an isomer of butane.

[215] Worst-case BLEVE/Vapor Cloud Explosion = 6.8 mi/0.1 mi = 68.

[216] Cornerstone Technologies, Inc., Quantitative Risk Analysis for Amerigas Butane Storage Facility, September 2010, Section 7.0, p. 12, pdf 18; http://nwsanpedro.org/wp-content/uploads/2012/10/RISK-ANALYSIS-ON-TANKS-PDF2.pdf.

[217] Revised impact radius = (0.3 mi)(68) = 20 mi. Project impact radius of 0.3 miles from IS, pdf 311, Table 6.

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firefighters were killed and 31 injured. These are highly significant impacts.[218] The IS failed to address impacts to on-site workers.

If the new and/or existing isopentane tanks were engulfed in a fire, for example, a BLEVE could result.[219] The most common cause of a BLEVE is a fire near tanks containing volatile chemicals, caused by external high temperatures surrounding the tank that increase the temperatures inside of the tank, potentially to the breaking point. The result is a BLEVE, a rapid phase transition in which a liquid contained above its atmospheric boiling point is rapidly depressurized, causing nearly instantaneous transition from liquid to vapor with a corresponding energy release.

When a tank experiences a BLEVE, the vessel fully opens, releasing contained energy. As explained by Birk et al.:[220]

> When a tank suffers a BLEVE the vessel opens fully to release the contained energy. The release is strongly directional since the tank wall does not move away instantaneously. The piston effect of the expanding vapour generates a shock at some distance away from the tank. This shock then propagates into the surroundings. Behind this shock is an additional blast wind caused by liquid flashing. This may also produce a shock. When the tank opens fully and is flattened on the ground this produces a large impulse load. Long range projectiles are also possible.

As there are six tanks in close proximity, this could involve all tanks in a catastrophic accident, far worse than the accident evaluated in the IS.

8.2. Impact of Future Plans on Release Scenario

The Hazard Analysis failed to consider Imperial County's recently adopted "specific plan area" that covers the Heber Known Geothermal Resource Area (KGRA). The Heber Specific Plan allows commercial, residential, industrial, and other employment-oriented development in a mixed-use orientation, which currently

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[218] Anton Riecher and Davis White, Sunray, Texas: July 29, 1956, Industrial Fire World, November 1, 2006; https://www.industrialfireworld.com/536610/sunray-refinery-blast.

[219] Joaquim Casal (ed.), Chapter 5, Evaluation of the Effects and Consequences of Major Accidents in Industrial Plants, Industrial Safety Series, v. 8, 2000.

[220] A. M. Birk et al., Near Field Blast Effects from BLEVE, *Chemical Engineering Transactions*, v. 48, 2016; https://www.aidic.it/cet/16/48/048.pdf#:~:text=A%20BLEVE%20takes%20place%20when,et%20al.%2C%202013).&text=This%20work%20presents%20some%20preliminary,blast%20effects%20from%20a%20BLEVE.

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includes geothermal uses. This plan could place many sensitive receptors close to the Project.[221] Heber's annual report discloses:[222]

> geothermal uses. Several of the landowners from whom we hold geothermal leases have expressed an interest in developing their land for residential, commercial, industrial or other surface uses in accordance with the parameters of the Heber Specific Plan Area. Currently, Imperial County's Heber Specific Plan Area is coordinated with the cities of El Centro and Calexico. There has been ongoing underlying interest since the early 1990s to incorporate the community of Heber. While any incorporation process would likely take several years, if Heber were to be incorporated, the City of Heber could replace Imperial County as the governing land use authority, which, depending on its policies, could have a significant effect on land use and availability of geothermal resources.

8.3. On-Site Receptors Excluded

The hazard analysis only considered "offsite sensitive receptors." However, one of the most at-risk populations are on-site workers, emergency responders, the Applicant's office/control room/shop building at the power plant, and agricultural workers in the surrounding fields. The impact to on-site workers would be highly significant. The Imperial County Fire Department, for example, reviewed the CUP. In their comments, they pointed out that isopentane is a hazardous substance with the following impacts:[223]

> Isopentane is highly flammable liquid that fire behavior can be highly volatile and vapors may explode when mixed with air. The amount of propose storage and the location rises concerns for Imperial County Fire Department and the surrounding community of Heber. The Emergency

The Fire Department specifically requested the following mitigation measures to protect the Imperial County Fire Department staff, facility staff, and citizens of Heber and Imperial County:

> - A certified fire protection engineer survey and analysis of current and proposed fire suppression and detection equipment be performed to evaluate the current systems performance and coverage of protection. Evaluate propose fire suppression and detection equipment in conjunction with existing equipment. A full report of findings must be provided to Imperial County Fire Department for review
> - Isopentane leak or fire will require a large scale evacuation area and create a large scale hazardous material incident with a large operational zone. To minimize potential extremely dangerous condition to firefighters and hazardous material teams Imperial County Fire Department is requiring that a Drone be purchase for Imperial County Fire Department. The final cost, details, and equipment of the drone shall be determined prior the issuance of the building permit.

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[221] U.S. Securities and Exchange Commission, Form 10-K, Ormat Technologies, Inc., Fiscal Year Ended December 31, 2019; https://sec.report/Document/0001437749-20-004072/. See also: Ormat Technologies, Inc., 2019 Annual Report, pdf 77; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.

[222] See, e.g. Ormat Technologies, Inc., 2019 Annual Report, pdf 77; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.

[223] IS, Letter from Andrew Loper, Fire Protection Bureau, to Imperial County Planning & Development Services, Re: Conditional Use Permit #19-0017, September 18, 2019, pdf 351-354.

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- All isopentane above ground storage tanks shall be protected by approved automatic fire suppression equipment. All automatic fire suppression shall be installed and maintained to the current adapted fire code and regulation.
- An approved automatic fire detection system shall be installed as per the California Fire Code. All fire detection systems shall be installed and maintained to the current adapted fire code and regulations.
- Fire department access roads and gates will be in accordance with the current adapted fire code and the facility will maintain a Knox Box for access on site.
- Compliance with all required sections of the fire code.
- Applicant shall provide product containment areas(s) for both product and water run-off in case of fire applications and retained for removal.

The IS fails as an informational document under CEQA for failing to identify the fire risk and for failing to require mitigation.

8.4. Mitigation for Hazard Impacts

To address potential hazards associated with use, storage, and disposal of the highly flammable motive fluid isopentane requires, at a minimum, the following mitigation measures based on commitments by Ormat and required by the County for the East Brawley Geothermal project:[224,225]

a) Disclose the potential project and cumulative risk of an isopentane vapor cloud explosion and fire to potentially affected residents and offer to relocate the residence.
b) Prepare a Hazard and Operability Review for the final geothermal plant design containing a structured and systematic examination of the planned operation for the power plant in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation. Incorporate control valves, pump kill switches, and motor-operated valves into the final design. Monitoring and enforcement shall be the responsibility of the Imperial County Planning and Development Services Department, Imperial County Fire Department, and the California Department of Toxic Substances Control ("DTSC") as the Certified Unified Program Agency ("CUPA") for Imperial County.

Further, as required by the County for the East Brawley Geothermal project, implement at Heber Complex or expand to include the following plans:[226]

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[224] County of Imperial, East Brawley Geothermal, Final Environmental Impact Report, May 2012, p. 4.0-27 and 4.0-28, Item #23 on the Board of Supervisors agenda at: http://imperial.granicus.com/player/clip/356?view_id=2&meta_id=43881&redirect=true.

[225] County of Imperial, East Brawley Geothermal, Draft Environmental Impact Report, March 2011, p. 4.7-18.

[226] *Ibid*.

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c) Prior to issuance of a conditional use permit, prepare a comprehensive Hazardous Materials Business Plan for the Project in accordance with the California Accidental Release Prevention Program. The Hazardous Materials Management Plan ("HMMP") shall include (1) an Inventory and Site Map, (2) an Emergency Response Plan ("ERP") and Owner/Operator Identification, and (3) employee training.

The HMMP will be prepared and submitted to the California Department of Toxic Substances Control ("DTSC"), as the Certified Unified Program Agency ("CUPA") for Imperial County, and shall be maintained and revised as necessary.

The Project shall comply with all federal, state, Imperial County, and fire district requirements for temporary storage of flammable/combustible materials at construction sites. The proposed Project shall include staging areas where materials shall be stored during construction. Monitoring and enforcement shall be the responsibility of Imperial County Planning and Development Services Department, Imperial County Fire Department, and DTSC).

d) Prepare a comprehensive Emergency Response Plan ("ERP"). Consult with local emergency response providers. Require approval of this ERP by the Imperial County Sheriff's Office, Imperial County Office of Emergency Services, Imperial County Fire Department, Imperial County Department of Public Health, California Highway Patrol, and Caltrans prior to the commencement of site operations. The ERP shall address potential safety hazards associated with the project and identify public safety hazards that can be reduced or eliminated through specific protocols. The ERP also shall provide an overview of general procedures required to protect people and property during an emergency or disaster situation. The intent of the ERP is to establish a clear understanding of responsibilities for first responders, sheriff and police, local fire departments, emergency medical service agencies, and management of staff during an emergency situation.

The ERP shall identify and assign personnel to various emergency tasks and responsibilities, thus creating a site emergency team. The ERP shall describe the emergency management procedures to cover possible emergencies (i.e., well blowouts, major fluid spills, earthquakes, etc.). There shall be at least one employee on call at all times (*i.e.*, available to respond to an emergency by reaching the facility within a short period of time) with the responsibility of coordinating all emergency response

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measures. The on-call emergency coordinator would be familiar with the ERP and would have the authority to commit the resources needed to carry out the contingency plan. Additionally, the ERP shall include designated assignments for on-site personnel, details of each position's responsibilities, procedures for coordination with outside resources, and establishment of a chain of command to take precedence in emergencies.

The Emergency Response Plan shall be updated annually in coordination with the Imperial County Fire Department, the Imperial County Public Health Department, the Imperial County Certified Unified Program Agency, and the Imperial County Office of Emergency Services. Enforcement/Monitoring shall be the responsibility of the Imperial County Department of Planning and Development Services.

9. GEOLOGIC IMPACTS

The IS does not discuss geologic impacts of extending the life of the Heber facilities for 30 more years, from 2019 to 2049.[227] Instead, the IS asserts with no analysis and contrary to supporting geotechnical reports, that "[d]evelopment of the proposed facilities would not result in the destabilization of any soils or geologic units that could cause a landslide, subsidence, or liquefaction."[228]

However, the Geotechnical Report Update indicates in bold that "**The entire plan area overlays a geothermal fluids reservoir that geothermal fluids extraction and reinjection is causing annual ground settlement of 1 to 2 inches per year. The settlement is not uniform**."[229]

Scientific studies confirm the surface deformation caused by the Heber geothermal field:[230]

> Using data from two satellites, Envisat and Sentinel, we observe changes in surface deformation at the Heber geothermal field, corresponding to changes in production and injection. Subsidence at the center of the field is observed in both study periods, August 2005 – August 2010 and April 2015 – April 2018, while a significant uplift is observed to the northwest of the subsidence bowl during the earlier period, but not in the later period. This is also confirmed by data from leveling surveys. Based on the apparent capability of InSAR to capture the dynamics of surface deformation, we suggest that it would be very beneficial to integrate such satellite measurements in the geothermal operation strategies.

The applicant itself has disclosed the resulting impacts in its annual report, admitting that withdrawing geothermal fluid creates localized ground subsidence,

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[227] IS, pdf 331, 345, 361.

[228] IS, Section VII: Geology and Soils, Sections VII(c) and (d), pdf 24.

[229] IS, pdf 96, 97.

[230] Mariana Eneva and others, Surface Deformation at the Heber Geothermal Field in Southern California, Proceedings, 44th Workshop on Geothermal Reservoir Engineering, February 11-13, 2019, p. 9, pdf 9; https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2019/Eneva2.pdf.

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while pressure in peripheral areas has caused localized ground inflation. Inflation and subsidence, if not controlled, can adversely affect farming operations and other infrastructure at or near the land surface. This could result in damage to gravity-based farm irrigation systems and municipal sewer piping, local roads, and bridges.[231] The 2019 SEC filing further indicates:[232]

> Another aspect of geothermal operations is the management and stabilization of subsurface impacts caused by fluid injection pressures of production and injection fluids to mitigate subsidence. In the case of the geothermal resource supplying the Heber complex, pressure drawdown in the center of the well field has caused some localized ground subsidence, while pressure in the peripheral areas has caused localized ground inflation. Inflation and subsidence, if not controlled, can adversely affect farming operations and other infrastructure at or near the land surface. Costs of failing to stabilize site pressures in the Heber Complex area include repair and modification of gravity-based farm irrigation systems and municipal sewer piping and repair or replacement of a local road bridge spanning an irrigation canal.

The IS is silent on this significant impact, failing as an informational document under CEQA.

Finally, the Project is located in a seismically active area. Significant nearby earthquake activity has been recently experienced.[233] The IS admits that in the event of an earthquake, "[s]eismic ground-shaking could be experienced in the vicinity of the Project Site … Seismic ground-shaking and seismically induced liquefaction could result in structural damage to power plant infrastructure and facilities." The IS then incorrectly concludes that "However, the Project does not involve any infrastructure or facilities that would include human occupancy … Therefore, impacts to people or structure from the Project would be less than significant."[234]

However, as discussed in Comment 4.1, the OEC units and storage tanks contain isopentane, which is highly explosive. Structural damage could result in accidents, resulting in mortality and significant health impacts to off-site receptors and response personnel. Comment 8. This is a significant impact that was not disclosed in the IS, which thus fails as an informational document under CEQA.

10. WATER USE

The IS concludes with no analysis at all that "[t]he Project would not require any additional water supplies … Therefore, no impacts to any water entitlements or resources would occur as a result of the Project."[235] Elsewhere, the IS asserts that "[n]o additional water will be required to support the proposed facilities … The existing

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[231] See, e.g., Ormat Technologies, Inc., 2019 Annual Report, pdf 61.

[232] SEC 2019, p. 53, pdf 41.

[233] Rong-Gong Lin II, Swarm of Salton Sea Earthquakes Sparks Worry About the San Andreas Fault, Los Angeles Times, August 10, 2020; https://www.latimes.com/california/story/2020-08-10/swarm-of-earthquakes-shakes-salton-sea-area-raising-worry-about-the-san-andreas.

[234] IS, pdf 23.

[235] IS, Section XIX, p. 32, pdf 33.

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Heber 2 facility will provide the water via existing permits."[236] The IS and supporting files do not contain any support for this assertion, which is incorrect as demonstrated below.

The Project includes two new "water-cooled ORMAT Energy Converters,"[237] that will restore output from 81 MW to 92 MW (Comment 1) and will use existing cooling towers[238] to cool heated water from these new OECs. The existing cooling towers cool heated water from the OECs by evaporating water. Thus, the cooling towers are a net water user. In fact, wet-cooled geothermal binary power plants, such as the subject Heber units, have the highest water consumption rate per megawatt hour of any thermal power plant technology (over 1,600 gallons per megawatt hour).[239] Relative to the baseline, the period prior to the start of environmental review, the Project will increase water use at the facility by 69% relative to 2019 conditions. Comment 2.2. Thus, the proposed action would increase water use by approximately 2/3. This increase was not disclosed in the IS.

The average water use for the period 2004 to 2009 was 1,017 acre-feet per year (AFY) for Heber 1 and 3,978 AFY for Heber 2,[240] or a total of 4,995 AFY. Thus, the Project will increase the amount of water required to operate the facility from 4,995 AFY to 8,325 AFY.[241] The Applicant currently has a Water Supply Agreement with Imperial Irrigation District ("IID") for up to 5,000 AFY of water.[242] Further, the existing Conditional Use Permit (CUP) between Imperial County and ORCAL/Heber Field Company limits water usage to 5,000 AFY of irrigation water for up to five years from the date of commencement of water usage.

The existing CUP further states that "If the amount of water available to Imperial County is reduced by the Central Arizona project, the right to the irrigation water for

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[236] IS, Reclamation Plan Application, pdf 333.

[237] IS, Section VI, p. 39, pdf 40.

[238] IS, Integration of Heber II Facilities, pdf 46.

[239] California Energy Commission (CEC) et al, Best Management Practices and Guidance Manual, Desert Renewable Energy Projects, November 2010, pdf 88; https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.432.1193&rep=rep1&type=pdf.

[240] Brandon Doering and Eddie Jordan, Integrated Engineers & Contractors Corporation, Memorandum to GEI Consultants, Inc., Re: Imperial Irrigation District Power Plant Water Use Evaluation, September 15, 2009; Reported in: Imperial Irrigation District, IID Power Plant Water Use Evaluation, October 2012, Table 4, p. 7; https://www.iid.com/home/showdocument?id=9550.

[241] Water use after the Project is operational = (4,995 AFY)(0.69) + 4,995 = 8,442 AFY.

[242] Water Supply Agreement, October 27, 1992 (Exhibit 12).

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the five years granted herein may be terminated."[243] Ongoing drought conditions in the area supplying the IID water puts the Project's water supply at risk. Thus, the existing water supply is not only inadequate, it is also insecure. The IS is silent on the availability and source of the increase in water required to operate the Project and alternative water supply sources in the event that IID water is inadequate.

Thus, the Project will require an increase in water from IID that was not disclosed in the IS. This increase will result in significant impacts not disclosed or mitigated in the IS. This increase in water use is for cooling purposes, specifically for evaporation and blowdown in the Project's cooling towers.[244] Heber 1 is primarily a flash steam plant. The only significant water use is for cooling tower water makeup. The cooling system is an evaporative (wet) system, and all makeup water not supplied by condensate is provided by water from the IID canal. At Heber 2, the condensers are cooled by a closed-loop wet cooling tower system. Because all of the geothermal brine is returned to the resource aquifer, and none is used for steam production, there is no condensate to be recovered for other uses. Thus, all of the cooling tower makeup water is supplied from the IID canal.[245]

The only water available to the IID originates from the Colorado River via the All-American Canal, which diverts the river's flow away from Mexico and the Gulf of California and toward Imperial Valley in southeastern California.[246] Record drought conditions and overuse of water in the American Southwest have put tremendous strain on the lower part of the Colorado River. Tree-ring reconstructions of stream flow suggest the past decades rank among the lowest stream-flow periods in 1,200 years.[247]

The IID's Interim Water Supply Policy ("IWSP"), which provides a mechanism to address new water supply requests for proposed projects being developed within the IID service area, currently designates up to 25,000 AFY of IID's annual Colorado River water supply for non-agricultural projects within its service area.[248] The Imperial Integrated Regional Water Management Plan ("IRWMP"), adopted by IID's Board of

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[243] Imperial County, Agreement for Conditional Use Permit #06-0006, ORCAL/Heber Field Company, April 25, 2006, Document 2006-020097, pdf 14 (Exhibit 13).

[244] Doering and Jordan, Heber KGRA, pdf 11-12.

[245] Ibid.

[246] Jeff Berndt, The Coming Water Crisis in America, last updated October 17, 2013; http://hubpages.com/hub/The-Coming-Water-Crisis-in-America.

[247] National Geographic, Daily News, Feds Slash Colorado River Release to Historic Lows, August 16, 2013; http://news.nationalgeographic.com/news/2013/08/130816-colorado-river-drought-lake-powell-mead-water-scarcity/.

[248] IID, IID's Interim Water Supply Policy for Non-Agricultural Projects, adopted September 29, 2009, fee schedule revised 2015, p. 1; http://www.iid.com/home/showdocument?id=9599.

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Directors in December 2012, finds that "[r]enewable energy projects that result in intensification of water use could have a negative effect on agricultural water supplies unless mitigated" and requires that "to the extent that water is proposed for power plant cooling, the developer shall demonstrate that alternative water supply sources and alternative cooling technologies are unavailable, environmentally undesirable, or economically unsound."[249] The IS contains no such demonstration and fails to even disclose that the Project will increase water use from the IID relative to baseline conditions. Thus, the IS fails as an informational document under CEQA.

Further, the Water Quality Control Plan (Basin Plan) for the Colorado River Basin Region[250] states that fresh inland waters should only be used for power plant cooling if other sources or other methods of cooling would be environmentally undesirable or economically unsound. This policy requires that power plant cooling water should come from, in order of priority: (1) wastewater being discharged to the ocean; (2) ocean water; (3) brackish water from natural sources or irrigation return flow; (4) inland waste waters of low total dissolved solids; (5) other inland waters.[251] The IS is silent on this policy and its application to the Project's water use, thus failing as an informational document under CEQA. Irrigation return flows, for example, would be available from IID.

Thus, the Project's increase in the generation capacity of the Heber units, relative to baseline generation, would increase the facility's water consumption by a factor of 1.6. Any increase in water use in this area is significant as the water supply must be imported from distant and overtapped sources and violates the Basin Plan and underlying Principle #1 of the "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling." This increase could be mitigated by replacing one or more of the facility's wet cooling towers with a dry/hybrid cooling system and by treating the cooling water.

This is consistent with best management practices recommended by the CEC for desert renewable energy projects, which only approves the use of fresh water for cooling by power plants where alternative water supply sources and alternative cooling

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[249] Imperial Water Forum, Imperial Region Integrated Regional Water Management Plan, October 2012, Chapter 8, Reduce Water Demand—Increase Water Use Efficiency, p. 8-22; http://imperialirwmp.org/2013%20Updates/finalirwmp.html.

[250] Water Quality Control Plan for the Colorado River Basin Region, January 8, 2019; https://www.waterboards.ca.gov/coloradoriver/water_issues/programs/basin_planning/docs/bp032014/r7_bp2019fullbp.pdf.

[251] Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling, p. 4, Principle #1. Adopted June 19, 1975, Resolution No. 75-58; https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1975/rs75_058.pdf.

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technologies are shown to be "environmentally undesirable" or "economically unsound."[252] Specifically, the CEC recommends the following for geothermal power plants:[253]

> Consistent with the Board policy and the Warren-Alquist Act, the Energy Commission will approve the use of fresh water for cooling purposes by power plants which it licenses only where alternative water supply sources and alternative cooling technologies are shown to be 'environmentally undesirable' or 'economically unsound.' Additionally, as a way to reduce the use of fresh water and to avoid discharges in keeping with the Board's policy, the Energy Commission will require zero-liquid discharge technologies unless such technologies are shown to be 'environmentally undesirable' or 'economically unsound.' The Energy Commission interprets 'environmentally undesirable' to mean the same as having a 'significant adverse environmental impact' and 'economically unsound' to mean the same as 'economically or otherwise infeasible.'"

These methods are in use at other Ormat facilities as well as elsewhere and thus are clearly feasible for this Project.

10.1. Dry or Wet/Dry Hybrid Cooling

Dry cooling, also called air cooling, is technologically feasible as demonstrated by some of Ormat's other operational geothermal binary OEC plants in the United States and all over the world. These include, for example, the 86-MW Steamboat Hills Complex and the 30-MW McGinness plant in Nevada; the 0.2-MW CRADA in Wyoming; the 20-MW Amatitlan and 24-MW Zunil plants in Guatemala; the 7.4-MW Dora I and 17-MW IREM plants in Turkey; the 88-MW Olkaria III Complex in Kenya; and the 26.6-MW TeHuka Complex in New Zealand.[254] In addition, all of Ormat's recent binary OEC geothermal plants in the Casa Diablo and Mammoth Pacific complex in northern California are air-cooled.[255]

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[252] IID, October 2012, pdf 21; CEC et al., Best Management Practices and Guidance Manual: Desert Renewable Energy Projects, pdf 76; https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.432.1193&rep=rep1&type=pdf.

[253] CEC et al., pdf 76.

[254] *See* Ormat, Global Projects; https://www.ormat.com/en/projects/all/main/.

[255] *See*, for example, United States Department of the Interior, Bureau of Land Management, United States Department of Agriculture Forest Service, and Great Basin Unified Air Pollution Control District, Casa Diablo IV Geothermal Development Project, Public Draft Joint Environmental Impact Statement and Environmental Impact Report, DOI Control #: DES 12-21, Publication Index #: BLM/CA-ES-2013-002+1793, SCH No. 2011041008, November 2012; https://openei.org/wiki/DOI-BLM-CA-ES-2013-002%2B1793-EIS and Charlene Wardlow, Ormat, Update on Mammoth Pacific, LP Operations, CGEC Summit—Mammoth Mountain, May 26, 2011; https://cgec.ucdavis.edu/wp-content/uploads/lessonslearned-ormat-2011.pdf.

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Ormat, for example, explains that its proprietary technology is capable of using air cooling processes: [256]

> Ormat's geothermal power plants implement either air or water cooling, depending on the availability and cost of suitable water resources. Air cooling systems feature low operating costs and an exceptionally low environmental profile. They operate in a closed loop, do not require chemical additives and involve no waste disposal. In addition, air cooled power plants do not produce a visible plume and have a lower impact on the landscape.

Clearly, there is no question as to the technological feasibility of dry cooling for geothermal binary OEC plants.

Further, dry or wet/dry hybrid cooling systems have been built and are in operation all over the world in all, including the most extreme, climates. For example, the Shell Pearl gas-to-liquids integrated gasification combined-cycle project in Qatar, one of the most extreme climates with respect to temperature and low water supply, relies on dry cooling for its cooling demands.[257]

Not only would dry cooling eliminate the plant's water demand, it would also eliminate particulate matter emissions in an airshed that is designated as nonattainment for PM10.[258]

With respect to cost-effectiveness and plant performance for geothermal and other power plants in the Imperial Valley, a study conducted for the IID in 2009 summarizes:

> The design change from wet to dry cooling is still undeniably more expensive, but in some cases is becoming more of a viable alternative. Using the Binary geothermal plant model previously discussed, the per-megawatt-hour cost of wet cooling is $69, while dry cooling is $81 per MWh, and hybrid cooling is somewhat less expensive at $76 per MWh. This premium of approximately 17% for dry cooling would likely be a serious drawback from an economic standpoint. Additionally, dry-cooled plants are also less efficient than wet-cooled plants in desert areas like Imperial Valley. Dry cooling technologies are capable of handling the entire cooling load up to an ambient temperature of 85-90°F. However, beyond that point the air temperature becomes too high for effective cooling and the plant performance suffers dramatically as a result. For

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[256] Ormat Technologies, Inc., Air and Water Cooling; https://www.energy-xprt.com/services/ormat-added-values-187202.

[257] Shell, Pearl GTL; http://www.shell.com/global/aboutshell/major-projects-2/pearl.html; *see* Google view of facility: Linde—Gama Construction site (SPX Cooling Tech) ACC Plant; http://wikimapia.org/7535982/Linde-Gama-Construction-site-SPX-Cooling-Tech-ACC-Plant.

[258] IS, pdf 19.

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example, on an 110°F day, a dry cooled plant will have an energy production penalty of approximately 5-10% as compared to a wet cooled plant. Therefore, the plant will be producing less power during peak demand periods of the day which is when it is needed most. *However, as the costs of water supplies, water-related environmental studies, and compliance with water regulations continue to rise, some are still finding dry cooling an increasingly attractive option. The performance losses and increase in capital costs will also become less of an issue as electricity prices rise.…*

…

*The recommendation that can be derived from this general overview is that consideration should be given to alternative cooling technologies for new power plant design, although it would initially appear undesirable from a production and economic standpoin*t. For larger plants (greater than 50 MW), the inclusion of dry cooling in the design study is already required, and this may be required for smaller plants in the future. As water costs and related impacts continue to increase, the alternative cooling technologies will become more feasible.[259]

10.2. Cooling Water Makeup Water Pretreatment

The Project could also reduce its water demand by pretreating the cooling tower makeup water, as recognized by the IID's IRWMP:

> Cooling water demands are in part based on water quality. Pre-treatment, whether on-site or off-site of the power plant or by a public agency or the power plant developer, would allow for more cooling cycles as compared to use of water of lesser quality.[260]

Pretreatment of water is technologically feasible, commercially available, and used at other power plants[261] and should be evaluated for the Project's cooling

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[259] Doering and Jordan 2009, pp. 17-18.

[260] IRWMP, Chapter 8. Reduce Water Demand—Increase Water Use Efficiency, 8.2.3.2 Treat Cooling Water to Improve Quality, October 2012, p. 8-31; https://imperialirwmp.org/wp-content/uploads/2013/07/CH08-Reduce-Water-Demand-20121010_Proof2.pdf.

[261] *See*, for example, Siemens, Cooling Tower Water Treatment Systems; https://web.archive.org/web/20130425134436/http://www.water.siemens.com/en/applications/industrial_process_water/cooling_tower_makeup/Pages/default.aspx. ("Cooling Towers with electric generators installed at power generation facilities require a consistent, reliable source of water that is cost-effective and sustainable. In many cases, cooling tower water must be treated to soften, remove solids, and deal with organics. With properly treated water, the potential for scaling in the cooling tower is significantly reduced which also lowers cooling circuit cleaning requirements, extends the life of the cooling equipment and reduces the cooling tower blowdown flow to the environment.")

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demands. Potential options include, for example, reverse osmosis treatment of the cooling water blowdown to increase the cycles of concentration and reduce overall water consumption and collection and treatment of relatively pure condensed water from air handlers.[262]

10.3. Best Management Practices

The IID's IRWMP sets forth the following best management practices for geothermal/renewable water sources, cooling alternatives, and other uses:

- *State policy supports the use of dry or hybrid cooling to conserve water in desert environments*.
- Dry cooling technology has limits and is not presently cost-effective in the Imperial Region.
- *Hybrid cooling should be encouraged if Colorado River water is used in order to demonstrate reasonable beneficial use of Colorado River entitlements*.
- The feasibility of changing wet cooled plants to dry or hybrid cooled plants may be cost prohibitive for the remaining life of the plant.
- A critical factor for conserving water used for cooling and other uses is the water quality. *The higher the incoming water quality, the more cooling cycles can occur*, resulting in both less use and reduced wastewater discharge.
- Use of recycled municipal water or desalination of brackish water for cooling and other uses in lieu of Colorado River water would mitigate for potential impacts to current agricultural water users, and would demonstrate reasonable beneficial use of Colorado River entitlements.
- Storage of Colorado River water in a groundwater bank would provide a supply for renewable/geothermal energy water use and could serve to mitigate or eliminate impacts to existing agricultural water users.
- *Use of recycled municipal water or desalination of brackish water for cooling purposes could provide multiple regional benefits*. Project, program, and policy recommendations should be developed through the Imperial IRWMP process.
- Encouraging use of recycled municipal water for cooling and other uses could support local communities by providing a source of revenue to upgrade treatment plants so as to improve water quality.

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[262] DoE, Energy Efficiency and Renewable Energy, Federal Energy Management Program, Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency, February 2011; https://www.energy.gov/sites/prod/files/2013/10/f3/waterfs_coolingtowers.pdf.

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- *Recycled municipal water or desalinated brackish water maybe cost-effective* when compared to the price of water from voluntary fallowing, and would serve to mitigate third party impacts to agriculture.
- Industrial customers shall be required by IID to follow appropriate water use efficiency BMPs, including but not limited to those established by the California Urban Water Conservation Council and California Energy Commission, as well as other water use efficiency standards, adopted by the District or local government agencies. (Interim Water Supply Policy (IWSP No. 11). IID may prescribe additional or different Best management practices for certain categories of Municipal and Industrial Water Users (IWSP No. 12).[263]

These best management practices are equally applicable to the Project and should be required.

11. THE PROJECT MAY NEED A CEC LICENSE

The subject geothermal facility as described in its Application for an Authority to Construct permit consists of six ORMAT Energy Converters (OECs) at Heber 2 (36 MW) that are operationally interconnected to each other as well as to Goulds 2 (12 MW) and Heber South (12 MW) for a total generating capacity of 60 MW.[264] Other information discussed in Comment 1 indicates that the Heber 2 Complex has a generating capacity of 81-82 MW. The Project will restore generating capacity of the Heber 2 Complex to its original capacity of 92 MW, not 33 MW as asserted in the IS.

The CEC licenses all thermal power plants over 50 MW in California.[265] The CEC's listing of licensed facilities does not include the Heber Complex.[266] The discussion in Comment 1 indicates that the Heber Complex currently exceeds 50 MW. The Project will extend the life of the Heber Complex by 30 years, from 2019 to 2049.[267] Thus, the Project requires a license from the CEC.

The CEC may delegate siting authority over geothermal power plants and related facilities to county governments that have adopted geothermal elements into

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[263] IRWMP, Chapter 8, pp. 8-22 and 8-23.

[264] Air Sciences Inc., Heber 2 Application for Authority to Construct, November 2019, Section 1.0, pdf 9 (Exhibit 10).

[265] U.S. Department of Energy, California State Plant Commissioning Process—Application for Certification (7-CA-a); https://openei.org/wiki/RAPID/Roadmap/7-CA-a.

[266] California Energy Commission, Alphabetical List of Power Plant Projects; https://ww2.energy.ca.gov/sitingcases/alphabetical_cms.html.

[267] IS, pdf 9.

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their general plan.[268] My research identified a geothermal element in Imperial County's General Plan.[269] However, this element clearly states that all energy facilities are required to undergo review by the CEC as part of an Application for Certification. "The CEC and County of Imperial coordinate the permitting and siting of power plants and any necessary transmission lines."[270] Two tests are required to establish that the Heber Complex is a single facility.

First, the net generating capacity must equal or exceed 50 MW using the calculation method in California Code of Regulations, Title 20, Section 203. The generating capacity of an electric generating facility is found by subtracting the minimum auxiliary load from the maximum gross rating of the plant's turbine generators. The IS and the record before the County does not contain the information required to make this determination. Thus, the IS fails as an informational document under CEQA.

The 2018 FERC Form 19-K[271] and 2019 FERC Form 10-K[272] reports indicate that the Heber Complex has a generating capacity, reported as gross net of auxiliary loads of 81 MW, which exceeds the CEC jurisdictional 50 MW limit. The generating capacity reported as gross of net auxiliary loads is the metric required under CCR Title 20, Section 203 to determine if the facility is subject to CEC licensing. Thus, the Heber Complex meets this requirement.

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[268] U.S. Department of Energy, California State Plant Commissioning Process—Application for Certification (7-CA-a).

[269] Imperial County Planning and Development Services Department, Geothermal/Alternative Energy and Transmission: Element, County of Imperial General Plan, October 17, 2006, p. 29; http://www.icpds.com/CMS/Media/Geothermal-TransmissionElement-(2006).pdf.

[270] Ibid.

[271] SEC, Form 10-K, Annual Report for the Fiscal Year Ended December 31, 2018, p.13, footnote 2, p. 14 ("References to generating capacity generally refer to the gross generating capacity less auxiliary power in the case of all of our existing power plants, except the Zunil power plant. We determine the generating capacity figures in these power plants by taking into account resource and power plant capabilities…."); https://www.sec.gov/Archives/edgar/data/1296445/000143774919003760/ora20181231_10k.htm.

[272] SEC, Form 10-K, December 31, 2019, pp. 11-12, footnote 2 ("References to generating capacity generally refer to the gross generating capacity less auxiliary power. We determine the generating capacity of these power plants by taking into account resource and power plant capabilities….").

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Second, one must establish the connectivity between the components of the Heber 2 Complex, which includes Gould 2 and Heber South.[273] This requires the consideration of four factors:

- sited on contiguous parcels,
- designed, installed, and operated by the same organization,
- have energy and environmental impacts greater than a jurisdictional 50 MW facility, and
- share utility services for water, electrical interconnection, natural gas lines, and/or road access.

All four of these tests are met by the Project.

First, the proposed development would occur entirely on a single 39.99-acre parcel, which also includes the other Heber Complex geothermal facilities, the Goulds 2 and Heber South projects.[274] The proposed Project site is within the existing Heber 2 power plant area. All proposed facilities would be located within the existing fence line and permit area.[275] Finally, the Project shares the same road access as the entire Heber 2 Complex on Dogwood Road,[276] the same fire and emergency access roads,[277] and shared pipelines.[278]

Second, Ormat will design, install, and operate the proposed modifications to the Heber Complex over the 30-year extension, from 2019 to 2049, as noted in numerous SEC filings and annual reported cited elsewhere in these comments.[279]

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[273] IS, pdf 9. Charlene Wardlow, Ormat's Geothermal Projects in Imperial County, Imperial Valley Renewable Energy Summit, March 11, 2016, Heber Facility Summary, p. 14; http://ivres.ivedc.com/media/managed/031116_Ormat_presentation_at_IVRES.pdf.

[274] IS, p. 10, 23 ("the proposed facilities would be located within the existing Heber 2 Complex site."), 39 ("The proposed development would occur entirely on the 39.99 Assessor's Parcel Number (APN) 054-250-031. This parcel also includes geothermal facilities for the Goulds 2 and Heber South projects.").

[275] IS, p. 39.

[276] IS, p. 8 (project location and location of entire Heber 2 Complex is 855 Dogwood Road, Heber, CA 92249), p. 30 ("Lone site access is provided via Dogwood Road.").

[277] IS, p. 24 (discussing fire department access roads and gates at Heber 2 Complex site); p. 31 (all proposed facilities would be constructed within the existing Heber 2 Complex site and not introduce any transportation hazards, design features, or incompatible uses with surrounding roadways); p. 33 ("The existing Heber 2 Emergency Response Plan addresses project construction and operations. The proposed work is within the existing footprint of ongoing geothermal activities in the Heber 2 plant site.").

[278] IS, p. 8 (Project will add additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex).

[279] See, for example, https://www.ormat.com/en/projects/all/main/?Country=USA&Seg=0&Tech=6 and the Ormat May 2020 10-Q report cited in Comment 2.1, which states: "Heber Complex (California).

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Third, the Project proposes to extend the life of the entire Heber 2 complex by an additional 30 years.[280] As demonstrated in Comments 3 to 10, the environmental impacts of the operation of the entire Heber 2 Complex, a 92 MW facility,[281] will be significant over the 30 year extension, requiring mitigation.

Fourth, the Heber Complex geothermal facilities all rely on the same support facilities: cooling towers, vapor recovery unit, emergency generator, fire pumps, and emergency pump.[282] Thus, the proposed 30-year extension of the lifetime of the Heber 2 Complex requires a license from the CEC.

12. EXTENDED LIFETIME

The Project would extend the lifetime of the entire Heber 2 Complex for 30 years, from 2019 to 2049. The impacts beyond 2019 were not considered in the IS. These include GHG emission increases. Thus, the IS fails as an informational document under CEQA.

We are currently in the process of repowering the Heber 1 and Heber 2 power plants. We are planning to replace steam turbine and old OEC units with new advanced technology equipment that will add a net capacity of 11 MW. Following these enhancements, we expect the capacity of the complex to reach 92 MW. Permitting, engineering and procurement are ongoing as well as manufacturing and site construction. We expect commercial operation in the second half of 2021."

[280] IS, p. 8.

[281] The current capacity of the complex is 81 MW with a planned expansion to add 11 MW; https://www.ormat.com/en/projects/all/main/?Country=USA&Seg=0&Tech=6.

[282] ATC Application, p. 5, pdf 13, Table 1. Existing and Proposed Equipment at Heber 2, Heber South, and Goulds 2.

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Dr. Fox has over 40 years of experience in the field of environmental engineering, including air pollution control (BACT, BART, MACT, LAER, RACT), greenhouse gas emissions and control, cost effectiveness analyses, water quality and water supply investigations, hydrology, hazardous waste investigations, environmental permitting, nuisance investigations (odor, noise), environmental impact reports, CEQA/NEPA documentation, risk assessments, and litigation support.

EDUCATION

Ph.D. Environmental/Civil Engineering, University of California, Berkeley, 1980.
M.S. Environmental/Civil Engineering, University of California, Berkeley, 1975.
B.S. Physics (with high honors), University of Florida, Gainesville, 1971.

REGISTRATION

Registered Professional Engineer: Arizona (2001-2014: #36701; retired), California (2002-present; CH 6058), Florida (2001-2016; #57886; retired), Georgia (2002-2014; #PE027643; retired), Washington (2002-2014; #38692; retired), Wisconsin (2005-2014; #37595-006; retired)
Board Certified Environmental Engineer, American Academy of Environmental Engineers, Certified in Air Pollution Control (DEE #01-20014), 2002-2014; retired)
Qualified Environmental Professional (QEP), Institute of Professional Environmental Practice (QEP #02-010007, 2001-2015: retired).

PROFESSIONAL HISTORY

Environmental Management, Principal, 1981-present
Lawrence Berkeley National Laboratory, Principal Investigator, 1977-1981
University of California, Berkeley, Program Manager, 1976-1977
Bechtel, Inc., Engineer, 1971-1976, 1964-1966

PROFESSIONAL AFFILIATIONS

American Chemical Society (1981-2010)
Phi Beta Kappa (1970-present)
Sigma Pi Sigma (1970-present)

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Who's Who Environmental Registry, PH Publishing, Fort Collins, CO, 1992.
Who's Who in the World, Marquis Who's Who, Inc., Chicago, IL, 11th Ed., p. 371, 1993-present.
Who's Who of American Women, Marquis Who's Who, Inc., Chicago, IL, 13th Ed., p. 264, 1984-present.
Who's Who in Science and Engineering, Marquis Who's Who, Inc., New Providence, NJ, 5th Ed., p. 414, 1999-present.
Who's Who in America, Marquis Who's Who, Inc., 59th Ed., 2005.
Guide to Specialists on Toxic Substances, World Environment Center, New York, NY, p. 80, 1980.
National Research Council Committee on Irrigation-Induced Water Quality Problems (Selenium), Subcommittee on Quality Control/Quality Assurance (1985-1990).
National Research Council Committee on Surface Mining and Reclamation, Subcommittee on Oil Shale (1978-80)

REPRESENTATIVE EXPERIENCE

Performed environmental and engineering investigations, as outlined below, for a wide range of industrial and commercial facilities including: petroleum refineries and upgrades thereto; reformulated fuels projects; refinery upgrades to process heavy sour crudes, including tar sands and light sweet crudes from the Eagle Ford and Bakken Formations; petroleum, gasoline and ethanol distribution terminals; coal, coke, and ore/mineral export terminals; LNG export, import, and storage terminals; crude-by-rail projects; shale oil plants; crude oil/condensate marine and rail terminals; coal gasification and liquefaction plants; oil and gas production, including conventional, thermally enhanced, hydraulic fracking, and acid stimulation techniques; underground storage tanks; pipelines; compressor stations; gasoline stations; landfills; railyards; hazardous waste treatment facilities; nuclear, hydroelectric, geothermal, wood, biomass, waste, tire-derived fuel, gas, oil, coke and coal-fired power plants; wind farms; solar energy facilities; battery storage facilities; transmission lines; airports; hydrogen plants; petroleum coke calcining plants; coke plants; activated carbon manufacturing facilities; asphalt plants; cement plants; incinerators; flares; manufacturing facilities (e.g., semiconductors, electronic assembly, aerospace components, printed circuit boards, amusement park rides); lanthanide processing plants; ammonia plants; nitric acid plants; urea plants; food processing plants; wineries; almond hulling facilities; composting facilities; grain processing facilities; grain elevators; ethanol production facilities; soy bean oil extraction plants; biodiesel plants; paint formulation plants; wastewater treatment plants; marine terminals and ports; gas processing plants; steel mills; iron nugget production facilities; pig iron plant, based on blast furnace technology; direct reduced iron plant; acid regeneration facilities; railcar refinishing facility; battery manufacturing plants; pesticide manufacturing and repackaging facilities; pulp

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and paper mills; olefin plants; methanol plants; ethylene crackers; alumina plants, desalination plants; battery storage facilities; data centers; covered lagoon anaerobic digesters with biogas generators and upgrading equipment to produce renewable natural gas and electricity; selective catalytic reduction (SCR) systems; selective noncatalytic reduction (SNCR) systems; halogen acid furnaces; contaminated property redevelopment projects (e.g., Mission Bay, Southern Pacific Railyards, Moscone Center expansion, San Diego Padres Ballpark); residential developments; commercial office parks, campuses, and shopping centers; server farms; transportation plans; and a wide range of mines including sand and gravel, hard rock, limestone, nacholite, coal, molybdenum, gold, zinc, and oil shale.

EXPERT WITNESS/LITIGATION SUPPORT

- For plaintiffs-intervenors (Sierra Club), in civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications at Rush Island Units 1 and 2 and Labadie Energy Center, assist counsel in evaluating best available control technology (BACT) to reduce SO2 emissions, including wet and dry scrubbing, sorbent injection, and offsets. Case settled. *U.S. and Sierra Club vs. Ameren Missouri*, Case No. 4-11 CV 77 RWS, U.S. District Court, Eastern District of Missouri, Eastern Division, September 30, 2019.
- For the California Attorney General, assist in determining compliance with probation terms in the matter of People v. Chevron USA.
- For plaintiffs, assist in developing Petitioners' proof brief for National Parks Conservation Association et al v. U.S. EPA, Petition for Review of Final Administrative Action of the U.S. EPA, In the U.S. Court of Appeals for the Third Circuit, Docket No. 14-3147.
- For plaintiffs, expert witness in civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1997-2000) at the Cemex cement plant in Lyons, Colorado. Reviewed produced documents, prepared expert and rebuttal reports on PSD applicability based on NOx emission calculations for a collection of changes considered both individually and collectively. Deposed August 2011. *United States v. Cemex, Inc.*, In U.S. District Court for the District of Colorado (Civil Action No. 09-cv-00019-MSK-MEH). Case settled June 13, 2013.
- For plaintiffs, in civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1988 – 2000) at James De Young Units 3, 4, and 5. Reviewed produced documents, analyzed CEMS and EIA data, and prepared netting and BACT analyses for NOx, SO2, and PM10 (PSD case). Expert report February 24, 2010 and affidavit February 20, 2010. *Sierra Club v. City of Holland, et al.*, U.S. District Court, Western District of Michigan (Civil Action 1:08-cv-1183). Case settled. Consent Decree 1/19/14.

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- For plaintiffs, in civil action alleging failure to obtain MACT permit, expert on potential to emit hydrogen chloride (HCl) from a new coal-fired boiler. Reviewed record, estimated HCl emissions, wrote expert report June 2010 and March 2013 (Cost to Install a Scrubber at the Lamar Repowering Project Pursuant to Case-by-Case MACT), deposed August 2010 and March 2013. *Wildearth Guardian et al. v. Lamar Utilities Board,* Civil Action No. 09-cv-02974, U.S. District Court, District of Colorado. Case settled August 2013.
- For plaintiffs, expert witness on permitting, emission calculations, and wastewater treatment for coal-to-gasoline plant. Reviewed produced documents. Assisted in preparation of comments on draft minor source permit. Wrote two affidavits on key issues in case. Presented direct and rebuttal testimony 10/27 - 10/28/10 on permit enforceability and failure to properly calculate potential to emit, including underestimate of flaring emissions and omission of VOC and CO emissions from wastewater treatment, cooling tower, tank roof landings, and malfunctions. *Sierra Club, Ohio Valley Environmental Coalition, Coal River Mountain Watch, West Virginia Highlands Conservancy v. John Benedict, Director, Division of Air Quality, West Virginia Department of Environmental Protection and TransGas Development System, LLC*, Appeal No. 10-01-AQB. Virginia Air Quality Board remanded the permit on March 28, 2011 ordering reconsideration of potential to emit calculations, including: (1) support for assumed flare efficiency; (2) inclusion of startup, shutdown and malfunction emissions; and (3) inclusion of wastewater treatment emissions in potential to emit calculations.
- For plaintiffs, expert on BACT emission limits for gas-fired combined cycle power plant. Prepared declaration in support of CBE's Opposition to the United States' Motion for Entry of Proposed Amended Consent Decree. Assisted in settlement discussions. *U.S. EPA, Plaintiff, Communities for a Better Environment, Intervenor Plaintiff, v. Pacific Gas & Electric Company, et al.*, U.S. District Court, Northern District of California, San Francisco Division, Case No. C-09-4503 SI.
- Technical expert in confidential settlement discussions with large coal-fired utility on BACT control technology and emission limits for NOx, SO2, PM, PM2.5, and CO for new natural gas fired combined cycle and simple cycle turbines with oil backup. (July 2010). Case settled.
- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1998-99) at Gallagher Units 1 and 3. Reviewed produced documents, prepared expert and rebuttal reports on historic and current-day BACT for SO2, control costs, and excess emissions of SO2. Deposed 11/18/09. *United States et al. v. Cinergy, et al.*, In U.S. District Court for the Southern District of Indiana, Indianapolis Division, Civil Action No. IP99-1693 C-M/S. Settled 12/22/09.

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- For plaintiffs, expert witness on MACT, BACT for NOx, and enforceability in an administrative appeal of draft state air permit issued for four 300-MW pet-coke-fired CFBs. Reviewed produced documents and prepared prefiled testimony. Deposed 10/8/09 and 11/9/09. Testified 11/10/09. *Application of Las Brisas Energy Center, LLC for State Air Quality Permit*; before the State Office of Administrative Hearings, Texas. Permit remanded 3/29/10 as LBEC failed to meet burden of proof on a number of issues including MACT. Texas Court of Appeals dismissed an appeal to reinstate the permit. The Texas Commission on Environmental Quality and Las Brisas Energy Center, LLC sought to overturn the Court of Appeals decision but moved to have their appeal dismissed in August 2013.
- For defense, expert witness in unlawful detainer case involving a gasoline station, minimart, and residential property with contamination from leaking underground storage tanks. Reviewed agency files and inspected site. Presented expert testimony on July 6, 2009, on causes of, nature and extent of subsurface contamination. *A. Singh v. S. Assaedi,* in Contra Costa County Superior Court, CA. Settled August 2009.
- For plaintiffs, expert witness on netting and enforceability for refinery being upgraded to process tar sands crude. Reviewed produced documents. Prepared expert and rebuttal reports addressing use of emission factors for baseline, omitted sources including coker, flares, tank landings and cleaning, and enforceability. Deposed. *In the Matter of Objection to the Issuance of Significant Source Modification Permit No. 089-25484-00453 to BP Products North America Inc., Whiting Business Unit, Save the Dunes Council, Inc., Sierra Club., Inc., Hoosier Environmental Council et al., Petitioners, B. P. Products North American, Respondents/Permittee,* before the Indiana Office of Environmental Adjudication. Case settled.
- For plaintiffs, expert witness on BACT, MACT, and enforceability in appeal of Title V permit issued to 600 MW coal-fired power plant burning Powder River Basin coal. Prepared technical comments on draft air permit. Reviewed record on appeal, drafted BACT, MACT, and enforceability pre-filed testimony. Drafted MACT and enforceability pre-filed rebuttal testimony. Deposed March 24, 2009. Testified June 10, 2009. *In Re: Southwestern Electric Power Company*, Arkansas Pollution Control and Ecology Commission, Consolidated Docket No. 08-006-P. Recommended Decision issued December 9, 2009 upholding issued permit. Commission adopted Recommended Decision January 22, 2010.
- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1989-1992) at Wabash Units 2, 3 and 5. Reviewed produced documents, prepared expert and rebuttal report on historic and current-day BACT for NOx and SO2, control costs, and excess emissions of NOx, SO2, and mercury. Deposed 10/21/08. *United States et al. v.*

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Cinergy, et al., In U.S. District Court for the Southern District of Indiana, Indianapolis Division, Civil Action No. IP99-1693 C-M/S. Testified 2/3/09. Memorandum Opinion & Order 5-29-09 requiring shutdown of Wabash River Units 2, 3, 5 by September 30, 2009, run at baseline until shutdown, and permanently surrender SO2 emission allowances.

- For plaintiffs, expert witness in liability phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for three historic modifications (1997-2001) at two portland cement plants involving three cement kilns. Reviewed produced documents, analyzed CEMS data covering subject period, prepared netting analysis for NOx, SO_2 and CO, and prepared expert and rebuttal reports. *United States v. Cemex California Cement,* In U.S. District Court for the Central District of California, Eastern Division, Case No. ED CV 07-00223-GW (JCRx). Settled 1/15/09.
- For intervenors Clean Wisconsin and Citizens Utility Board, prepared data requests, reviewed discovery and expert report. Prepared prefiled direct, rebuttal and surrebuttal testimony on cost to extend life of existing Oak Creek Units 5-8 and cost to address future regulatory requirements to determine whether to control or shutdown one or more of the units. Oral testimony 2/5/08. Application for a Certificate of Authority to Install Wet Flue Gas Desulfurization and Selective Catalytic Reduction Facilities and Associated Equipment for Control of Sulfur Dioxide and Nitrogen Oxide Emissions at Oak Creek Power Plant Units 5, 6, 7 and 8, WPSC Docket No. 6630-CE-299.
- For plaintiffs, expert witness on alternatives analysis and BACT for NOx, SO2, total PM10, and sulfuric acid mist in appeal of PSD permit issued to 1200 MW coal fired power plant burning Powder River Basin and/or Central Appalachian coal (Longleaf). Assisted in drafting technical comments on NOx on draft permit. Prepared expert disclosure. Presented 8+ days of direct and rebuttal expert testimony. Attended all 21 days of evidentiary hearing from 9/5/07 – 10/30/07 assisting in all aspects of hearing. *Friends of the Chatahooche and Sierra Club v. Dr. Carol Couch, Director, Environmental Protection Division of Natural Resources Department, Respondent, and Longleaf Energy Associates, Intervener*. ALJ Final Decision 1/11/08 denying petition. ALJ Order vacated & remanded for further proceedings, Fulton County Superior Court, 6/30/08. Court of Appeals of GA remanded the case with directions that the ALJ's final decision be vacated to consider the evidence under the correct standard of review, July 9, 2009. The ALJ issued an opinion April 2, 2010 in favor of the applicant. Final permit issued April 2010.
- For plaintiffs, expert witness on diesel exhaust in inverse condemnation case in which Port expanded maritime operations into residential neighborhoods, subjecting plaintiffs to noise, light, and diesel fumes. Measured real-time diesel particulate concentrations from marine vessels and tug boats on plaintiffs' property. Reviewed documents, depositions, DVDs, and photographs provided by counsel. Deposed. Testified October 24, 2006. *Ann Chargin, Richard Hackett, Carolyn Hackett, et al. v. Stockton Port District*, Superior Court

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of California, County of San Joaquin, Stockton Branch, No. CV021015. Judge ruled for plaintiffs.

- For plaintiffs, expert witness on NOx emissions and BACT in case alleging failure to obtain necessary permits and install controls on gas-fired combined-cycle turbines. Prepared and reviewed (applicant analyses) of NOx emissions, BACT analyses (water injection, SCR, ultra low NOx burners), and cost-effectiveness analyses based on site visit, plant operating records, stack tests, CEMS data, and turbine and catalyst vendor design information. Participated in negotiations to scope out consent order. *United States v. Nevada Power.* Case settled June 2007, resulting in installation of dry low NOx burners (5 ppm NOx averaged over 1 hr) on four units and a separate solar array at a local business.
- For plaintiffs, expert witness in appeal of PSD permit issued to 850 MW coal fired boiler burning Powder River Basin coal (Iatan Unit 2) on BACT for particulate matter, sulfuric acid mist and opacity and emission calculations for alleged historic violations of PSD. Assisted in drafting technical comments, petition for review, discovery requests, and responses to discovery requests. Reviewed produced documents. Prepared expert report on BACT for particulate matter. Assisted with expert depositions. Deposed February 7, 8, 27, and 28, 2007. *In Re PSD Construction Permit Issued to Great Plains Energy, Kansas City Power & Light – Iatan Generating Station, Sierra Club v. Missouri Department of Natural Resources, Great Plains Energy, and Kansas City Power & Light.* Case settled March 27, 2007, providing offsets for over 6 million ton/yr of CO2 and lower NOx and SO_2 emission limits.
- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications of coal-fired boilers and associated equipment. Reviewed produced documents, prepared expert report on cost to retrofit 24 coal-fired power plants with scrubbers designed to remove 99% of the sulfur dioxide from flue gases. Prepared supplemental and expert report on cost estimates and BACT for SO2 for these 24 complaint units. Deposed 1/30/07 and 3/14/07. *United States and State of New York et al. v. American Electric Power*, In U.S. District Court for the Southern District of Ohio, Eastern Division, Consolidated Civil Action Nos. C2-99-1182 and C2-99-1250. Settlement announced 10/9/07.
- For plaintiffs, expert witness on BACT, enforceability, and alternatives analysis in appeal of PSD permit issued for a 270-MW pulverized coal fired boiler burning Powder River Basin coal (City Utilities Springfield Unit 2). Reviewed permitting file and assisted counsel draft petition and prepare and respond to interrogatories and document requests. Reviewed interrogatory responses and produced documents. Assisted with expert depositions. Deposed August 2005. Evidentiary hearings October 2005. *In the Matter of Linda Chipperfield and Sierra Club v. Missouri Department of Natural Resources.* Missouri Supreme Court denied review of adverse lower court rulings August 2007.

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- For plaintiffs, expert witness in civil action relating to plume touchdowns at AEP's Gavin coal-fired power plant. Assisted counsel draft interrogatories and document requests. Reviewed responses to interrogatories and produced documents. Prepared expert report ''Releases of Sulfuric Acid Mist from the Gavin Power Station.'' The report evaluates sulfuric acid mist releases to determine if AEP complied with the requirements of CERCLA Section 103(a) and EPCRA Section 304. This report also discusses the formation, chemistry, release characteristics, and abatement of sulfuric acid mist in support of the claim that these releases present an imminent and substantial endangerment to public health under Section 7002(a)(1)(B) of the Resource Conservation and Recovery Act (''RCRA''). *Citizens Against Pollution v. Ohio Power Company*, In the U.S. District Court for the Southern District of Ohio, Eastern Division, Civil Action No. 2-04-cv-371. Case settled 12-8-06.

- For petitioners, expert witness in contested case hearing on BACT, enforceability, and emission estimates for an air permit issued to a 500-MW supercritical Power River Basin coal-fired boiler (Weston Unit 4). Assisted counsel prepare comments on draft air permit and respond to and draft discovery. Reviewed produced file, deposed (7/05), and prepared expert report on BACT and enforceability. Evidentiary hearings September 2005. *In the Matter of an Air Pollution Control Construction Permit Issued to Wisconsin Public Service Corporation for the Construction and Operation of a 500 MW Pulverized Coal-fired Power Plant Known as Weston Unit 4 in Marathon County, Wisconsin*, Case No. IH-04-21. The Final Order, issued 2/10/06, lowered the NOx BACT limit from 0.07 lb/MMBtu to 0.06 lb/MMBtu based on a 30-day average, added a BACT SO2 control efficiency, and required a 0.0005% high efficiency drift eliminator as BACT for the cooling tower. The modified permit, including these provisions, was issued 3/28/07. Additional appeals in progress.
- For plaintiffs, adviser on technical issues related to Citizen Suit against U.S. EPA regarding failure to update New Source Performance Standards for petroleum refineries, 40 CFR 60, Subparts J, VV, and GGG. *Our Children's Earth Foundation and Sierra Club v. U.S. EPA et al.* Case settled July 2005. CD No. C 05-00094 CW, U.S. District Court, Northern District of California – Oakland Division. Proposed revisions to standards of performance for petroleum refineries published 72 FR 27178 (5/14/07).
- For interveners, reviewed proposed Consent Decree settling Clean Air Act violations due to historic modifications of boilers and associated equipment at two coal-fired power plants. In response to stay order, reviewed the record, selected one representative activity at each of seven generating units, and analyzed to identify CAA violations. Identified NSPS and NSR violations for NOx, SO_2, PM/PM10, and sulfuric acid mist. Summarized results in an expert report. *United States of America, and Michael A. Cox, Attorney General of the State of Michigan, ex rel. Michigan Department of Environmental Quality, Plaintiffs, and Clean Wisconsin, Sierra Club, and Citizens' Utility Board, Intervenors, v. Wisconsin*

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Electric Power Company, Defendant, U.S. District Court for the Eastern District of Wisconsin, Civil Action No. 2:03-CV-00371-CNC. Order issued 10-1-07 denying petition.

- For a coalition of Nevada labor organizations (ACE), reviewed preliminary determination to issue a Class I Air Quality Operating Permit to Construct and supporting files for a 250-MW pulverized coal-fired boiler (Newmont). Prepared about 100 pages of technical analyses and comments on BACT, MACT, emission calculations, and enforceability. Assisted counsel draft petition and reply brief appealing PSD permit to U.S. EPA Environmental Appeals Board (EAB). Order denying review issued 12/21/05. *In re Newmont Nevada Energy Investment, LLC, TS Power Plant*, PSD Appeal No. 05-04 (EAB 2005).
- For petitioners and plaintiffs, reviewed and prepared comments on air quality and hazardous waste based on negative declaration for refinery ultra low sulfur diesel project located in SCAQMD. Reviewed responses to comments and prepared responses. Prepared declaration and presented oral testimony before SCAQMD Hearing Board on exempt sources (cooling towers) and calculation of potential to emit under NSR. Petition for writ of mandate filed March 2005. Case remanded by Court of Appeals to trial court to direct SCAQMD to re-evaluate the potential environmental significance of NOx emissions resulting from the project in accordance with court's opinion. California Court of Appeals, Second Appellate Division, on December 18, 2007, affirmed in part (as to baseline) and denied in part. *Communities for a Better Environment v. South Coast Air Quality Management District and ConocoPhillips and Carlos Valdez et al v. South Coast Air Quality Management District and ConocoPhillips*. Certified for partial publication 1/16/08. Appellate Court opinion upheld by CA Supreme Court 3/15/10. *(2010) 48 Cal.4th 310*.
- For amici seeking to amend a proposed Consent Decree to settle alleged NSR violations at Chevron refineries, reviewed proposed settlement, related files, subject modifications, and emission calculations. Prepared declaration on emission reductions, identification of NSR and NSPS violations, and BACT/LAER for FCCUs, heaters and boilers, flares, and sulfur recovery plants. *U.S. et al. v. Chevron U.S.A.*, Northern District of California, Case No. C 03-04650. Memorandum and Order Entering Consent Decree issued June 2005. Case No. C 03-4650 CRB.
- For petitioners, prepared declaration on enforceability of periodic monitoring requirements, in response to EPA's revised interpretation of 40 CFR 70.6(c)(1). This revision limited additional monitoring required in Title V permits. 69 FR 3203 (Jan. 22, 2004). *Environmental Integrity Project et al. v. EPA* (U.S. Court of Appeals for the District of Columbia). Court ruled the Act requires all Title V permits to contain monitoring requirements to assure compliance. *Sierra Club v. EPA*, 536 F.3d 673 (D.C. Cir. 2008).
- For interveners in application for authority to construct a 500 MW supercritical coal-fired generating unit before the Wisconsin Public Service Commission, prepared pre-filed

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written direct and rebuttal testimony with oral cross examination and rebuttal on BACT and MACT (Weston 4). Prepared written comments on BACT, MACT, and enforceability on draft air permit for same facility.

- For property owners in Nevada, evaluated the environmental impacts of a 1,450-MW coal-fired power plant proposed in a rural area adjacent to the Black Rock Desert and Granite Range, including emission calculations, air quality modeling, comments on proposed use permit to collect preconstruction monitoring data, and coordination with agencies and other interested parties. Project cancelled.
- For environmental organizations, reviewed draft PSD permit for a 600-MW coal-fired power plant in West Virginia (Longview). Prepared comments on permit enforceability; coal washing; BACT for SO_2 and PM10; Hg MACT; and MACT for HCl, HF, non-Hg metallic HAPs, and enforceability. Assist plaintiffs draft petition appealing air permit. Retained as expert to develop testimony on MACT, BACT, offsets, enforceability. Participate in settlement discussions. Case settled July 2004.
- For petitioners, reviewed record produced in discovery and prepared affidavit on emissions of carbon monoxide and volatile organic compounds during startup of GE 7FA combustion turbines to successfully establish plaintiff standing. *Sierra Club et al. v. Georgia Power Company* (Northern District of Georgia).
- For building trades, reviewed air quality permitting action for 1500-MW coal-fired power plant before the Kentucky Department for Environmental Protection (Thoroughbred).
- For petitioners, expert witness in administrative appeal of the PSD/Title V permit issued to a 1500-MW coal-fired power plant. Reviewed over 60,000 pages of produced documents, prepared discovery index, identified and assembled plaintiff exhibits. Deposed. Assisted counsel in drafting discovery requests, with over 30 depositions, witness cross examination, and brief drafting. Presented over 20 days of direct testimony, rebuttal and sur-rebuttal, with cross examination on BACT for NOx, SO_2, and PM/PM10; MACT for Hg and non-Hg metallic HAPs; emission estimates for purposes of Class I and II air modeling; risk assessment; and enforceability of permit limits. Evidentiary hearings from November 2003 to June 2004. *Sierra Club et al. v. Natural Resources & Environmental Protection Cabinet, Division of Air Quality and Thoroughbred Generating Company et al.* Hearing Officer Decision issued August 9, 2005 finding in favor of plaintiffs on counts as to risk, BACT (IGCC/CFB, NOx, SO_2, Hg, Be), single source, enforceability, and errors and omissions. Assist counsel draft exceptions. Cabinet Secretary issued Order April 11, 2006 denying Hearing Offer's report, except as to NOx BACT, Hg, 99% SO2 control and certain errors and omissions.
- For citizens group in Massachusetts, reviewed, commented on, and participated in permitting of pollution control retrofits of coal-fired power plant (Salem Harbor).

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- Assisted citizens group and labor union challenge issuance of conditional use permit for a 317,000 ft^2 discount store in Honolulu without any environmental review. In support of a motion for preliminary injunction, prepared 7-page declaration addressing public health impacts of diesel exhaust from vehicles serving the Project. In preparation for trial, prepared 20-page preliminary expert report summarizing results of diesel exhaust and noise measurements at two big box retail stores in Honolulu, estimated diesel PM10 concentrations for Project using ISCST, prepared a cancer health risk assessment based on these analyses, and evaluated noise impacts.
- Assisted environmental organizations to challenge the DOE Finding of No Significant Impact (FONSI) for the Baja California Power and Sempra Energy Resources Cross-Border Transmissions Lines in the U.S. and four associated power plants located in Mexico (DOE EA-1391). Prepared 20-page declaration in support of motion for summary judgment addressing emissions, including CO_2 and NH_3, offsets, BACT, cumulative air quality impacts, alternative cooling systems, and water use and water quality impacts. Plaintiff's motion for summary judgment granted in part. U.S. District Court, Southern District decision concluded that the Environmental Assessment and FONSI violated NEPA and the APA due to their inadequate analysis of the potential controversy surrounding the project, water impacts, impacts from NH_3 and CO_2, alternatives, and cumulative impacts. *Border Power Plant Working Group v. Department of Energy and Bureau of Land Management*, Case No. 02-CV-513-IEG (POR) (May 2, 2003).
- For Sacramento school, reviewed draft air permit issued for diesel generator located across from playfield. Prepared comments on emission estimates, enforceability, BACT, and health impacts of diesel exhaust. Case settled. BUG trap installed on the diesel generator.
- Assisted unions in appeal of Title V permit issued by BAAQMD to carbon plant that manufactured coke. Reviewed District files, identified historic modifications that should have triggered PSD review, and prepared technical comments on Title V permit. Reviewed responses to comments and assisted counsel draft appeal to BAAQMD hearing board, opening brief, motion to strike, and rebuttal brief. Case settled.
- Assisted California Central Coast city obtain controls on a proposed new city that would straddle the Ventura-Los Angeles County boundary. Reviewed several environmental impact reports, prepared an air quality analysis, a diesel exhaust health risk assessment, and detailed review comments. Governor intervened and State dedicated the land for conservation purposes April 2004.
- Assisted Central California city to obtain controls on large alluvial sand quarry and asphalt plant proposing a modernization. Prepared comments on Negative Declaration on air quality, public health, noise, and traffic. Evaluated process flow diagrams and engineering reports to determine whether proposed changes increased plant capacity or substantially modified plant operations. Prepared comments on application for categorical exemption from CEQA. Presented testimony to County Board of Supervisors. Developed controls to

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mitigate impacts. Assisted counsel draft Petition for Writ. Case settled June 2002. Substantial improvements in plant operations were obtained including cap on throughput, dust control measures, asphalt plant loadout enclosure, and restrictions on truck routes.

- Assisted oil companies on the California Central Coast in defending class action citizen's lawsuit alleging health effects due to emissions from gas processing plant and leaking underground storage tanks. Reviewed regulatory and other files and advised counsel on merits of case. Case settled November 2001.
- Assisted oil company on the California Central Coast in defending property damage claims arising out of a historic oil spill. Reviewed site investigation reports, pump tests, leachability studies, and health risk assessments, participated in design of additional site characterization studies to assess health impacts, and advised counsel on merits of case. Prepare health risk assessment.
- Assisted unions in appeal of Initial Study/Negative Declaration ("IS/ND") for an MTBE phaseout project at a Bay Area refinery. Reviewed IS/ND and supporting agency permitting files and prepared technical comments on air quality, groundwater, and public health impacts. Reviewed responses to comments and final IS/ND and ATC permits and assisted counsel to draft petitions and briefs appealing decision to Air District Hearing Board. Presented sworn direct and rebuttal testimony with cross examination on groundwater impacts of ethanol spills on hydrocarbon contamination at refinery. Hearing Board ruled 5 to 0 in favor of appellants, remanding ATC to district to prepare an EIR.
- Assisted Florida cities in challenging the use of diesel and proposed BACT determinations in prevention of significant deterioration (PSD) permits issued to two 510-MW simple cycle peaking electric generating facilities and one 1,080-MW simple cycle/combined cycle facility. Reviewed permit applications, draft permits, and FDEP engineering evaluations, assisted counsel in drafting petitions and responding to discovery. Participated in settlement discussions. Cases settled or applications withdrawn.
- Assisted large California city in federal lawsuit alleging peaker power plant was violating its federal permit. Reviewed permit file and applicant's engineering and cost feasibility study to reduce emissions through retrofit controls. Advised counsel on feasible and cost-effective NOx, SOx, and PM10 controls for several 1960s diesel-fired Pratt and Whitney peaker turbines. Case settled.
- Assisted coalition of Georgia environmental groups in evaluating BACT determinations and permit conditions in PSD permits issued to several large natural gas-fired simple cycle and combined-cycle power plants. Prepared technical comments on draft PSD permits on BACT, enforceability of limits, and toxic emissions. Reviewed responses to comments, advised counsel on merits of cases, participated in settlement discussions, presented oral

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and written testimony in adjudicatory hearings, and provided technical assistance as required. Cases settled or won at trial.

- Assisted construction unions in review of air quality permitting actions before the Indiana Department of Environmental Management ("IDEM") for several natural gas-fired simple cycle peaker and combined cycle power plants.
- Assisted coalition of towns and environmental groups in challenging air permits issued to 523 MW dual fuel (natural gas and distillate) combined-cycle power plant in Connecticut. Prepared technical comments on draft permits and 60 pages of written testimony addressing emission estimates, startup/shutdown issues, BACT/LAER analyses, and toxic air emissions. Presented testimony in adjudicatory administrative hearings before the Connecticut Department of Environmental Protection in June 2001 and December 2001.
- Assisted various coalitions of unions, citizens groups, cities, public agencies, and developers in licensing and permitting of over 110 coal, gas, oil, biomass, and pet coke-fired power plants generating over 75,000 MW of electricity. These included base-load, combined cycle, simple cycle, and peaker power plants in Alaska, Arizona, Arkansas, California, Colorado, Georgia, Florida, Illinois, Indiana, Kentucky, Michigan, Missouri, Ohio, Oklahoma, Oregon, Texas, West Virginia, Wisconsin, and elsewhere. Prepared analyses of and comments on applications for certification, preliminary and final staff assessments, and various air, water, wastewater, and solid waste permits issued by local agencies. Presented written and oral testimony before various administrative bodies on hazards of ammonia use and transportation, health effects of air emissions, contaminated property issues, BACT/LAER issues related to SCR and SCONOx, criteria and toxic pollutant emission estimates, MACT analyses, air quality modeling, water supply and water quality issues, and methods to reduce water use, including dry cooling, parallel dry-wet cooling, hybrid cooling, and zero liquid discharge systems.
- Assisted unions, cities, and neighborhood associations in challenging an EIR issued for the proposed expansion of the Oakland Airport. Reviewed two draft EIRs and prepared a health risk assessment and extensive technical comments on air quality and public health impacts. The California Court of Appeals, First Appellate District, ruled in favor of appellants and plaintiffs, concluding that the EIR "2) erred in using outdated information in assessing the emission of toxic air contaminants (TACs) from jet aircraft; 3) failed to support its decision not to evaluate the health risks associated with the emission of TACs with meaningful analysis," thus accepting my technical arguments and requiring the Port to prepare a new EIR. *See Berkeley Keep Jets Over the Bay Committee, City of San Leandro, and City of Alameda et al. v. Board of Port Commissioners* (August 30, 2001) 111 Cal.Rptr.2d 598.
- Assisted lessor of former gas station with leaking underground storage tanks and TCE contamination from adjacent property. Lessor held option to purchase, which was forfeited

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based on misrepresentation by remediation contractor as to nature and extent of contamination. Remediation contractor purchased property. Reviewed regulatory agency files and advised counsel on merits of case. Case not filed.

- Advised counsel on merits of several pending actions, including a Proposition 65 case involving groundwater contamination at an explosives manufacturing firm and two former gas stations with leaking underground storage tanks.
- Assisted defendant foundry in Oakland in a lawsuit brought by neighbors alleging property contamination, nuisance, trespass, smoke, and health effects from foundry operation. Inspected and sampled plaintiff's property. Advised counsel on merits of case. Case settled.
- Assisted business owner facing eminent domain eviction. Prepared technical comments on a negative declaration for soil contamination and public health risks from air emissions from a proposed redevelopment project in San Francisco in support of a CEQA lawsuit. Case settled.
- Assisted neighborhood association representing residents living downwind of a Berkeley asphalt plant in separate nuisance and CEQA lawsuits. Prepared technical comments on air quality, odor, and noise impacts, presented testimony at commission and council meetings, participated in community workshops, and participated in settlement discussions. Cases settled. Asphalt plant was upgraded to include air emission and noise controls, including vapor collection system at truck loading station, enclosures for noisy equipment, and improved housekeeping.
- Assisted a Fortune 500 residential home builder in claims alleging health effects from faulty installation of gas appliances. Conducted indoor air quality study, advised counsel on merits of case, and participated in discussions with plaintiffs. Case settled.
- Assisted property owners in Silicon Valley in lawsuit to recover remediation costs from insurer for large TCE plume originating from a manufacturing facility. Conducted investigations to demonstrate sudden and accidental release of TCE, including groundwater modeling, development of method to date spill, preparation of chemical inventory, investigation of historical waste disposal practices and standards, and on-site sewer and storm drainage inspections and sampling. Prepared declaration in opposition to motion for summary judgment. Case settled.
- Assisted residents in east Oakland downwind of a former battery plant in class action lawsuit alleging property contamination from lead emissions. Conducted historical research and dry deposition modeling that substantiated claim. Participated in mediation at JAMS. Case settled.
- Assisted property owners in West Oakland who purchased a former gas station that had leaking underground storage tanks and groundwater contamination. Reviewed agency files

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and advised counsel on merits of case. Prepared declaration in opposition to summary judgment. Prepared cost estimate to remediate site. Participated in settlement discussions. Case settled.

- Consultant to counsel representing plaintiffs in two Clean Water Act lawsuits involving selenium discharges into San Francisco Bay from refineries. Reviewed files and advised counsel on merits of case. Prepared interrogatory and discovery questions, assisted in deposing opposing experts, and reviewed and interpreted treatability and other technical studies. Judge ruled in favor of plaintiffs.
- Assisted oil company in a complaint filed by a resident of a small California beach community alleging that discharges of tank farm rinse water into the sanitary sewer system caused hydrogen sulfide gas to infiltrate residence, sending occupants to hospital. Inspected accident site, interviewed parties to the event, and reviewed extensive agency files related to incident. Used chemical analysis, field simulations, mass balance calculations, sewer hydraulic simulations with SWMM44, atmospheric dispersion modeling with SCREEN3, odor analyses, and risk assessment calculations to demonstrate that the incident was caused by a faulty drain trap and inadequate slope of sewer lateral on resident's property. Prepared a detailed technical report summarizing these studies. Case settled.
- Assisted large West Coast city in suit alleging that leaking underground storage tanks on city property had damaged the waterproofing on downgradient building, causing leaks in an underground parking structure. Reviewed subsurface hydrogeologic investigations and evaluated studies conducted by others documenting leakage from underground diesel and gasoline tanks. Inspected, tested, and evaluated waterproofing on subsurface parking structure. Waterproofing was substandard. Case settled.
- Assisted residents downwind of gravel mine and asphalt plant in Siskiyou County, California, in suit to obtain CEQA review of air permitting action. Prepared two declarations analyzing air quality and public health impacts. Judge ruled in favor of plaintiffs, closing mine and asphalt plant.
- Assisted defendant oil company on the California Central Coast in class action lawsuit alleging property damage and health effects from subsurface petroleum contamination. Reviewed documents, prepared risk calculations, and advised counsel on merits of case. Participated in settlement discussions. Case settled.
- Assisted defendant oil company in class action lawsuit alleging health impacts from remediation of petroleum contaminated site on California Central Coast. Reviewed documents, designed and conducted monitoring program, and participated in settlement discussions. Case settled.

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- Consultant to attorneys representing irrigation districts and municipal water districts to evaluate a potential challenge of USFWS actions under CVPIA section 3406(b)(2). Reviewed agency files and collected and analyzed hydrology, water quality, and fishery data. Advised counsel on merits of case. Case not filed.
- Assisted residents downwind of a Carson refinery in class action lawsuit involving soil and groundwater contamination, nuisance, property damage, and health effects from air emissions. Reviewed files and provided advice on contaminated soil and groundwater, toxic emissions, and health risks. Prepared declaration on refinery fugitive emissions. Prepared deposition questions and reviewed deposition transcripts on air quality, soil contamination, odors, and health impacts. Case settled.
- Assisted residents downwind of a Contra Costa refinery who were affected by an accidental release of naphtha. Characterized spilled naphtha, estimated emissions, and modeled ambient concentrations of hydrocarbons and sulfur compounds. Deposed. Presented testimony in binding arbitration at JAMS. Judge found in favor of plaintiffs.
- Assisted residents downwind of Contra Costa County refinery in class action lawsuit alleging property damage, nuisance, and health effects from several large accidents as well as routine operations. Reviewed files and prepared analyses of environmental impacts. Prepared declarations, deposed, and presented testimony before jury in one trial and judge in second. Case settled.
- Assisted business owner claiming damages from dust, noise, and vibration during a sewer construction project in San Francisco. Reviewed agency files and PM10 monitoring data and advised counsel on merits of case. Case settled.
- Assisted residents downwind of Contra Costa County refinery in class action lawsuit alleging property damage, nuisance, and health effects. Prepared declaration in opposition to summary judgment, deposed, and presented expert testimony on accidental releases, odor, and nuisance before jury. Case thrown out by judge, but reversed on appeal and not retried.
- Presented testimony in small claims court on behalf of residents claiming health effects from hydrogen sulfide from flaring emissions triggered by a power outage at a Contra Costa County refinery. Analyzed meteorological and air quality data and evaluated potential health risks of exposure to low concentrations of hydrogen sulfide. Judge awarded damages to plaintiffs.
- Assisted construction unions in challenging PSD permit for an Indiana steel mill. Prepared technical comments on draft PSD permit, drafted 70-page appeal of agency permit action to the Environmental Appeals Board challenging permit based on faulty BACT analysis for electric arc furnace and reheat furnace and faulty permit conditions, among others, and drafted briefs responding to four parties. EPA Region V and the EPA General Counsel

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intervened as amici, supporting petitioners. EAB ruled in favor of petitioners, remanding permit to IDEM on three key issues, including BACT for the reheat furnace and lead emissions from the EAF. Drafted motion to reconsider three issues. Prepared 69 pages of technical comments on revised draft PSD permit. Drafted second EAB appeal addressing lead emissions from the EAF and BACT for reheat furnace based on European experience with SCR/SNCR. Case settled. Permit was substantially improved. See *In re: Steel Dynamics, Inc.*, PSD Appeal Nos. 99-4 & 99-5 (EAB June 22, 2000).

- Assisted defendant urea manufacturer in Alaska in negotiations with USEPA to seek relief from penalties for alleged violations of the Clean Air Act. Reviewed and evaluated regulatory files and monitoring data, prepared technical analysis demonstrating that permit limits were not violated, and participated in negotiations with EPA to dismiss action. Fines were substantially reduced and case closed.
- Assisted construction unions in challenging PSD permitting action for an Indiana grain mill. Prepared technical comments on draft PSD permit and assisted counsel draft appeal of agency permit action to the Environmental Appeals Board challenging permit based on faulty BACT analyses for heaters and boilers and faulty permit conditions, among others. Case settled.
- As part of a consent decree settling a CEQA lawsuit, assisted neighbors of a large west coast port in negotiations with port authority to secure mitigation for air quality impacts. Prepared technical comments on mobile source air quality impacts and mitigation and negotiated a $9 million CEQA mitigation package. Represented neighbors on technical advisory committee established by port to implement the air quality mitigation program. Program successfully implemented.
- Assisted construction unions in challenging permitting action for a California hazardous waste incinerator. Prepared technical comments on draft permit, assisted counsel prepare appeal of EPA permit to the Environmental Appeals Board. Participated in settlement discussions on technical issues with applicant and EPA Region 9. Case settled.
- Assisted environmental group in challenging DTSC Negative Declaration on a hazardous waste treatment facility. Prepared technical comments on risk of upset, water, and health risks. Writ of mandamus issued.
- Assisted several neighborhood associations and cities impacted by quarries, asphalt plants, and cement plants in Alameda, Shasta, Sonoma, and Mendocino counties in obtaining mitigations for dust, air quality, public health, traffic, and noise impacts from facility operations and proposed expansions.
- For over 100 industrial facilities, commercial/campus, and redevelopment projects, developed the record in preparation for CEQA and NEPA lawsuits. Prepared technical comments on hazardous materials, solid wastes, public utilities, noise, worker safety, air

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quality, public health, water resources, water quality, traffic, and risk of upset sections of EIRs, EISs, FONSIs, initial studies, and negative declarations. Assisted counsel in drafting petitions and briefs and prepared declarations.

- For several large commercial development projects and airports, assisted applicant and counsel prepare defensible CEQA documents, respond to comments, and identify and evaluate "all feasible" mitigation to avoid CEQA challenges. This work included developing mitigation programs to reduce traffic-related air quality impacts based on energy conservation programs, solar, low-emission vehicles, alternative fuels, exhaust treatments, and transportation management associations.

SITE INVESTIGATION/REMEDIATION/CLOSURE

- Technical manager and principal engineer for characterization, remediation, and closure of waste management units at former Colorado oil shale plant. Constituents of concern included BTEX, As, 1,1,1-TCA, and TPH. Completed groundwater monitoring programs, site assessments, work plans, and closure plans for seven process water holding ponds, a refinery sewer system, and processed shale disposal area. Managed design and construction of groundwater treatment system and removal actions and obtained clean closure.
- Principal engineer for characterization, remediation, and closure of process water ponds at a former lanthanide processing plant in Colorado. Designed and implemented groundwater monitoring program and site assessments and prepared closure plan.
- Advised the city of Sacramento on redevelopment of two former railyards. Reviewed work plans, site investigations, risk assessment, RAPS, RI/FSs, and CEQA documents. Participated in the development of mitigation strategies to protect construction and utility workers and the public during remediation, redevelopment, and use of the site, including buffer zones, subslab venting, rail berm containment structure, and an environmental oversight plan.
- Provided technical support for the investigation of a former sanitary landfill that was redeveloped as single family homes. Reviewed and/or prepared portions of numerous documents, including health risk assessments, preliminary endangerment assessments, site investigation reports, work plans, and RI/FSs. Historical research to identify historic waste disposal practices to prepare a preliminary endangerment assessment. Acquired, reviewed, and analyzed the files of 18 federal, state, and local agencies, three sets of construction field notes, analyzed 21 aerial photographs and interviewed 14 individuals associated with operation of former landfill. Assisted counsel in defending lawsuit brought by residents

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alleging health impacts and diminution of property value due to residual contamination. Prepared summary reports.

- Technical oversight of characterization and remediation of a nitrate plume at an explosives manufacturing facility in Lincoln, CA. Provided interface between owners and consultants. Reviewed site assessments, work plans, closure plans, and RI/FSs.
- Consultant to owner of large western molybdenum mine proposed for NPL listing. Participated in negotiations to scope out consent order and develop scope of work. Participated in studies to determine premining groundwater background to evaluate applicability of water quality standards. Served on technical committees to develop alternatives to mitigate impacts and close the facility, including resloping and grading, various thickness and types of covers, and reclamation. This work included developing and evaluating methods to control surface runoff and erosion, mitigate impacts of acid rock drainage on surface and ground waters, and stabilize nine waste rock piles containing 328 million tons of pyrite-rich, mixed volcanic waste rock (andesites, rhyolite, tuff) Evaluated stability of waste rock piles. Represented client in hearings and meetings with state and federal oversight agencies.

REGULATORY (PARTIAL LIST)

- In September 2019, reviewed City of Sunnyvale's file on Google's proposed Central Utility Plant and researched and wrote 34 pages of comments on construction and operational air quality impacts, cumulative impacts, and battery fire and explosion impacts.
- In August 2019, researched and wrote 25 pages of comments on IS/MND for the Hanford-Lakeside Dairy digester Project, Kings County, on project description (piecemealing), cumulative impacts, construction impacts, air quality impacts, valley fever and risk of upset.
- In July 2019, researched and wrote 48 pages of comments on IS/MND for the Five Points Pipeline Dairy Digester Cluster Project, including on air quality, cumulative impacts, worker and public health impacts (including on pesticide-contaminated soils), Valley Fever, construction air quality impacts, and risk of upset.
- In June 2019, researched and wrote 15 pages of responses to comments on IS/MND for SV1 Data Center, including operational NOx emissions, air quality analyses, construction emissions, battery hazards, and mitigation plans for noise, vibration, risk management, storm water pollution, and emergency response and evacuation plans.

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- In June 2019, researched and wrote 30 pages of comments on DEIR for the Humboldt Wind Energy Project on fire and aesthetic impacts of transmission line, construction air quality impacts and mitigation, and greenhouse gas emissions.
- In May 2019, researched and wrote 25 pages of comments on the DEIR for the ExxonMobil Interim Trucking for Santa Ynez Phased Restart Project on project description, baseline, and mitigation.
- In April 2019, researched and wrote a 16 page letter critiquing the adequacy of the FEIR for CalAm Desalination Project to support a Monterey County Combined Development Permit, consisting of a Use Permit, an Administrative Permit, and Design Approval for the Desalination Plant and Carmel Valley Pump Station.
- In April 2019, researched and wrote 22 pages of comments on DEIR for the Eco-Energy Liquid Bulk Terminal at the Port of Stockton on emissions, air quality impact mitigation, and health risk assessment.
- In March 2019, researched and wrote 43 pages of comments on DEIR for Contanda Renewable Diesel Bulk Liquid Terminal at the Port of Stockton on operational emissions, air quality impacts and mitigation and health risks.
- In February 2019, researched and wrote 36 pages of comments on general cumulative impacts, air quality, accidents, and valley fever for IS/MND for biogas cluster project in Kings County.
- In January 2019, researched and wrote 30 pages of comments on air quality and valley fever for IS/MND for energy storage facility in Kings County.
- In December 2018, researched and wrote 11 pages of comments on air quality for IS/MND for biomass gasification facility in Madera County.
- In December 2018, researched and wrote 10 pages of responses to comments on IS/MND for a wind energy project in Riverside County.
- In December 2018, researched and wrote 12 pages of responses to comments on IS/MND for a large Safeway fueling station in Petaluma. The Planning Commission voted unanimously to require an EIR.
- In November 2018, researched and wrote 30 pages of comments on IS/MND on wind energy project in Riverside County on construction health risks, odor impacts, waste disposal, transportation, construction emissions and mitigation and Valley Fever.
- In November 2018, researched and wrote 32 pages of comments on the DEIR for a solar energy generation and storage project in San Bernardino County on hazards, health risks, odor, construction emissions and mitigation, and Valley Fever.

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- In September 2018, researched and wrote 36 pages of comments on the FEIR for the Newland Sierra Project including on greenhouse gas emissions, construction emissions, and cumulative impacts.
- In August 2018, researched and wrote 20 pages of comments on the health risk assessment in the IS/MND for a large Safeway fueling station in Petaluma.
- In August 2018, researched and wrote responses to comments on DEIR for the Newland Sierra Project, San Diego County on greenhouse gas emissions, construction emissions, odor, and Valley Fever.
- In July/August 2018, researched and wrote 12 pages of comments on DEIR for proposed Doheny Desal Project, on GHG, criteria pollutant, and TAC emissions and public health impacts during construction and indirect emissions during operation.
- In June 2018, researched and wrote 12 pages of technical comments rebutting NDDH responses to comments on Meridian Davis Refinery.
- In April 2018, researched and wrote 26 pages of comments on greenhouse gas emissions and mitigation as proposed in the San Diego County Climate Action Plan.
- In April 2018, researched and wrote 24 pages of comments on the FEIR for Monterey County water supply project, including GHG mitigation, air quality impacts and mitigation, and Valley Fever.
- In March-June 2018, researched and wrote 37 pages of comments on the IS/MND for the 2305 Mission College Boulevard Data Center, Santa Clara, California and responded to responses to comments.
- In March 2018, researched and wrote 40 pages of comments on the IS/MND for the Diablo Energy Storage Facility in Pittsburg, California.
- In March 2018, researched and wrote 19 pages of comments on Infill Checklist/Mitigated Negative Declaration for the Legacy@Livermore Project on CalEEMod emission calculations, including NOx and PM10 and construction health risk assessment, including Valley Fever.
- In January 2018, researched and wrote 28 pages of comments on draft Permit to Construct for the Davis Refinery Project, North Dakota, as a minor source of criteria pollutants and HAPs.
- In December 2017, researched and wrote 19 pages of comments on DEIR for the Rialto Bioenergy Facility, Rialto, California.
- In November and December 2017, researched and wrote 6 pages of comments on the Ventura County Air Pollution Control District's Preliminary Determination if Compliance (PDOC) for Mission Rock Energy Center.

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- In November 2017, researched and wrote 11 pages of comments on control technology evaluation for the National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry Residual Risk and Technology Review.
- In September and November 2017, prepared comments on revised Negative Declaration for Delicato Winery in San Joaquin County, California.
- In October and November 2017, researched and wrote comments on North City Project Pure Water San Diego Program DEIR/DEIS to reclaim wastewater for municipal use.
- In August 2017, reviewed DEIR on a new residential community in eastern San Diego County (Newland Sierra) and research and wrote 60 pages of comments on air quality, greenhouse gas emissions and health impacts, including Valley Fever.
- In August 2017, reviewed responses to comments on Part 70 operating permit for IGP Methanol's Gulf Coast Methanol Complex, near Myrtle Grove, Louisiana, and researched and wrote comments on metallic HAP issues.
- In July 2017, reviewed the FEIS for an expansion of the Port of Gulfport and researched and wrote 10 pages of comments on air quality and public health.
- In June 2017, reviewed and prepared technical report on an Application for a synthetic minor source construction permit for a new Refinery in North Dakota.
- In June 2017, reviewed responses to NPCA and other comments on the BP Cherry Point Refinery modifications and assisted counsel in evaluating issues to appeal, including GHG BACT, coker heater SCR cost effectiveness analysis, and SO_2 BACT.
- In June 2017, reviewed Part 70 Operating Permit Renewal/Modification for the Noranda Alumina LC/Gramercy Holdings I, LLC alumina processing plant, St. James, Louisiana, and prepared comments on HAP emissions from bauxite feedstock.
- In May and June 2017, reviewed FEIR on Tesoro Integration Project and prepared responses to comments on the DEIR.
- In May 2017, prepared comments on tank VOC and HAP emissions from Tesoro Integration Project, based on real time monitoring at the Tesoro and other refineries in the SCAQMD.
- In April 2017, prepared comments on Negative Declaration for Delicato Winery in San Joaquin County, California.
- In March 2017, reviewed Negative Declaration for Ellmore geothermal facility in Imperial County, California and prepared summary of issues.

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- In March 2017, prepared response to Phillips 66 Company's Appeal of the San Luis Obispo County Planning Commission's Decision Denying the Rail Spur Extension Project Proposed for the Santa Maria Refinery.
- In February 2017, researched and wrote comments on Kalama draft Title V permit for 10,000 MT/day methanol production and marine export facility in Kalama, Washington.
- In January 2017, researched and wrote 51 pages of comments on proposed Title V and PSD permits for the St. James Methanol Plant, St. James Louisiana, on BACT and enforceability of permit conditions.
- In December 2016, researched and wrote comments on draft Title V Permit for Yuhuang Chemical Inc. Methanol Plant, St. James, Louisiana, responding to EPA Order addressing enforceability issues.
- In November 2016, researched and wrote comments on Initial Study/Mitigated Negative Declaration for the AES Battery Energy Storage Facility, Long Beach, CA.
- In November 2016, researched and wrote comments on Campo Verde Battery Energy Storage System Draft Environmental Impact Report.
- In October 2016, researched and wrote comments on Title V Permit for NuStar Terminal Operations Partnership L.P, Stockton, CA.
- In October 2016, prepared expert report, Technical Assessment of Achieving the 40 CFR Part 423 Zero Discharge Standard for Bottom Ash Transport Water at the Belle River Power Plant, East China, Michigan. Reported resulted in a 2 year reduction in compliance date for elimination of bottom ash transport water. 1/30/17 DEQ Letter.
- In September 2016, researched and wrote comments on Proposed Title V Permit and Environmental Assessment Statement, Yuhuang Chemical Inc. Methanol Plant, St. James, Louisiana.
- In September 2016, researched and wrote response to ''Further Rebuttal in Support of Appeal of Planning Commission Resolution No. 16-1, Denying Use Permit Application 12PLN-00063 and Declining to Certify Final Environmental Impact Report for the Valero Benicia Crude-by-Rail Project.
- In August 2016, reviewed and prepared comments on manuscript: Hutton et al., Freshwater Flows to the San Francisco Bay-Delta Estuary over Nine Decades: Trends Evaluation.
- In August/September 2016, researched and wrote comments on Mitigated Negative Declaration for the Chevron Long Wharf Maintenance and Efficiency Project.

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- In July 2016, researched and wrote comments on the Ventura County APCD Preliminary Determination of Compliance and the California Energy Commission Revised Preliminary Staff Assessment for the Puente Power Project.
- In June 2016, researched and wrote comments on an Ordinance (1) Amending the Oakland Municipal Code to Prohibit the Storage and Handling of Coal and Coke at Bulk Material Facilities or Terminals Throughout the City of Oakland and (2) Adopting CEQA Exemption Findings and supporting technical reports. Council approved Ordinance on an 8 to 0 vote on June 27, 2016.
- In May 2016, researched and wrote comments on Draft Title V Permit and Draft Environmental Impact Report for the Tesoro Los Angeles Refinery Integration and Compliance Project.
- In March 2016, researched and wrote comments on Valero's Appeal of Planning Commission's Denial of Valero Crude-by-Rail Project.
- In February 2016, researched and wrote comments on Final Environmental Impact Report, Santa Maria Rail Spur Project.
- In February 2016, researched and wrote comments on Final Environmental Impact Report, Valero Benicia Crude by Rail Project.
- In January 2016, researched and wrote comments on Draft Programmatic Environmental Impact Report for the Southern California Association of Government's (SCAG) 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy.
- In November 2015, researched and wrote comments on Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance – 2015(C) (Focused on Oil and Gas Local Permitting), November 2015.
- In October 2015, researched and wrote comments on Revised Draft Environmental Report, Valero Benicia Crude by Rail Project.
- In September 2015, prepared report, ''Environmental, Health and Safety Impacts of the Proposed Oakland Bulk and Oversized Terminal, and presented oral testimony on September 21, 2015 before Oakland City Council on behalf of the Sierra Club.
- In September 2015, researched and wrote comments on revisions to two chapters of EPA's Air Pollution Control Cost Manual: Docket ID No. EPA-HQ-OAR-2015-0341.
- In June 2015, researched and wrote comments on DEIR for the CalAm Monterey Peninsula Water Supply Project.
- In April 2015, researched and wrote comments on proposed Title V Operating Permit Revision and Prevention of Significant Deterioration Permit for Arizona Public Service's

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Ocotillo Power Plant Modernization Project (5 GE LMS100 105-MW simple cycle turbines operated as peakers), in Tempe, Arizona; Final permit appealed to EAB.

- In March 2015, researched and wrote ''Comments on Proposed Title V Air Permit, Yuhuang Chemical Inc. Methanol Plant, St. James, Louisiana''. Client filed petition objecting to the permit. EPA granted majority of issues. In the Matter of Yuhuang Chemical Inc. Methanol Plant, St. James Parish, Louisiana, Permit No. 2560-00295-V0, Issued by the Louisiana Department of Environmental Quality, Petition No. VI-2015-03, Order Responding to the Petitioners' Request for Objection to the Issuance of a Title V Operating Permit, September 1, 2016.
- In February 2015, prepared compilation of BACT cost effectiveness values in support of comments on draft PSD Permit for Bonanza Power Project.
- In January 2015, prepared cost effectiveness analysis for SCR for a 500-MW coal fire power plant, to address unpermitted upgrades in 2000.
- In January 2015, researched and wrote comments on Revised Final Environmental Impact Report for the Phillips 66 Propane Recovery Project. *Communities for a Better Environment et al. v. Contra Costa County et al. Contra Costa County (Superior Court, Contra Costa County, Case No. MSN15-0301, December 1, 2016).*
- In December 2014, researched and wrote ''Report on Bakersfield Crude Terminal Permits to Operate.'' In response, the U.S. EPA cited the Terminal for 10 violations of the Clean Air Act. The Fifth Appellate District Court upheld the finding in this report in CBE et al v. San Joaquin Valley Unified Air Pollution Control District and Bakersfield Crude Terminal LLC et al, Super. Ct. No. 284013, June 23, 2017.
- In December 2014, researched and wrote comments on Revised Draft Environmental Impact Report for the Phillips 66 Propane Recovery Project.
- In November 2014, researched and wrote comments on Revised Draft Environmental Impact Report for Phillips 66 Rail Spur Extension Project and Crude Unloading Project, Santa Maria, CA to allow the import of tar sands crudes.
- In November 2014, researched and wrote comments on Draft Environmental Impact Report for Phillips 66 Ultra Low Sulfur Diesel Project, responding to the California Supreme Court Decision, *Communities for a Better Environment v. South Coast Air Quality Management Dist. (2010) 48 Cal.4th 310.*
- In November 2014, researched and wrote comments on Draft Environmental Impact Report for the Tesoro Avon Marine Oil Terminal Lease Consideration.
- In October 2014, prepared: ''Report on Hydrogen Cyanide Emissions from Fluid Catalytic Cracking Units'', pursuant to the Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards, 79 FR 36880.

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- In October 2014, researched and wrote technical comments on Final Environmental Impact Reports for Alon Bakersfield Crude Flexibility Project to build a rail terminal to allow the import/export of tar sands and Bakken crude oils and to upgrade an existing refinery to allow it to process a wide range of crudes.
- In October 2014, researched and wrote technical comments on the Title V Permit Renewal and three De Minimus Significant Revisions for the Tesoro Logistics Marine Terminal in the SCAQMD.
- In September 2014, researched and wrote technical comments on the Draft Environmental Impact Report for the Valero Crude by Rail Project.
- In August 2014, for EPA Region 6, prepared technical report on costing methods for upgrades to existing scrubbers at coal-fired power plants.
- In July 2014, researched and wrote technical comments on Draft Final Environmental Impact Reports for Alon Bakersfield Crude Flexibility Project to build a rail terminal to allow the import/export of tar sands and Bakken crude oils and to upgrade an existing refinery to allow it to process a wide range of crudes.
- In June 2014, researched and wrote technical report on Initial Study and Draft Negative Declaration for the Tesoro Logistics Storage Tank Replacement and Modification Project.
- In May 2014, researched and wrote technical comments on Intent to Approve a new refinery and petroleum transloading operation in Utah.
- In March and April 2014, prepared declarations on air permits issued for two crude-by-rail terminals in California, modified to switch from importing ethanol to importing Bakken crude oils by rail and transferring to tanker cars. Permits were issued without undergoing CEQA review. One permit was upheld by the San Francisco Superior Court as statute of limitations had run. The Sacramento Air Quality Management District withdrew the second one due to failure to require BACT and conduct CEQA review.
- In March 2014, researched and wrote technical report on Negative Declaration for a proposed modification of the air permit for a bulk petroleum and storage terminal to the allow the import of tar sands and Bakken crude oil by rail and its export by barge, under the New York State Environmental Quality Review Act (SEQRA).
- In February 2014, researched and wrote technical report on proposed modification of air permit for midwest refinery upgrade/expansion to process tar sands crudes.
- In January 2014, prepared cost estimates to capture, transport, and use CO2 in enhanced oil recovery, from the Freeport LNG project based on both Selexol and Amine systems.
- In January 2014, researched and wrote technical report on Draft Environmental Impact Report for Phillips 66 Rail Spur Extension Project, Santa Maria, CA. Comments

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addressed project description (piecemealing, crude slate), risk of upset analyses, mitigation measures, alternative analyses and cumulative impacts.

- In November 2013, researched and wrote technical report on the Phillips 66 Propane Recovery Project, Rodeo, CA. Comments addressed project description (piecemealing, crude slate) and air quality impacts.
- In September 2013, researched and wrote technical report on the Draft Authority to Construct Permit for the Casa Diablo IV Geothermal Development Project Environmental Impact Report and Declaration in Support of Appeal and Petition for Stay, U.S. Department of the Interior, Board of Land Appeals, Appeal of Decision Record for the Casa Diablo IV Geothermal Development Project.
- In September 2013, researched and wrote technical report on Effluent Limitation Guidelines for Best Available Technology Economically Available (BAT) for Bottom Ash Transport Waters from Coal-Fired Power Plants in the Steam Electric Power Generating Point Source Category.
- In July 2013, researched and wrote technical report on Initial Study/Mitigated Negative Declaration for the Valero Crude by Rail Project, Benicia, California, Use Permit Application 12PLN-00063.
- In July 2013, researched and wrote technical report on fugitive particulate matter emissions from coal train staging at the proposed Coyote Island Terminal, Oregon, for draft Permit No. 25-0015-ST-01.
- In July 2013, researched and wrote technical comments on air quality impacts of the Finger Lakes LPG Storage Facility as reported in various Environmental Impact Statements.
- In July 2013, researched and wrote technical comments on proposed Greenhouse Gas PSD Permit for the Celanese Clear Lake Plant, including cost analysis of CO2 capture, transport, and sequestration.
- In June/July 2013, researched and wrote technical comments on proposed Draft PSD Preconstruction Permit for Greenhouse Gas Emission for the ExxonMobil Chemical Company Baytown Olefins Plant, including cost analysis of CO2 capture, transport, and sequestration.
- In June 2013, researched and wrote technical report on a Mitigated Negative Declaration for a new rail terminal at the Valero Benicia Refinery to import increased amounts of "North American" crudes. Comments addressed air quality impacts of refining increased amounts of tar sands crudes.
- In June 2013, researched and wrote technical report on Draft Environmental Impact Report for the California Ethanol and Power Imperial Valley 1 Project.

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- In May 2013, researched and wrote comments on draft PSD permit for major expansion of midwest refinery to process 100% tar sands crudes, including a complex netting analysis involving debottlenecking, piecemealing, and BACT analyses.
- In April 2013, researched and wrote technical report on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Keystone XL Pipeline on air quality impacts from refining increased amount of tar sands crudes at Refineries in PADD 3.
- In October 2012, researched and wrote technical report on the Environmental Review for the Coyote Island Terminal Dock at the Port of Morrow on fugitive particulate matter emissions.
- In October 2012-October 2014, review and evaluate Flint Hills West Application for an expansion/modification for increased (Texas, Eagle Ford Shale) crude processing and related modification, including netting and BACT analysis. Assist in settlement discussions.
- In February 2012, researched and wrote comments on BART analysis in PA Regional Haze SIP, 77 FR 3984 (Jan. 26, 2012). On Sept. 29, 2015, a federal appeals court overturned the U.S. EPA's approval of this plan, based in part on my comments, concluding ''..we will vacate the 2014 Final Rule to the extent it approved Pennsylvania's source-specific BART analysis and remand to the EPA for further proceedings consistent with this Opinion.'' Nat'l Parks Conservation Assoc. v. EPA, 3d Cir., No. 14-3147, 9/19/15.
- Prepared cost analyses and comments on New York's proposed BART determinations for NOx, SO2, and PM and EPA's proposed approval of BART determinations for Danskammer Generating Station under New York Regional Haze State Implementation Plan and Federal Implementation Plan, 77 FR 51915 (August 28, 2012).
- Prepared cost analyses and comments on NOx BART determinations for Regional Haze State Implementation Plan for State of Nevada, 77 FR 23191 (April 18, 2012) and 77 FR 25660 (May 1, 2012).
- Prepared analyses of and comments on New Source Performance Standards for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units, 77 FR 22392 (April 13, 2012).
- Researched and wrote comments on CASPR-BART emission equivalency and NOx and PM BART determinations in EPA proposed approval of State Implementation Plan for Pennsylvania Regional Haze Implementation Plan, 77 FR 3984 (January 26, 2012).
- Researched and wrote comments and statistical analyses on hazardous air pollutants (HAPs) emission controls, monitoring, compliance methods, and the use of surrogates for acid gases, organic HAPs, and metallic HAPs for proposed National Emission Standards for

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Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units, 76 FR 24976 (May 3, 2011).

- Prepared cost analyses and comments on NOx BART determinations and emission reductions for proposed Federal Implementation Plan for Four Corners Power Plant, 75 FR 64221 (October 19, 2010).
- Prepared cost analyses and comments on NOx BART determinations for Colstrip Units 1- 4 for Montana State Implementation Plan and Regional Haze Federal Implementation Plan, 77 FR 23988 (April 20, 2010).
- For EPA Region 8, prepared report: Revised BART Cost Effectiveness Analysis for Tail-End Selective Catalytic Reduction at the Basin Electric Power Cooperative Leland Olds Station Unit 2 Final Report, March 2011, in support of 76 FR 58570 (Sept. 21, 2011).
- For EPA Region 6, prepared report: Revised BART Cost-Effectiveness Analysis for Selective Catalytic Reduction at the Public Service Company of New Mexico San Juan Generating Station, November 2010, in support of 76 FR 52388 (Aug. 22, 2011).
- For EPA Region 6, prepared report: Revised BART Cost-Effectiveness Analysis for Flue Gas Desulfurization at Coal-Fired Electric Generating Units in Oklahoma: Sooner Units 1 & 2, Muskogee Units 4 & 5, Northeastern Units 3 &4, October 2010, in support of 76 FR 16168 (March 26, 2011). My work was upheld in: *State of Oklahoma v. EPA*, App. Case 12-9526 (10th Cri. July 19, 2013).
- Identified errors in N_2O emission factors in the Mandatory Greenhouse Gas Reporting Rule, 40 CFR 98, and prepared technical analysis to support Petition for Rulemaking to Correct Emissions Factors in the Mandatory Greenhouse Gas Reporting Rule, filed with EPA on 10/28/10.
- Assisted interested parties develop input for and prepare comments on the Information Collection Request for Petroleum Refinery Sector NSPS and NESHAP Residual Risk and Technology Review, 75 FR 60107 (9/29/10).
- Technical reviewer of EPA's "Emission Estimation Protocol for Petroleum Refineries," posted for public comments on CHIEF on 12/23/09, prepared in response to the City of Houston's petition under the Data Quality Act (March 2010).
- Researched and wrote comments on SCR cost effectiveness for EPA's Advanced Notice of Proposed Rulemaking, Assessment of Anticipated Visibility Improvements at Surrounding Class I Areas and Cost Effectiveness of Best Available Retrofit Technology for Four Corners Power Plant and Navajo Generating Station, 74 FR 44313 (August 28, 2009).
- Researched and wrote comments on Proposed Rule for Standards of Performance for Coal Preparation and Processing Plants, 74 FR 25304 (May 27, 2009).

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- Prepared comments on draft PSD permit for major expansion of midwest refinery to process up to 100% tar sands crudes. Participated in development of monitoring and controls to mitigate impacts and in negotiating a Consent Decree to settle claims in 2008.
- Reviewed and assisted interested parties prepare comments on proposed Kentucky air toxic regulations at 401 KAR 64:005, 64:010, 64:020, and 64:030 (June 2007).
- Prepared comments on proposed Standards of Performance for Electric Utility Steam Generating Units and Small Industrial-Commercial-Industrial Steam Generating Units, 70 FR 9706 (February 28, 2005).
- Prepared comments on Louisville Air Pollution Control District proposed Strategic Toxic Air Reduction regulations.
- Prepared comments and analysis of BAAQMD Regulation, Rule 11, Flare Monitoring at Petroleum Refineries.
- Prepared comments on Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electricity Utility Steam Generating Units (MACT standards for coal-fired power plants).
- Prepared Authority to Construct Permit for remediation of a large petroleum-contaminated site on the California Central Coast. Negotiated conditions with agencies and secured permits.
- Prepared Authority to Construct Permit for remediation of a former oil field on the California Central Coast. Participated in negotiations with agencies and secured permits.
- Prepared and/or reviewed hundreds of environmental permits, including NPDES, UIC, Stormwater, Authority to Construct, Prevention of Significant Deterioration, Nonattainment New Source Review, Title V, and RCRA, among others.
- Participated in the development of the CARB document, *Guidance for Power Plant Siting and Best Available Control Technology*, including attending public workshops and filing technical comments.
- Performed data analyses in support of adoption of emergency power restoration standards by the California Public Utilities Commission for ''major'' power outages, where major is an outage that simultaneously affects 10% of the customer base.
- Drafted portions of the Good Neighbor Ordinance to grant Contra Costa County greater authority over safety of local industry, particularly chemical plants and refineries.
- Participated in drafting BAAQMD Regulation 8, Rule 28, Pressure Relief Devices, including participation in public workshops, review of staff reports, draft rules and other

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technical materials, preparation of technical comments on staff proposals, research on availability and costs of methods to control PRV releases, and negotiations with staff.

- Participated in amending BAAQMD Regulation 8, Rule 18, Valves and Connectors, including participation in public workshops, review of staff reports, proposed rules and other supporting technical material, preparation of technical comments on staff proposals, research on availability and cost of low-leak technology, and negotiations with staff.
- Participated in amending BAAQMD Regulation 8, Rule 25, Pumps and Compressors, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak and seal-less technology, and negotiations with staff.
- Participated in amending BAAQMD Regulation 8, Rule 5, Storage of Organic Liquids, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of controlling tank emissions, and presentation of testimony before the Board.
- Participated in amending BAAQMD Regulation 8, Rule 18, Valves and Connectors at Petroleum Refinery Complexes, including participation in public workshops, review of staff reports, proposed rules and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak technology, and presentation of testimony before the Board.
- Participated in amending BAAQMD Regulation 8, Rule 22, Valves and Flanges at Chemical Plants, etc, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak technology, and presentation of testimony before the Board.
- Participated in amending BAAQMD Regulation 8, Rule 25, Pump and Compressor Seals, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability of low-leak technology, and presentation of testimony before the Board.
- Participated in the development of the BAAQMD Regulation 2, Rule 5, Toxics, including participation in public workshops, review of staff proposals, and preparation of technical comments.
- Participated in the development of SCAQMD Rule 1402, Control of Toxic Air Contaminants from Existing Sources, and proposed amendments to Rule 1401, New Source

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Review of Toxic Air Contaminants, in 1993, including review of staff proposals and preparation of technical comments on same.

- Participated in the development of the Sunnyvale Ordinance to Regulate the Storage, Use and Handling of Toxic Gas, which was designed to provide engineering controls for gases that are not otherwise regulated by the Uniform Fire Code.
- Participated in the drafting of the Statewide Water Quality Control Plans for Inland Surface Waters and Enclosed Bays and Estuaries, including participation in workshops, review of draft plans, preparation of technical comments on draft plans, and presentation of testimony before the SWRCB.
- Participated in developing Se permit effluent limitations for the five Bay Area refineries, including review of staff proposals, statistical analyses of Se effluent data, review of literature on aquatic toxicity of Se, preparation of technical comments on several staff proposals, and presentation of testimony before the Bay Area RWQCB.
- Represented the California Department of Water Resources in the 1991 Bay-Delta Hearings before the State Water Resources Control Board, presenting sworn expert testimony with cross examination and rebuttal on a striped bass model developed by the California Department of Fish and Game.
- Represented the State Water Contractors in the 1987 Bay-Delta Hearings before the State Water Resources Control Board, presenting sworn expert testimony with cross examination and rebuttal on natural flows, historical salinity trends in San Francisco Bay, Delta outflow, and hydrodynamics of the South Bay.
- Represented interveners in the licensing of over 20 natural-gas-fired power plants and one coal gasification plant at the California Energy Commission and elsewhere. Reviewed and prepared technical comments on applications for certification, preliminary staff assessments, final staff assessments, preliminary determinations of compliance, final determinations of compliance, and prevention of significant deterioration permits in the areas of air quality, water supply, water quality, biology, public health, worker safety, transportation, site contamination, cooling systems, and hazardous materials. Presented written and oral testimony in evidentiary hearings with cross examination and rebuttal. Participated in technical workshops.
- Represented several parties in the proposed merger of San Diego Gas & Electric and Southern California Edison. Prepared independent technical analyses on health risks, air quality, and water quality. Presented written and oral testimony before the Public Utilities Commission administrative law judge with cross examination and rebuttal.
- Represented a PRP in negotiations with local health and other agencies to establish impact of subsurface contamination on overlying residential properties. Reviewed health studies

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prepared by agency consultants and worked with agencies and their consultants to evaluate health risks.

WATER QUALITY/RESOURCES

- Directed and participated in research on environmental impacts of energy development in the Colorado River Basin, including contamination of surface and subsurface waters and modeling of flow and chemical transport through fractured aquifers.
- Played a major role in Northern California water resource planning studies since the early 1970s. Prepared portions of the Basin Plans for the Sacramento, San Joaquin, and Delta basins including sections on water supply, water quality, beneficial uses, waste load allocation, and agricultural drainage. Developed water quality models for the Sacramento and San Joaquin Rivers.
- Conducted hundreds of studies over the past 40 years on Delta water supplies and the impacts of exports from the Delta on water quality and biological resources of the Central Valley, Sacramento-San Joaquin Delta, and San Francisco Bay. Typical examples include:
    1. Evaluate historical trends in salinity, temperature, and flow in San Francisco Bay and upstream rivers to determine impacts of water exports on the estuary;
    2. Evaluate the role of exports and natural factors on the food web by exploring the relationship between salinity and primary productivity in San Francisco Bay, upstream rivers, and ocean;
    3. Evaluate the effects of exports, other in-Delta, and upstream factors on the abundance of salmon and striped bass;
    4. Review and critique agency fishery models that link water exports with the abundance of striped bass and salmon;
    5. Develop a model based on GLMs to estimate the relative impact of exports, water facility operating variables, tidal phase, salinity, temperature, and other variables on the survival of salmon smolts as they migrate through the Delta;
    6. Reconstruct the natural hydrology of the Central Valley using water balances, vegetation mapping, reservoir operation models to simulate flood basins, precipitation records, tree ring research, and historical research;
    7. Evaluate the relationship between biological indicators of estuary health and down-estuary position of a salinity surrogate (X2);
    8. Use real-time fisheries monitoring data to quantify impact of exports on fish migration;

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9. Refine/develop statistical theory of autocorrelation and use to assess strength of relationships between biological and flow variables;
10. Collect, compile, and analyze water quality and toxicity data for surface waters in the Central Valley to assess the role of water quality in fishery declines;
11. Assess mitigation measures, including habitat restoration and changes in water project operation, to minimize fishery impacts;
12. Evaluate the impact of unscreened agricultural water diversions on abundance of larval fish;
13. Prepare and present testimony on the impacts of water resources development on Bay hydrodynamics, salinity, and temperature in water rights hearings;
14. Evaluate the impact of boat wakes on shallow water habitat, including interpretation of historical aerial photographs;
15. Evaluate the hydrodynamic and water quality impacts of converting Delta islands into reservoirs;
16. Use a hydrodynamic model to simulate the distribution of larval fish in a tidally influenced estuary;
17. Identify and evaluate non-export factors that may have contributed to fishery declines, including predation, shifts in oceanic conditions, aquatic toxicity from pesticides and mining wastes, salinity intrusion from channel dredging, loss of riparian and marsh habitat, sedimentation from upstream land alternations, and changes in dissolved oxygen, flow, and temperature below dams.

- Developed, directed, and participated in a broad-based research program on environmental issues and control technology for energy industries including petroleum, oil shale, coal mining, and coal slurry transport. Research included evaluation of air and water pollution, development of novel, low-cost technology to treat and dispose of wastes, and development and application of geohydrologic models to evaluate subsurface contamination from in-situ retorting. The program consisted of government and industry contracts and employed 45 technical and administrative personnel.
- Coordinated an industry task force established to investigate the occurrence, causes, and solutions for corrosion/erosion and mechanical/engineering failures in the waterside systems (e.g., condensers, steam generation equipment) of power plants. Corrosion/erosion failures caused by water and steam contamination that were investigated included waterside corrosion caused by poor microbiological treatment of cooling water, steam-side corrosion caused by ammonia-oxygen attack of copper alloys, stress-corrosion

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cracking of copper alloys in the air cooling sections of condensers, tube sheet leaks, oxygen in-leakage through condensers, volatilization of silica in boilers and carry over and deposition on turbine blades, and iron corrosion on boiler tube walls. Mechanical/engineering failures investigated included: steam impingement attack on the steam side of condenser tubes, tube-to-tube-sheet joint leakage, flow-induced vibration, structural design problems, and mechanical failures due to stresses induced by shutdown, startup and cycling duty, among others. Worked with electric utility plant owners/operators, condenser and boiler vendors, and architect/engineers to collect data to document the occurrence of and causes for these problems, prepared reports summarizing the investigations, and presented the results and participated on a committee of industry experts tasked with identifying solutions to prevent condenser failures.

- Evaluated the cost effectiveness and technical feasibility of using dry cooling and parallel dry-wet cooling to reduce water demands of several large natural-gas fired power plants in California and Arizona.
- Designed and prepared cost estimates for several dry cooling systems (e.g., fin fan heat exchangers) used in chemical plants and refineries.
- Designed, evaluated, and costed several zero liquid discharge systems for power plants.
- Evaluated the impact of agricultural and mining practices on surface water quality of Central Valley steams. Represented municipal water agencies on several federal and state advisory committees tasked with gathering and assessing relevant technical information, developing work plans, and providing oversight of technical work to investigate toxicity issues in the watershed.

AIR QUALITY/PUBLIC HEALTH

- Prepared or reviewed the air quality and public health sections of hundreds of EIRs and EISs on a wide range of industrial, commercial and residential projects.
- Prepared or reviewed hundreds of NSR and PSD permits for a wide range of industrial facilities.
- Designed, implemented, and directed a 2-year-long community air quality monitoring program to assure that residents downwind of a petroleum-contaminated site were not impacted during remediation of petroleum-contaminated soils. The program included real-time monitoring of particulates, diesel exhaust, and BTEX and time integrated monitoring for over 100 chemicals.
- Designed, implemented, and directed a 5-year long source, industrial hygiene, and ambient monitoring program to characterize air emissions, employee exposure, and downwind environmental impacts of a first-generation shale oil plant. The program included stack monitoring of heaters, boilers, incinerators, sulfur recovery units, rock crushers, API

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separator vents, and wastewater pond fugitives for arsenic, cadmium, chlorine, chromium, mercury, 15 organic indicators (e.g., quinoline, pyrrole, benzo(a)pyrene, thiophene, benzene), sulfur gases, hydrogen cyanide, and ammonia. In many cases, new methods had to be developed or existing methods modified to accommodate the complex matrices of shale plant gases.

- Conducted investigations on the impact of diesel exhaust from truck traffic from a wide range of facilities including mines, large retail centers, light industrial uses, and sports facilities. Conducted traffic surveys, continuously monitored diesel exhaust using an aethalometer, and prepared health risk assessments using resulting data.
- Conducted indoor air quality investigations to assess exposure to natural gas leaks, pesticides, molds and fungi, soil gas from subsurface contamination, and outgasing of carpets, drapes, furniture and construction materials. Prepared health risk assessments using collected data.
- Prepared health risk assessments, emission inventories, air quality analyses, and assisted in the permitting of over 70 1 to 2 MW emergency diesel generators.
- Prepare over 100 health risk assessments, endangerment assessments, and other health-based studies for a wide range of industrial facilities.
- Developed methods to monitor trace elements in gas streams, including a continuous real-time monitor based on the Zeeman atomic absorption spectrometer, to continuously measure mercury and other elements.
- Performed nuisance investigations (odor, noise, dust, smoke, indoor air quality, soil contamination) for businesses, industrial facilities, and residences located proximate to and downwind of pollution sources.

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J.P. Fox, P.H. Hutton, D.J. Howes, A.J. Draper, and L. Sears, Reconstructing the Natural Hydrology of the San Francisco Bay-Delta Watershed, Hydrology and Earth System Sciences, Special Issue: Predictions under Change: Water, Earth, and Biota in the Anthropocene, v. 19, pp. 4257-4274, 2015. http://www.hydrol-earth-syst-sci.net/19/4257/2015/hess-19-4257-2015.pdf. See also: Estimates of Natural and Unimpaired Flows for the Central Valley of California: Water Years 1922-2014 at: https://msb.water.ca.gov/documents/86728/a702a57f-ae7a-41a3-8bff-722e144059d6.

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(Partial)

S-Plus Data Analysis, MathSoft, 6/94.
Air Pollutant Emission Calculations, UC Berkeley Extension, 6-7/94
Assessment, Control and Remediation of LNAPL Contaminated Sites, API and USEPA, 9/94
Pesticides in the TIE Process, SETAC, 6/96
Sulfate Minerals: Geochemistry, Crystallography, and Environmental Significance, Mineralogical Society of America/Geochemical Society, 11/00.
Design of Gas Turbine Combined Cycle and Cogeneration Systems, Thermoflow, 12/00
Air-Cooled Steam Condensers and Dry- and Hybrid-Cooling Towers, Power-Gen, 12/01
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CEQA Update, UC Berkeley Extension, 3/02
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Noise Exposure Measurement Instruments and Techniques, AIHA PDC 302, 6/02
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Utility Industry Issues, Power-Gen, 12/02
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Coal-to-Liquids – A Timely Revival, 9th Electric Power, 4/30/07
Advances in Multi-Pollutant and CO_2 Control Technologies, 9th Electric Power, 4/30/07
McIlvaine Hot Topic Hour, Measurement & Control of PM2.5, 5/17/07
McIlvaine Hot Topic Hour, Co-firing and Gasifying Biomass, 5/31/07
McIlvaine Hot Topic Hour, Mercury Cost and Performance, 6/14/07
Ethanol 101: Points to Consider When Building an Ethanol Plant, BBI International, 6/26/07
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EXHIBIT B

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Shawn Smallwood, PhD
3108 Finch Street
Davis, CA 95616

Attn: David Black, Planner IV
Imperial County Planning & Development Services Department
801 Main Street
El Centro, CA 92243 1 July 2020

RE: Heber 2 Geothermal Repower Project

Dear Mr. Black,

I write to comment on the Initial Study and Mitigated Negative Declaration (IS/MND) prepared for the proposed Heber 2 Geothermal Repower Project (County of Imperial 2020), which I understand would modify the existing facilities and repower the project for another 30 years of operations.

My qualifications for preparing expert comments are the following. I hold a Ph.D. degree in Ecology from University of California at Davis, where I subsequently worked for four years as a post-graduate researcher in the Department of Agronomy and Range Sciences. My research has been on animal density and distribution, habitat selection, habitat restoration, interactions between wildlife and human infrastructure and activities, conservation of rare and endangered species, and on the ecology of invading species. I performed research on wildlife mortality caused by wind turbines, electric distribution lines, agricultural practices, and road traffic. I authored numerous papers on special-status species issues. I served as Chair of the Conservation Affairs Committee for The Wildlife Society – Western Section. I am a member of The Wildlife Society and the Raptor Research Foundation, and I've been a part-time lecturer at California State University, Sacramento. I was Associate Editor of wildlife biology's premier scientific journal, The Journal of Wildlife Management, as well as of Biological Conservation, and I was on the Editorial Board of Environmental Management. I have performed wildlife surveys in California for thirty-three years, including at many proposed project sites. My CV is attached.

IMPACTS TO BIOLOGICAL RESOURCES

Insufficient survey effort has been committed to the potential impacts to wildlife from the proposed project. A single visit was made by a wildlife biologist, who on June 1, 2019, visited at an unreported time of day and for an unreported time period. No use was made of richly informative data sets on wildlife occurrences, such as eBird. Had appropriate use of the available information been made, and had consideration been given to the aerial portion of wildlife habitat, the list of special-status species likely affected by the project would look more like that in Table 1. Available evidence supports the conclusion that up to 45 special-status species of wildlife likely occur at the project site at one time or another, most of them flying across the site for various reasons. Six of the species in Table 1 are threatened or endangered, or a candidate for listing.

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Table 1. *Occurrence likelihoods of wildlife species at the project site according to County of Imperial (2020) ("Imperial") and myself. eBird records are those occurring on or near the project site, and represent my conclusion that the species probably occurs at the site at various times. The right column identifies those species with documented collision fatalities along fences or powerlines or powerblocks of industrial solar projects that were monitored for fatalities.*

Common name, *Species name*	**Status**[1]	**Occurrence likelihood**		**Known collisions**
		Imperial	**Smallwood**	
Marbled godwit, *Limosa fedua*	BCC		eBird nearby	
Mountain plover, *Charadrius montanus*	BCC, SSC2		eBird nearby	
Long-billed curlew, *Numenius americanus*	BCC, TWL	Possible	eBird nearby	
Whimbrel, *Numenius phaeopus*	BCC	Possible	eBird nearby	
Swainson's hawk, *Buteo swainsoni*	CT, BCC, FGC 3503.5		eBird nearby	
Ferruginous hawk, Buteo regalis	TWL, FGC 3503.5		eBird nearby	
Red-tailed hawk, *Buteo jamaicensis*	FGC 3503.5		eBird nearby	Yes
Red-shouldered hawk, *Buteo lineatus*	FGC 3503.5		eBird nearby	
Osprey, *Pandion haliaetus*	FGC 3503.5		eBird nearby	
Sharp-shinned hawk, *Accipiter striatus*	FGC 3503.5		eBird nearby	
Cooper's hawk, *Accipiter cooperi*	FGC 3503.5, TWL		eBird nearby	Yes
Northern harrier, *Circus cyaneus*	SSC3, FGC 3503.5		eBird nearby	Yes
White-tailed kite, *Elanus leucurus*	CFP, FGC 3503.5		eBird nearby	
American kestrel, *Falco sparverius*	FGC 3503.5		eBird nearby	Yes
Merlin, *Falco columbarius*	FGC 3503.5, TWL		eBird nearby	
Prairie falcon, *Falco mexicanus*	BCC, FGC 3503.5, TWL		eBird nearby	
Peregrine falcon, *Falco peregrinus*	CE, CFP, BCC		eBird nearby	
Barn owl, *Tyto alba*	FGC 3503.5		eBird nearby	Yes
Burrowing owl, *Athene cunicularia*	BCC, SSC2, FGC 3503.5	Possible	eBird nearby	Yes
Yellow-billed cuckoo, *Coccyzus americanus*	FT, CE, BCC		eBird nearby	Yes
Gila woodpecker, *Melanerpes uropygialis*	CE, BCC	Possible	eBird nearby	
California gull, *Larus californicus*	TWL		eBird nearby	
Costa's hummingbird, *Calypte costae*	BCC	Possible	eBird nearby	
California horned lark, *Eremophila alpestris actia*	TWL		eBird nearby	Yes
Vermilion flycatcher, *Pyrocephalus rubinus*	SSC2		eBird nearby	
Loggerhead shrike, *Lanius ludovicianus*	FSC, SSC2		eBird nearby	Yes
Bank swallow, *Riparia riparia*	CT		eBird nearby	Yes

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Common name, *Species name*	Status[1]	Occurrence likelihood		Known collisions
		Imperial	Smallwood	
Cactus wren, *Campylorhychus brunneicapillus*	BCC		In region	
Yellow warbler, *Setophaga petechia*	BCC, SSC2		eBird nearby	Yes
Yellow-breasted chat, *Icteria virens*	SSC3		eBird nearby	Yes
Summer tanager, *Piranga rubra*	SSC1		eBird nearby	
Large-billed savannah sparrow, *Passerculus s. rostratus*	SSC2		eBird nearby	Yes
Yellow-headed blackbird, *X. xanthocephalus*	SSC3		eBird nearby	Yes
Pallid bat, *Antrozous pallidus*	SSC		iNaturalist nearby	Yes (fence)
Townsend's western big-eared bat, *Plecotus t. townsendii*	SSC		In range	
Western red bat, *Lasiurus blossevillii*	SSC		In range	
Western yellow bat, *Lasiurus xanthinus*	SSC		In range	
Small-footed myotis, *Myotis cililabrum*	WBWG		In range	
Long-eared myotis, *Myotis evotis*	WBWG		In range	
Fringed myotis, *Myotis thysanodes*	WBWG		In range	
Long-legged myotis, *Myotis volans*	WBWG		In range	
Yuma myotis, *Myotis yumanensis*	WBWG		In range	
Pocketed free-tailed bat, *Nyctinomops femorosaccus*	SSC		In range	
Big free-tailed bat, *Nyctinomops macrotis*	SSC		In range	
Flat-tailed horned lizard, *Phrynosoma mcallii*	SSC		iNaturalist nearby	

[1] Listed as FE or FT = federal endangered or threatened, BCC = U.S. Fish and Wildlife Service Bird of Conservation Concern, CE or CT = California endangered or threatened, CFP = California Fully Protected (CDFG Code 3511), SSC = California species of special concern (not threatened with extinction, but rare, very restricted in range, declining throughout range, peripheral portion of species' range, associated with habitat that is declining in extent) with priorities 1, 2 and 3, respectively (Shuford and Gardali 2008), FGC 3503.5 = California Fish and Game Code 3503.5 (Birds of prey), TWL = Taxa to Watch List (Shuford and Gardali 2008), WBWG = Western Bat Working Group listing with level of priority.

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County of Imperial (2020) gave no consideration to collision fatalities of volant wildlife attempting to fly across the existing or proposed future project. Furthermore, no collision, electrocution or entrapment fatality monitoring appears to have been performed at the project site. If there exists any form of volunteer reporting of wildlife fatalities found at the site, some summary of what has been found needs to be shared in the environmental review. If no such monitoring and reporting exists, the County of Imperial should rectify the situation by requiring both.

County of Imperial (2020:20) concludes that because "*the Project Site is completely devoid of any vegetation or water resources, the proposed disturbance area is not suitable habitat for any of the sensitive species…*" However, many volant species, including those with special status, inhabit the lower atmosphere just as they necessarily inhabit terrestrial or aquatic environments. Volant wildlife often fly over bare ground to migrate, disperse, forage, patrol home ranges, or to move from one habitat patch to another. This use of the lower atmosphere is the subject of study referred to as Aeroecology (Kunz et al. 2007). Aeroecology is a field of study I have been involved with for 21 years, because I study collisions of volant wildlife with anthropogenic structures inserted into the airspaces used by wildlife.

Anthropogenic structures known to cause fatal collisions of volant wildlife already occur on the project site, and with project approval these structures would continue to pose hazards to wildlife for another 30 years. These structures include at least 1,615 m of security fence and 1,000 m of electric distribution lines. The proposed project would replace some existing structures with 2 ORMAT energy converters and 3 above-ground, 10,000-gallon, isopentane storage tanks. Due to wildlife fatality monitoring at multiple industrial solar projects, where anthropogenic structures are just as static as those in the existing and proposed projects, empirical evidence is available to estimate ongoing and likely future wildlife collision mortality at the project.

Based on an average collision and entrapment (Photo 1) fatality rate of 17.4 birds/km of security fence surrounding 5 industrial solar projects (Campo Verde near the proposed project site, Desert Sunlight, McCoy, Blythe, and Genesis), the project's fencing likely kills 28.1 birds per year (17.4 bird fatalities/km × 1.615 km of fence at the project site). After 30 more years of this level of mortality, the project's fence will have killed another 843 birds.

Based on an average collision fatality rate of 91.4 birds/km of generation tie-ins of 8 industrial solar projects (Campo Verde and Centinela near the proposed project site, California Valley, Desert Sunlight, McCoy, Blythe, Stateline, and Genesis), the project's powerlines likely kill 91.4 birds per year (91.4 bird fatalities/km × 1 km of powerlines at the project site). After 30 more years of this level of mortality, the project's powerlines will have killed another 2,742 birds.

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Photo 1. *A great-horned owl died after becoming entangled on the razor wire placed on top of this cyclone fence surrounding a substation in Alameda County. Photo by Joanne Mount.*

The basis is more limited for predicting the level of collision mortality that would result from 30 years of operations of 2 ORMAT energy converters and 3 above-ground, 10,000-gallon, isopentane storage tanks. Collision fatality monitoring was performed at 2 powerblocks at the Genesis Solar Energy Project, where 94 bats and 968 birds were killed annually. Assuming the combined volume of the proposed 2 ORMAT energy converters and 3 above-ground, 10,000-gallon, isopentane storage tanks would compose about 65% of the volume of one of the powerblocks at Genesis, I can project the Genesis powerblock fatality rates to the proposed project to predict annual fatalities of about 31 bats and 315 birds.

Together, the existing structures and proposed new structures would result in annual collision fatalities of 435 birds and 31 bats. After 30 years of operations, this level of mortality would have accumulated 13,050 birds and 930 bats. These fatality totals might seem incredible by those inexperienced with wildlife fatality monitoring, so I will explain why these estimates are credible even though few fatalities are actually ever seen. Many collision fatalities happen at night. Those that happen during daylight often escape witness by human eyes because facility personnel do not spend much time staring at fences, powerlines or other structures. Once the fatalities occur, vertebrate scavengers remove carcasses shortly after the victims fall to the ground (Smallwood et al. 2018). Vertebrate scavengers entrain on facilities that produce dead birds and bats. Carcasses are typically removed within a few days, and removal rates increase as ground cover diminishes. There is no ground cover at the project site, so vertebrate scavengers quickly detect newly killed birds and bats, and they quickly remove them.

That vertebrate scavengers occur on the site is indisputable, as they are visible in Google Earth imagery (Photo 2). Google Earth imagery shows 4 common ravens taking off from structures on the project site. In my experience, common ravens remove carcasses of collision victims faster than any other vertebrate scavengers, sometimes removing

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carcasses within a minute of deposition (Smallwood et al. 2010). That common ravens are readily detectable in Google Earth imagery suggests to me that the site is providing vertebrate scavengers with regular, reliable food resources, which means the project is likely already killing birds and bats. A fair argument can be made for the need to prepare an EIR to assess the project's impacts to wildlife in terms of direct mortality and interference with the ability of wildlife to move within the region.



Photo 2. *Four common ravens leaving the project site. Photo by Google Earth StreetView.*

The fatalities I predicted above need to be assessed for their contribution to cumulative impacts caused by existing and future projects that cause collision fatalities. For example, the California Energy Commission estimates 1,488.5 MW of industrial solar have been installed in Imperial County (https://ww2.energy.ca.gov/almanac/renewables_data/solar/index_cms.php). Applying the MW-weighted average of the number of bird collision fatalities/MW from nearby solar projects (Campo Verde, Centinela, Imperial, Calipatria, and Midway [Smallwood, unpublished data]) to the CEC's estimated 1,488.5 MW of installed capacity, I estimate a cumulative annual mortality of 29,268 (95% CI: 24,803-47,476) birds. This is a substantial number of birds – a number that easily qualifies as a significant cumulative impact which the proposed project would worsen. A fair argument can be made for the need to prepare an EIR to assess the project's contribution to cumulative impacts to wildlife.

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MITIGATION

According to County of Imperial (2020:20), "*…SIGG will perform a pre-construction survey to verify the absence of any sensitive species (i.e. burrowing owl).*" However, preconstruction surveys cannot verify the absence of any species, as verification of absence is not what preconstruction surveys are designed to achieve. Preconstruction surveys are surveys intended to detect and salvage readily detectable individuals before they are destroyed by heavy machinery. The only type of survey that can verify absence is a 'detection survey.' Detection surveys are intended for providing the best means of detecting a particular species and for supporting determinations of absence when the species has not been detected despite implementation of detection surveys. Detection surveys are also intended to inform preconstruction surveys and to inform mitigation planning. The protocols for detection surveys have been developed by experts on the species, usually in coordination with natural resource agencies. The protocol for detection surveys applied to burrowing owl can be found in CDFW (2012). Detection surveys need to be performed according to available guidelines, and prior to preconstruction surveys.

Both a preconstruction survey for wildlife and an on-site speed-limit should be implemented as mitigation to minimize project impacts. However, much more is needed, including appropriate detection surveys, as discussed above, as well as compensatory mitigation for those impacts that could not be avoided. Compensatory mitigation should be provided in the form of off-site habitat protections and donations to wildlife rehabilitation facilities. With the ongoing collision-injuries of the current project and the collision-injuries at 1,488.5 MW of installed industrial solar facilities in Imperial County, local wildlife rehabilitation facilities probably need considerable support to treat and release the animals they receive. A fair argument can be made for the need to prepare an EIR to appropriately formulate mitigation measures to further minimize and to compensate for project impacts to wildlife.

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Kenneth Shawn Smallwood
Curriculum Vitae

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Born May 3, 1963 in Sacramento, California. Married, father of two.

Ecologist

Expertise

- Finding solutions to controversial problems related to wildlife interactions with human industry, infrastructure, and activities;
- Wildlife monitoring and field study using GPS, thermal imaging, behavior surveys;
- Using systems analysis and experimental design principles to identify meaningful ecological patterns that inform management decisions.

Education

Ph.D. Ecology, University of California, Davis. September 1990.
M.S. Ecology, University of California, Davis. June 1987.
B.S. Anthropology, University of California, Davis. June 1985.
Corcoran High School, Corcoran, California. June 1981.

Experience

- 480 professional publications, including:
- 83 peer reviewed publications
- 24 in non-reviewed proceedings
- 371 reports, declarations, posters and book reviews
- 8 in mass media outlets
- 87 public presentations of research results

Editing for scientific journals: Guest Editor, *Wildlife Society Bulletin*, 2012-2013, of invited papers representing international views on the impacts of wind energy on wildlife and how to mitigate the impacts. Associate Editor, *Journal of Wildlife Management*, March 2004 to 30 June 2007. Editorial Board Member, *Environmental Management*, 10/1999 to 8/2004. Associate Editor, *Biological Conservation*, 9/1994 to 9/1995.

Member, Alameda County Scientific Review Committee (SRC), August 2006 to April 2011. The five-member committee investigated causes of bird and bat collisions in the Altamont Pass Wind Resource Area, and recommended mitigation and monitoring measures. The SRC

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reviewed the science underlying the Alameda County Avian Protection Program, and advised the County on how to reduce wildlife fatalities.

Consulting Ecologist, 2004-2007, California Energy Commission (CEC). Provided consulting services as needed to the CEC on renewable energy impacts, monitoring and research, and produced several reports. Also collaborated with Lawrence-Livermore National Lab on research to understand and reduce wind turbine impacts on wildlife.

Consulting Ecologist, 1999-2013, U.S. Navy. Performed endangered species surveys, hazardous waste site monitoring, and habitat restoration for the endangered San Joaquin kangaroo rat, California tiger salamander, California red-legged frog, California clapper rail, western burrowing owl, salt marsh harvest mouse, and other species at Naval Air Station Lemoore; Naval Weapons Station, Seal Beach, Detachment Concord; Naval Security Group Activity, Skaggs Island; National Radio Transmitter Facility, Dixon; and, Naval Outlying Landing Field Imperial Beach.

Part-time Lecturer, 1998-2005, California State University, Sacramento. Instructed Mammalogy, Behavioral Ecology, and Ornithology Lab, Contemporary Environmental Issues, Natural Resources Conservation.

Senior Ecologist, 1999-2005, BioResource Consultants. Designed and implemented research and monitoring studies related to avian fatalities at wind turbines, avian electrocutions on electric distribution poles across California, and avian fatalities at transmission lines.

Chairman, Conservation Affairs Committee, The Wildlife Society--Western Section, 1999-2001. Prepared position statements and led efforts directed toward conservation issues, including travel to Washington, D.C. to lobby Congress for more wildlife conservation funding.

Systems Ecologist, 1995-2000, Institute for Sustainable Development. Headed ISD's program on integrated resources management. Developed indicators of ecological integrity for large areas, using remotely sensed data, local community involvement and GIS.

Associate, 1997-1998, Department of Agronomy and Range Science, University of California, Davis. Worked with Shu Geng and Mingua Zhang on several studies related to wildlife interactions with agriculture and patterns of fertilizer and pesticide residues in groundwater across a large landscape.

Lead Scientist, 1996-1999, National Endangered Species Network. Informed academic scientists and environmental activists about emerging issues regarding the Endangered Species Act and other environmental laws. Testified at public hearings on endangered species issues.

Ecologist, 1997-1998, Western Foundation of Vertebrate Zoology. Conducted field research to determine the impact of past mercury mining on the status of California red-legged frogs in Santa Clara County, California.

Senior Systems Ecologist, 1994-1995, EIP Associates, Sacramento, California. Provided consulting services in environmental planning, and quantitative assessment of land units for their

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conservation and restoration opportunities basedon ecological resource requirements of 29 special-status species. Developed ecological indicators for prioritizing areas within Yolo County to receive mitigation funds for habitat easements and restoration.

Post-Graduate Researcher, 1990-1994, Department of Agronomy and Range Science, *U.C. Davis*. Under Dr. Shu Geng's mentorship, studied landscape and management effects on temporal and spatial patterns of abundance among pocket gophers and species of Falconiformes and Carnivora in the Sacramento Valley. Managed and analyzed a data base of energy use in California agriculture. Assisted with landscape (GIS) study of groundwater contamination across Tulare County, California.

Work experience in graduate school: Co-taught Conservation Biology with Dr. Christine Schonewald, 1991 & 1993, UC Davis Graduate Group in Ecology; Reader for Dr. Richard Coss's course on Psychobiology in 1990, UC Davis Department of Psychology; Research Assistant to Dr. Walter E. Howard, 1988-1990, UC Davis Department of Wildlife and Fisheries Biology, testing durable baits for pocket gopher management in forest clearcuts; Research Assistant to Dr. Terrell P. Salmon, 1987-1988, UC Wildlife Extension, Department of Wildlife and Fisheries Biology, developing empirical models of mammal and bird invasions in North America, and a rating system for priority research and control of exotic species based on economic, environmental and human health hazards in California. Student Assistant to Dr. E. Lee Fitzhugh, 1985-1987, UC Cooperative Extension, Department of Wildlife and Fisheries Biology, developing and implementing statewide mountain lion track count for long-term monitoring.

Fulbright Research Fellow, Indonesia, 1988. Tested use of new sampling methods for numerical monitoring of Sumatran tiger and six other species of endemic felids, and evaluated methods used by other researchers.

Projects

Repowering wind energy projects through careful siting of new wind turbines using map-based collision hazard models to minimize impacts to volant wildlife. Funded by wind companies (principally NextEra Renewable Energy, Inc.), California Energy Commission and East Bay Regional Park District, I have collaborated with a GIS analyst and managed a crew of five field biologists performing golden eagle behavior surveys and nocturnal surveys on bats and owls. The goal is to quantify flight patterns for development of predictive models to more carefully site new wind turbines in repowering projects. Focused behavior surveys began May 2012 and continue. Collision hazard models have been prepared for seven wind projects, three of which were built. Planning for additional repowering projects is underway.

Test avian safety of new mixer-ejector wind turbine (MEWT). Designed and implemented a before-after, control-impact experimental design to test the avian safety of a new, shrouded wind turbine developed by Ogin Inc. (formerly known as FloDesign Wind Turbine Corporation). Supported by a $718,000 grant from the California Energy Commission's Public Interest Energy Research program and a 20% match share contribution from Ogin, I managed a crew of seven field biologists who performed periodic fatality searches and behavior surveys, carcass detection trials, nocturnal behavior surveys using a thermal camera, and spatial analyses with the collaboration of a GIS

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analyst. Field work began 1 April 2012 and ended 30 March 2015 without Ogin installing its MEWTs, but we still achieved multiple important scientific advances.

Reduce avian mortality due to wind turbines at Altamont Pass. Studied wildlife impacts caused by 5,400 wind turbines at the world's most notorious wind resource area. Studied how impacts are perceived by monitoring and how they are affected by terrain, wind patterns, food resources, range management practices, wind turbine operations, seasonal patterns, population cycles, infrastructure management such as electric distribution, animal behavior and social interactions.

Reduce avian mortality on electric distribution poles. Directed research toward reducing bird electrocutions on electric distribution poles, 2000-2007. Oversaw 5 founds of fatality searches at 10,000 poles from Orange County to Glenn County, California, and produced two large reports.

Cook *et al*. v. Rockwell International *et al*., No. 90-K-181 (D. Colorado). Provided expert testimony on the role of burrowing animals in affecting the fate of buried and surface-deposited radioactive and hazardous chemical wastes at the Rocky Flats Plant, Colorado. Provided expert reports based on four site visits and an extensive document review of burrowing animals. Conducted transect surveys for evidence of burrowing animals and other wildlife on and around waste facilities. Discovered substantial intrusion of waste structures by burrowing animals. I testified in federal court in November 2005, and my clients were subsequently awarded a $553,000,000 judgment by a jury. After appeals the award was increased to two billion dollars.

Hanford Nuclear Reservation Litigation. Provided expert testimony on the role of burrowing animals in affecting the fate of buried radioactive wastes at the Hanford Nuclear Reservation, Washington. Provided three expert reports based on three site visits and extensive document review. Predicted and verified a certain population density of pocket gophers on buried waste structures, as well as incidence of radionuclide contamination in body tissue. Conducted transect surveys for evidence of burrowing animals and other wildlife on and around waste facilities. Discovered substantial intrusion of waste structures by burrowing animals.

Expert testimony and declarations on proposed residential and commercial developments, gas-fired power plants, wind, solar and geothermal projects, water transfers and water transfer delivery systems, endangered species recovery plans, Habitat Conservation Plans and Natural Communities Conservation Programs. Testified before multiple government agencies, Tribunals, Boards of Supervisors and City Councils, and participated with press conferences and depositions. Prepared expert witness reports and court declarations, which are summarized under Reports (below).

Protocol-level surveys for special-status species. Used California Department of Fish and Wildlife and US Fish and Wildlife Service protocols to search for California red-legged frog, California tiger salamander, arroyo southwestern toad, blunt-nosed leopard lizard, western pond turtle, giant kangaroo rat, San Joaquin kangaroo rat, San Joaquin kit fox, western burrowing owl, Swainson's hawk, Valley elderberry longhorn beetle and other special-status species.

Conservation of San Joaquin kangaroo rat. Performed research to identify factors responsible for the decline of this endangered species at Lemoore Naval Air Station, 2000-2013, and implemented habitat enhancements designed to reverse the trend and expand the population.

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Impact of West Nile Virus on yellow-billed magpies. Funded by Sacramento-Yolo Mosquito and Vector Control District, 2005-2008, compared survey results pre- and post-West Nile Virus epidemic for multiple bird species in the Sacramento Valley, particularly on yellow-billed magpie and American crow due to susceptibility to WNV.

Workshops on HCPs. Assisted Dr. Michael Morrison with organizing and conducting a 2-day workshop on Habitat Conservation Plans, sponsored by Southern California Edison, and another 1-day workshop sponsored by PG&E. These Workshops were attended by academics, attorneys, and consultants with HCP experience. We guest-edited a Proceedings published in Environmental Management.

Mapping of biological resources along Highways 101, 46 and 41. Used GPS and GIS to delineate vegetation complexes and locations of special-status species along 26 miles of highway in San Luis Obispo County, 14 miles of highway and roadway in Monterey County, and in a large area north of Fresno, including within reclaimed gravel mining pits.

GPS mapping and monitoring at restoration sites and at Caltrans mitigation sites. Monitored the success of elderberry shrubs at one location, the success of willows at another location, and the response of wildlife to the succession of vegetation at both sites. Also used GPS to monitor the response of fossorial animals to yellow star-thistle eradication and natural grassland restoration efforts at Bear Valley in Colusa County and at the decommissioned Mather Air Force Base in Sacramento County.

Mercury effects on Red-legged Frog. Assisted Dr. Michael Morrison and US Fish and Wildlife Service in assessing the possible impacts of historical mercury mining on the federally listed California red-legged frog in Santa Clara County. Also measured habitat variables in streams.

Opposition to proposed No Surprises rule. Wrote a white paper and summary letter explaining scientific grounds for opposing the incidental take permit (ITP) rules providing ITP applicants and holders with general assurances they will be free of compliance with the Endangered Species Act once they adhere to the terms of a "properly functioning HCP." Submitted 188 signatures of scientists and environmental professionals concerned about No Surprises rule US Fish and Wildlife Service, National Marine Fisheries Service, all US Senators.

Natomas Basin Habitat Conservation Plan alternative. Designed narrow channel marsh to increase the likelihood of survival and recovery in the wild of giant garter snake, Swainson's hawk and Valley Elderberry Longhorn Beetle. The design included replication and interspersion of treatments for experimental testing of critical habitat elements. I provided a report to Northern Territories, Inc.

Assessments of agricultural production system and environmental technology transfer to China. Twice visited China and interviewed scientists, industrialists, agriculturalists, and the Directors of the Chinese Environmental Protection Agency and the Department of Agriculture to assess the need and possible pathways for environmental clean-up technologies and trade opportunities between the US and China.

Yolo County Habitat Conservation Plan. Conducted landscape ecology study of Yolo County to spatially prioritize allocation of mitigation efforts to improve ecosystem functionality within the

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County from the perspective of 29 special-status species of wildlife and plants. Used a hierarchically structured indicators approach to apply principles of landscape and ecosystem ecology, conservation biology, and local values in rating land units. Derived GIS maps to help guide the conservation area design, and then developed implementation strategies.

Mountain lion track count. Developed and conducted a carnivore monitoring program throughout California since 1985. Species counted include mountain lion, bobcat, black bear, coyote, red and gray fox, raccoon, striped skunk, badger, and black-tailed deer. Vegetation and land use are also monitored. Track survey transect was established on dusty, dirt roads within randomly selected quadrats.

Sumatran tiger and other felids. Upon award of Fulbright Research Fellowship, I designed and initiated track counts for seven species of wild cats in Sumatra, including Sumatran tiger, fishing cat, and golden cat. Spent four months on Sumatra and Java in 1988, and learned Bahasa Indonesia, the official Indonesian language.

Wildlife in agriculture. Beginning as post-graduate research, I studied pocket gophers and other wildlife in 40 alfalfa fields throughout the Sacramento Valley, and I surveyed for wildlife along a 200 mile road transect since 1989 with a hiatus of 1996-2004. The data are analyzed using GIS and methods from landscape ecology, and the results published and presented orally to farming groups in California and elsewhere. I also conducted the first study of wildlife in cover crops used on vineyards and orchards.

Agricultural energy use and Tulare County groundwater study. Developed and analyzed a data base of energy use in California agriculture, and collaborated on a landscape (GIS) study of groundwater contamination across Tulare County, California.

Pocket gopher damage in forest clear-cuts. Developed gopher sampling methods and tested various poison baits and baiting regimes in the largest-ever field study of pocket gopher management in forest plantations, involving 68 research plots in 55 clear-cuts among 6 National Forests in northern California.

Risk assessment of exotic species in North America. Developed empirical models of mammal and bird species invasions in North America, as well as a rating system for assigning priority research and control to exotic species in California, based on economic, environmental, and human health hazards.

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Comments on Environmental Documents

I was retained or commissioned to comment on environmental planning and review documents, including:

- The Villages of Lakeview EIR (2017; 28 pp);
- Notes on Proposed Study Options for Trail Impacts on Northern Spotted Owl (2017; 4 pp);
- San Gorgonio Crossings EIR (2017; 22 pp);
- Replies to responses on Jupiter Project IS and MND (2017; 12 pp);
- MacArthur Transit Village Project Modified 2016 CEQA Analysis (2017; 12 pp);
- Central SoMa Plan DEIR (2017; 14 pp);
- Colony Commerce Center Specific Plan DEIR (2016; 16 pp);
- Fairway Trails Improvements MND (2016; 13 pp);
- Review of Avian-Solar Science Plan (2016; 28 pp);
- Replies to responses on Initial Study for Pyramid Asphalt (2016; 5 pp);
- Initial Study for Pyramid Asphalt (2016; 4 pp);
- Agua Mansa Distribution Warehouse Project Initial Study (2016; 14 pp);
- Santa Anita Warehouse IS and MND (2016; 12 pp);
- CapRock Distribution Center III DEIR (2016: 12 pp);
- Orange Show Logistics Center Initial Study and MND (2016; 9 pp);
- City of Palmdale Oasis Medical Village Project IS and MND (2016; 7 pp);
- Comments on proposed rule for incidental eagle take (2016, 49 pp);
- Grapevine Specific and Community Plan FEIR (2016; 25 pp);
- Grapevine Specific and Community Plan DEIR (2016; 15 pp);
- Clinton County Zoning Ordinance for Wind Turbine siting (2016);
- Hallmark at Shenandoah Warehouse Project Initial Study (2016; 6 pp);
- Tri-City Industrial Complex Initial Study (2016; 5 pp);
- Hidden Canyon Industrial Park Plot Plan 16-PP-02 (2016; 12 pp);
- Kimball Business Park DEIR (2016; 10 pp);
- Jupiter Project IS and MND (2016; 9 pp);
- Revised Draft Giant Garter Snake Recovery Plan of 2015 (2016, 18 pp);
- Palo Verde Mesa Solar Project Draft Environmental Impact Report (2016; 27 pp);

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- Reply Witness Statement on Fairview Wind Project, Ontario, Canada (2016; 14 pp);
- Fairview Wind Project, Ontario, Canada (2016; 41 pp);
- Supplementary Reply Witness Statement Amherst Island Wind Farm, Ontario (2015, 38 pp);
- Witness Statement on Amherst Island Wind Farm, Ontario (2015, 31 pp);
- Second Reply Witness Statement on White Pines Wind Farm, Ontario (2015, 6 pp);
- Reply Witness Statement on White Pines Wind Farm, Ontario (2015, 10 pp);
- Witness Statement on White Pines Wind Farm, Ontario (2015, 9 pp);
- Proposed Section 24 Specific Plan Agua Caliente Band of Cahuilla Indians DEIS (2015, 9 pp);
- Replies to comments 24 Specific Plan Agua Caliente Band of Cahuilla Indians FEIS (2015, 6 pp);
- Willow Springs Solar Photovoltaic Project DEIR (2015; 28 pp);
- Sierra Lakes Commerce Center Project DEIR (2015, 9 pp);
- Columbia Business Center MND (2015; 8 pp);
- West Valley Logistics Center Specific Plan DEIR (2015, 10 pp);
- World Logistic Center Specific Plan FEIR (2015, 12 pp);
- Bay Delta Conservation Plan EIR/EIS (2014, 21 pp);
- Addison Wind Energy Project DEIR (2014, 32 pp);
- Response to Comments on the Addison Wind Energy Project DEIR (2014, 15 pp);
- Addison and Rising Tree Wind Energy Project FEIR (2014, 12 pp);
- Alta East Wind Energy Project FEIS (2013, 23 pp);
- Blythe Solar Power Project Staff Assessment, California Energy Commission (2013, 16 pp);
- Clearwater and Yakima Solar Projects DEIR (2013, 9 pp);
- Cuyama Solar Project DEIR (2014, 19 pp);
- Draft Desert Renewable Energy Conservation Plan (DRECP) EIR/EIS (2015, 49 pp);
- Kingbird Solar Photovoltaic Project EIR (2013, 19 pp);
- Lucerne Valley Solar Project Initial Study & Mitigated Negative Declaration (2013, 12 pp);
- Palen Solar Electric Generating System Final Staff Assessment of California Energy Commission, (2014, 20 pp);
- Rebuttal testimony on Palen Solar Energy Generating System (2014, 9 pp);
- Rising Tree Wind Energy Project DEIR (2014, 32 pp);
- Response to Comments on the Rising Tree Wind Energy Project DEIR (2014, 15 pp);
- Soitec Solar Development Project Draft PEIR (2014, 18 pp);
- Comment on the Biological Opinion (08ESMF-00-2012-F-0387) of Oakland Zoo expansion on Alameda whipsnake and California red-legged frog (2014; 3 pp);
- West Antelope Solar Energy Project Initial Study and Negative Declaration (2013, 18 pp);
- Willow Springs Solar Photovoltaic Project DEIR (2015, 28 pp);
- Alameda Creek Bridge Replacement Project DEIR (2015, 10 pp);
- Declaration on Tule Wind project FEIR/FEIS (2013; 24 pp);
- Sunlight Partners LANDPRO Solar Project Mitigated Negative Declaration (2013; 11 pp);
- Declaration in opposition to BLM fracking (2013; 5 pp);
- Rosamond Solar Project Addendum EIR (2013; 13 pp);
- Pioneer Green Solar Project EIR (2013; 13 pp);
- Reply to Staff Responses to Comments on Soccer Center Solar Project Mitigated Negative

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Declaration (2013; 6 pp);
- Soccer Center Solar Project Mitigated Negative Declaration (2013; 10 pp);
- Plainview Solar Works Mitigated Negative Declaration (2013; 10 pp);
- Reply to the County Staff's Responses on comments to Imperial Valley Solar Company 2 Project (2013; 10 pp);
- Imperial Valley Solar Company 2 Project (2013; 13 pp);
- FRV Orion Solar Project DEIR (PP12232) (2013; 9 pp);
- Casa Diablo IV Geothermal Development Project (3013; 6 pp);
- Reply to Staff Responses to Comments on Casa Diablo IV Geothermal Development Project (2013; 8 pp);
- FEIS prepared for Alta East Wind Project (2013; 23 pp);
- Metropolitan Air Park DEIR, City of San Diego (2013;);
- Davidon Homes Tentative Subdivision Map and Rezoning Project DEIR (2013; 9 pp);
- Analysis of Biological Assessment of Oakland Zoo Expansion Impacts on Alameda Whipsnake (2013; 10 pp);
- Declaration on Campo Verde Solar project FEIR (2013; 11pp);
- Neg Dec comments on Davis Sewer Trunk Rehabilitation (2013; 8 pp);
- Declaration on North Steens Transmission Line FEIS (2012; 62 pp);
- City of Lancaster Revised Initial Study for Conditional Use Permits 12-08 and 12-09, Summer Solar and Springtime Solar Projects (2012; 8 pp);
- J&J Ranch, 24 Adobe Lane Environmental Review (2012; 14 pp);
- Reply to the County Staff's Responses on comments to Hudson Ranch Power II Geothermal Project and the Simbol Calipatria Plant II (2012; 8 pp);
- Hudson Ranch Power II Geothermal Project and the Simbol Calipatria Plant II (2012; 9 pp);
- Desert Harvest Solar Project EIS (2012; 15 pp);
- Solar Gen 2 Array Project DEIR (2012; 16 pp);
- Ocotillo Sol Project EIS (2012; 4 pp);
- Beacon Photovoltaic Project DEIR (2012; 5 pp);
- Declaration on Initial Study and Proposed Negative Declaration for the Butte Water District 2012 Water Transfer Program (2012; 11 pp);
- Mount Signal and Calexico Solar Farm Projects DEIR (2011; 16 pp);
- City of Elk Grove Sphere of Influence EIR (2011; 28 pp);
- Comment on Sutter Landing Park Solar Photovoltaic Project MND (2011; 9 pp);
- Statement of Shawn Smallwood, Ph.D. Regarding Proposed Rabik/Gudath Project, 22611 Coleman Valley Road, Bodega Bay (CPN 10-0002) (2011; 4 pp);
- Declaration of K. Shawn Smallwood on Biological Impacts of the Ivanpah Solar Electric Generating System (ISEGS) (2011; 9 pp);
- Comments on Draft Eagle Conservation Plan Guidance (2011; 13 pp);
- Comments on Draft EIR/EA for Niles Canyon Safety Improvement Project (2011; 16 pp);
- Declaration of K. Shawn Smallwood, Ph.D., on Biological Impacts of the Route 84 Safety Improvement Project (2011; 7 pp);
- Rebuttal Testimony of Witness #22, K. Shawn Smallwood, Ph.D, on Behalf of Intervenors Friends of The Columbia Gorge & Save Our Scenic Area (2010; 6 pp);
- Prefiled Direct Testimony of Witness #22, K. Shawn Smallwood, Ph.D, on Behalf of

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Intervenors Friends of the Columbia Gorge & Save Our Scenic Area. Comments on Whistling Ridge Wind Energy Power Project DEIS, Skamania County, Washington (2010; 41 pp);

- Evaluation of Klickitat County's Decisions on the Windy Flats West Wind Energy Project (2010; 17 pp);
- St. John's Church Project Draft Environmental Impact Report (2010; 14 pp.);
- Initial Study/Mitigated Negative Declaration for Results Radio Zone File #2009-001 (2010; 20 pp);
- Rio del Oro Specific Plan Project Final Environmental Impact Report (2010;12 pp);
- Answers to Questions on 33% RPS Implementation Analysis Preliminary Results Report (2009: 9 pp);
- SEPA Determination of Non-significance regarding zoning adjustments for Skamania County, Washington. Second Declaration to Friends of the Columbia Gorge, Inc. and Save Our Scenic Area (Dec 2008; 17 pp);
- Comments on Draft 1A Summary Report to CAISO (2008; 10 pp);
- County of Placer's Categorical Exemption of Hilton Manor Project (2009; 9 pp);
- Protest of CARE to Amendment to the Power Purchase and Sale Agreement for Procurement of Eligible Renewable Energy Resources Between Hatchet Ridge Wind LLC and PG&E (2009; 3 pp);
- Tehachapi Renewable Transmission Project EIR/EIS (2009; 142 pp);
- Delta Shores Project EIR, south Sacramento (2009; 11 pp + addendum 2 pp);
- Declaration of Shawn Smallwood in Support of Care's Petition to Modify D.07-09-040 (2008; 3 pp);
- The Public Utility Commission's Implementation Analysis December 16 Workshop for the Governor's Executive Order S-14-08 to implement a 33% Renewable Portfolio Standard by 2020 (2008; 9 pp);
- The Public Utility Commission's Implementation Analysis Draft Work Plan for the Governor's Executive Order S-14-08 to implement a 33% Renewable Portfolio Standard by 2020 (2008; 11 pp);
- Draft 1A Summary Report to California Independent System Operator for Planning Reserve Margins (PRM) Study (2008; 7 pp.);
- SEPA Determination of Non-significance regarding zoning adjustments for Skamania County, Washington. Declaration to Friends of the Columbia Gorge, Inc. and Save Our Scenic Area (Sep 2008; 16 pp);
- California Energy Commission's Preliminary Staff Assessment of the Colusa Generating Station (2007; 24 pp);
- Rio del Oro Specific Plan Project Recirculated Draft Environmental Impact Report (2008: 66 pp);
- Replies to Response to Comments Re: Regional University Specific Plan Environmental Impact Report (2008; 20 pp);
- Regional University Specific Plan Environmental Impact Report (2008: 33 pp.);
- Clark Precast, LLC's "Sugarland" project, Negative Declaration (2008: 15 pp.);
- Cape Wind Project Draft Environmental Impact Statement (2008; 157 pp.);
- Yuba Highlands Specific Plan (or Area Plan) Environmental Impact Report (2006; 37 pp.);
- Replies to responses to comments on Mitigated Negative Declaration of the proposed

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Mining Permit (MIN 04-01) and Modification of Use Permit 96-02 at North Table Mountain (2006; 5 pp);

- Mitigated Negative Declaration of the proposed Mining Permit (MIN 04-01) and Modification of Use Permit 96-02 at North Table Mountain (2006; 15 pp);
- Windy Point Wind Farm Environmental Review and EIS (2006; 14 pp and 36 Powerpoint slides in reply to responses to comments);
- Shiloh I Wind Power Project EIR (2005; 18 pp);
- Buena Vista Wind Energy Project Notice of Preparation of EIR (2004; 15 pp);
- Negative Declaration of the proposed Callahan Estates Subdivision (2004; 11 pp);
- Negative Declaration of the proposed Winters Highlands Subdivision (2004; 9 pp);
- Negative Declaration of the proposed Winters Highlands Subdivision (2004; 13 pp);
- Negative Declaration of the proposed Creekside Highlands Project, Tract 7270 (2004; 21 pp);
- On the petition California Fish and Game Commission to list the Burrowing Owl as threatened or endangered (2003; 10 pp);
- Conditional Use Permit renewals from Alameda County for wind turbine operations in the Altamont Pass Wind Resource Area (2003; 41 pp);
- UC Davis Long Range Development Plan of 2003, particularly with regard to the Neighborhood Master Plan (2003; 23 pp);
- Anderson Marketplace Draft Environmental Impact Report (2003: 18 pp + 3 plates of photos);
- Negative Declaration of the proposed expansion of Temple B'nai Tikyah (2003: 6 pp);
- Antonio Mountain Ranch Specific Plan Public Draft EIR (2002: 23 pp);
- Response to testimony of experts at the East Altamont Energy Center evidentiary hearing on biological resources (2002: 9 pp);
- Revised Draft Environmental Impact Report, The Promenade (2002: 7 pp);
- Recirculated Initial Study for Calpine's proposed Pajaro Valley Energy Center (2002: 3 pp);
- UC Merced -- Declaration of Dr. Shawn Smallwood in support of petitioner's application for temporary restraining order and preliminary injunction (2002: 5 pp);
- Replies to response to comments in Final Environmental Impact Report, Atwood Ranch Unit III Subdivision (2003: 22 pp);
- Draft Environmental Impact Report, Atwood Ranch Unit III Subdivision (2002: 19 pp + 8 photos on 4 plates);
- California Energy Commission Staff Report on GWF Tracy Peaker Project (2002: 17 pp + 3 photos; follow-up report of 3 pp);
- Initial Study and Negative Declaration, Silver Bend Apartments, Placer County (2002: 13 pp);
- UC Merced Long-range Development Plan DEIR and UC Merced Community Plan DEIR (2001: 26 pp);
- Initial Study, Colusa County Power Plant (2001: 6 pp);
- Comments on Proposed Dog Park at Catlin Park, Folsom, California (2001: 5 pp + 4 photos);
- Pacific Lumber Co. (Headwaters) Habitat Conservation Plan and Environmental Impact Report (1998: 28 pp);
- Final Environmental Impact Report/Statement for Issuance of Take authorization for listed

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species within the MSCP planning area in San Diego County, California (Fed. Reg. 62 (60): 14938, San Diego Multi-Species Conservation Program) (1997: 10 pp);
- Permit (PRT-823773) Amendment for the Natomas Basin Habitat Conservation Plan, Sacramento, CA (Fed. Reg. 63 (101): 29020-29021) (1998);
- Draft Recovery Plan for the Giant Garter Snake (*Thamnophis gigas*). (Fed. Reg. 64(176): 49497-49498) (1999: 8 pp);
- Review of the Draft Recovery Plan for the Arroyo Southwestern Toad (*Bufo microscaphus californicus*) (1998);
- Ballona West Bluffs Project Environmental Impact Report (1999: oral presentation);
- California Board of Forestry's proposed amended Forest Practices Rules (1999);
- Negative Declaration for the Sunset Skyranch Airport Use Permit (1999);
- Calpine and Bechtel Corporations' Biological Resources Implementation and Monitoring Program (BRMIMP) for the Metcalf Energy Center (2000: 10 pp);
- California Energy Commission's Final Staff Assessment of the proposed Metcalf Energy Center (2000);
- US Fish and Wildlife Service Section 7 consultation with the California Energy Commission regarding Calpine and Bechtel Corporations' Metcalf Energy Center (2000: 4 pp);
- California Energy Commission's Preliminary Staff Assessment of the proposed Metcalf Energy Center (2000: 11 pp);
- Site-specific management plans for the Natomas Basin Conservancy's mitigation lands, prepared by Wildlands, Inc. (2000: 7 pp);
- Affidavit of K. Shawn Smallwood in Spirit of the Sage Council, et al. (Plaintiffs) vs. Bruce Babbitt, Secretary, U.S. Department of the Interior, et al. (Defendants), Injuries caused by the No Surprises policy and final rule which codifies that policy (1999: 9 pp).

Comments on other Environmental Review Documents:

- Proposed Regulation for California Fish and Game Code Section 3503.5 (2015: 12 pp);
- Statement of Overriding Considerations related to extending Altamont Winds, Inc.'s Conditional Use Permit PLN2014-00028 (2015; 8 pp);
- Draft Program Level EIR for Covell Village (2005; 19 pp);
- Bureau of Land Management Wind Energy Programmatic EIS Scoping document (2003: 7 pp.);
- NEPA Environmental Analysis for Biosafety Level 4 National Biocontainment Laboratory (NBL) at UC Davis (2003: 7 pp);
- Notice of Preparation of UC Merced Community and Area Plan EIR, on behalf of The Wildlife Society—Western Section (2001: 8 pp.);
- Preliminary Draft Yolo County Habitat Conservation Plan (2001; 2 letters totaling 35 pp.);
- Merced County General Plan Revision, notice of Negative Declaration (2001: 2 pp.);
- Notice of Preparation of Campus Parkway EIR/EIS (2001: 7 pp.);
- Draft Recovery Plan for the bighorn sheep in the Peninsular Range (*Ovis candensis*) (2000);
- Draft Recovery Plan for the California Red-legged Frog (*Rana aurora draytonii*), on behalf of The Wildlife Society—Western Section (2000: 10 pp.);
- Sierra Nevada Forest Plan Amendment Draft Environmental Impact Statement, on behalf of The Wildlife Society—Western Section (2000: 7 pp.);

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- State Water Project Supplemental Water Purchase Program, Draft Program EIR (1997);
- Davis General Plan Update EIR (2000);
- Turn of the Century EIR (1999: 10 pp);
- Proposed termination of Critical Habitat Designation under the Endangered Species Act (Fed. Reg. 64(113): 31871-31874) (1999);
- NOA Draft Addendum to the Final Handbook for Habitat Conservation Planning and Incidental Take Permitting Process, termed the HCP 5-Point Policy Plan (Fed. Reg. 64(45): 11485 - 11490) (1999; 2 pp + attachments);
- Covell Center Project EIR and EIR Supplement (1997).

Position Statements I prepared the following position statements for the Western Section of The Wildlife Society, and one for nearly 200 scientists:

- Recommended that the California Department of Fish and Game prioritize the extermination of the introduced southern water snake in northern California. The Wildlife Society--Western Section (2001);
- Recommended that The Wildlife Society—Western Section appoint or recommend members of the independent scientific review panel for the UC Merced environmental review process (2001);
- Opposed the siting of the University of California's 10th campus on a sensitive vernal pool/grassland complex east of Merced. The Wildlife Society--Western Section (2000);
- Opposed the legalization of ferret ownership in California. The Wildlife Society--Western Section (2000);
- Opposed the Proposed "No Surprises," "Safe Harbor," and "Candidate Conservation Agreement" rules, including permit-shield protection provisions (Fed. Reg. Vol. 62, No. 103, pp. 29091-29098 and No. 113, pp. 32189-32194). This statement was signed by 188 scientists and went to the responsible federal agencies, as well as to the U.S. Senate and House of Representatives.

Posters at Professional Meetings

Leyvas, E. and K. S. Smallwood. 2015. Rehabilitating injured animals to offset and rectify wind project impacts. Conference on Wind Energy and Wildlife Impacts, Berlin, Germany, 9-12 March 2015.

Smallwood, K. S., J. Mount, S. Standish, E. Leyvas, D. Bell, E. Walther, B. Karas. 2015. Integrated detection trials to improve the accuracy of fatality rate estimates at wind projects. Conference on Wind Energy and Wildlife Impacts, Berlin, Germany, 9-12 March 2015.

Smallwood, K. S. and C. G. Thelander. 2005. Lessons learned from five years of avian mortality research in the Altamont Pass WRA. AWEA conference, Denver, May 2005.

Neher, L., L. Wilder, J. Woo, L. Spiegel, D. Yen-Nakafugi, and K.S. Smallwood. 2005. Bird's eye view on California wind. AWEA conference, Denver, May 2005.

Smallwood, K. S., C. G. Thelander and L. Spiegel. 2003. Toward a predictive model of avian

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fatalities in the Altamont Pass Wind Resource Area. Windpower 2003 Conference and Convention, Austin, Texas.

Smallwood, K.S. and Eva Butler. 2002. Pocket Gopher Response to Yellow Star-thistle Eradication as part of Grassland Restoration at Decommissioned Mather Air Force Base, Sacramento County, California. White Mountain Research Station Open House, Barcroft Station.

Smallwood, K.S. and Michael L. Morrison. 2002. Fresno kangaroo rat (*Dipodomys nitratoides*) Conservation Research at Resources Management Area 5, Lemoore Naval Air Station. White Mountain Research Station Open House, Barcroft Station.

Smallwood, K.S. and E.L. Fitzhugh. 1989. Differentiating mountain lion and dog tracks. Third Mountain Lion Workshop, Prescott, AZ.

Smith, T. R. and K. S. Smallwood. 2000. Effects of study area size, location, season, and allometry on reported *Sorex* shrew densities. Annual Meeting of the Western Section of The Wildlife Society.

Presentations at Professional Meetings and Seminars

Repowering the Altamont Pass. Altamont Symposium, The Wildlife Society – Western Section, 5 February 2017.

Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area, 1999-2007. Altamont Symposium, The Wildlife Society – Western Section, 5 February 2017.

Conservation and recovery of burrowing owls in Santa Clara Valley. Santa Clara Valley Habitat Agency, Newark, California, 3 February 2017.

Mitigation of Raptor Fatalities in the Altamont Pass Wind Resource Area. Raptor Research Foundation Meeting, Sacramento, California, 6 November 2015.

From burrows to behavior: Research and management for burrowing owls in a diverse landscape. California Burrowing Owl Consortium meeting, 24 October 2015, San Jose, California.

The Challenges of repowering. Keynote presentation at Conference on Wind Energy and Wildlife Impacts, Berlin, Germany, 10 March 2015.

Research Highlights Altamont Pass 2011-2015. Scientific Review Committee, Oakland, California, 8 July 2015.

Siting wind turbines to minimize raptor collisions: Altamont Pass Wind Resource Area. US Fish and Wildlife Service Golden Eagle Working Group, Sacramento, California, 8 January 2015.

Evaluation of nest boxes as a burrowing owl conservation strategy. Sacramento Chapter of the Western Section, The Wildlife Society. Sacramento, California, 26 August 2013.

Predicting collision hazard zones to guide repowering of the Altamont Pass. Conference on wind

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power and environmental impacts. Stockholm, Sweden, 5-7 February 2013.

Impacts of Wind Turbines on Wildlife. California Council for Wildlife Rehabilitators, Yosemite, California, 12 November 2012.

Impacts of Wind Turbines on Birds and Bats. Madrone Audubon Society, Santa Rosa, California, 20 February 2012.

Comparing Wind Turbine Impacts across North America. California Energy Commission Staff Workshop: Reducing the Impacts of Energy Infrastructure on Wildlife, 20 July 2011.

Siting Repowered Wind Turbines to Minimize Raptor Collisions. California Energy Commission Staff Workshop: Reducing the Impacts of Energy Infrastructure on Wildlife, 20 July 2011.

Siting Repowered Wind Turbines to Minimize Raptor Collisions. Alameda County Scientific Review Committee meeting, 17 February 2011

Comparing Wind Turbine Impacts across North America. Conference on Wind energy and Wildlife impacts, Trondheim, Norway, 3 May 2011.

Update on Wildlife Impacts in the Altamont Pass Wind Resource Area. Raptor Symposium, The Wildlife Society—Western Section, Riverside, California, February 2011.

Siting Repowered Wind Turbines to Minimize Raptor Collisions. Raptor Symposium, The Wildlife Society - Western Section, Riverside, California, February 2011.

Wildlife mortality caused by wind turbine collisions. Ecological Society of America, Pittsburgh, Pennsylvania, 6 August 2010.

Map-based repowering and reorganization of a wind farm to minimize burrowing owl fatalities. California burrowing Owl Consortium Meeting, Livermore, California, 6 February 2010.

Environmental barriers to wind power. Getting Real About Renewables: Economic and Environmental Barriers to Biofuels and Wind Energy. A symposium sponsored by the Environmental & Energy Law & Policy Journal, University of Houston Law Center, Houston, 23 February 2007.

Lessons learned about bird collisions with wind turbines in the Altamont Pass and other US wind farms. Meeting with Japan Ministry of the Environment and Japan Ministry of the Economy, Wild Bird Society of Japan, and other NGOs Tokyo, Japan, 9 November 2006.

Lessons learned about bird collisions with wind turbines in the Altamont Pass and other US wind farms. Symposium on bird collisions with wind turbines. Wild Bird Society of Japan, Tokyo, Japan, 4 November 2006.

Responses of Fresno kangaroo rats to habitat improvements in an adaptive management framework. California Society for Ecological Restoration (SERCAL) 13th Annual Conference, UC Santa

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Barbara, 27 October 2006.

Fatality associations as the basis for predictive models of fatalities in the Altamont Pass Wind Resource Area. EEI/APLIC/PIER Workshop, 2006 Biologist Task Force and Avian Interaction with Electric Facilities Meeting, Pleasanton, California, 28 April 2006.

Burrowing owl burrows and wind turbine collisions in the Altamont Pass Wind Resource Area. The Wildlife Society - Western Section Annual Meeting, Sacramento, California, February 8, 2006.

Mitigation at wind farms. Workshop: Understanding and resolving bird and bat impacts. American Wind Energy Association and Audubon Society. Los Angeles, CA. January 10 and 11, 2006.

Incorporating data from the California Wildlife Habitat Relationships (CWHR) system into an impact assessment tool for birds near wind farms. Shawn Smallwood, Kevin Hunting, Marcus Yee, Linda Spiegel, Monica Parisi. Workshop: Understanding and resolving bird and bat impacts. American Wind Energy Association and Audubon Society. Los Angeles, CA. January 10 and 11, 2006.

Toward indicating threats to birds by California's new wind farms. California Energy Commission, Sacramento, May 26, 2005.

Avian collisions in the Altamont Pass. California Energy Commission, Sacramento, May 26, 2005.

Ecological solutions for avian collisions with wind turbines in the Altamont Pass Wind Resource Area. EPRI Environmental Sector Council, Monterey, California, February 17, 2005.

Ecological solutions for avian collisions with wind turbines in the Altamont Pass Wind Resource Area. The Wildlife Society—Western Section Annual Meeting, Sacramento, California, January 19, 2005.

Associations between avian fatalities and attributes of electric distribution poles in California. The Wildlife Society - Western Section Annual Meeting, Sacramento, California, January 19, 2005.

Minimizing avian mortality in the Altamont Pass Wind Resources Area. UC Davis Wind Energy Collaborative Forum, Palm Springs, California, December 14, 2004.

Selecting electric distribution poles for priority retrofitting to reduce raptor mortality. Raptor Research Foundation Meeting, Bakersfield, California, November 10, 2004.

Responses of Fresno kangaroo rats to habitat improvements in an adaptive management framework. Annual Meeting of the Society for Ecological Restoration, South Lake Tahoe, California, October 16, 2004.

Lessons learned from five years of avian mortality research at the Altamont Pass Wind Resources Area in California. The Wildlife Society Annual Meeting, Calgary, Canada, September 2004.

The ecology and impacts of power generation at Altamont Pass. Sacramento Petroleum Association,

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Sacramento, California, August 18, 2004.

Burrowing owl mortality in the Altamont Pass Wind Resource Area. California Burrowing Owl Consortium meeting, Hayward, California, February 7, 2004.

Burrowing owl mortality in the Altamont Pass Wind Resource Area. California Burrowing Owl Symposium, Sacramento, November 2, 2003.

Raptor Mortality at the Altamont Pass Wind Resource Area. National Wind Coordinating Committee, Washington, D.C., November 17, 2003.

Raptor Behavior at the Altamont Pass Wind Resource Area. Annual Meeting of the Raptor Research Foundation, Anchorage, Alaska, September, 2003.

Raptor Mortality at the Altamont Pass Wind Resource Area. Annual Meeting of the Raptor Research Foundation, Anchorage, Alaska, September, 2003.

California mountain lions. Ecological & Environmental Issues Seminar, Department of Biology, California State University, Sacramento, November, 2000.

Intra- and inter-turbine string comparison of fatalities to animal burrow densities at Altamont Pass. National Wind Coordinating Committee, Carmel, California, May, 2000.

Using a Geographic Positioning System (GPS) to map wildlife and habitat. Annual Meeting of the Western Section of The Wildlife Society, Riverside, CA, January, 2000.

Suggested standards for science applied to conservation issues. Annual Meeting of the Western Section of The Wildlife Society, Riverside, CA, January, 2000.

The indicators framework applied to ecological restoration in Yolo County, California. Society for Ecological Restoration, September 25, 1999.

Ecological restoration in the context of animal social units and their habitat areas. Society for Ecological Restoration, September 24, 1999.

Relating Indicators of Ecological Health and Integrity to Assess Risks to Sustainable Agriculture and Native Biota. International Conference on Ecosystem Health, August 16, 1999.

A crosswalk from the Endangered Species Act to the HCP Handbook and real HCPs. Southern California Edison, Co. and California Energy Commission, March 4-5, 1999.

Mountain lion track counts in California: Implications for Management. Ecological & Environmental Issues Seminar, Department of Biological Sciences, California State University, Sacramento, November 4, 1998.

“No Surprises” -- Lack of science in the HCP process. California Native Plant Society Annual Conservation Conference, The Presidio, San Francisco, September 7, 1997.

EEC ORIGINAL PKG

In Your Interest. A half hour weekly show aired on Channel 10 Television, Sacramento. In this episode, I served on a panel of experts discussing problems with the implementation of the Endangered Species Act. Aired August 31, 1997.

Spatial scaling of pocket gopher (*Geomyidae*) density. Southwestern Association of Naturalists 44th Meeting, Fayetteville, Arkansas, April 10, 1997.

Estimating prairie dog and pocket gopher burrow volume. Southwestern Association of Naturalists 44th Meeting, Fayetteville, Arkansas, April 10, 1997.

Ten years of mountain lion track survey. Fifth Mountain Lion Workshop, San Diego, February 27, 1996.

Study and interpretive design effects on mountain lion density estimates. Fifth Mountain Lion Workshop, San Diego, February 27, 1996.

Small animal control. Session moderator and speaker at the California Farm Conference, Sacramento, California, Feb. 28, 1995.

Small animal control. Ecological Farming Conference, Asylomar, California, Jan. 28, 1995.

Habitat associations of the Swainson's Hawk in the Sacramento Valley's agricultural landscape. 1994 Raptor Research Foundation Meeting, Flagstaff, Arizona.

Alfalfa as wildlife habitat. Seed Industry Conference, Woodland, California, May 4, 1994.

Habitats and vertebrate pests: impacts and management. Managing Farmland to Bring Back Game Birds and Wildlife to the Central Valley. Yolo County Resource Conservation District, U.C. Davis, February 19, 1994.

Management of gophers and alfalfa as wildlife habitat. Orland Alfalfa Production Meeting and Sacramento Valley Alfalfa Production Meeting, February 1 and 2, 1994.

Patterns of wildlife movement in a farming landscape. Wildlife and Fisheries Biology Seminar Series: Recent Advances in Wildlife, Fish, and Conservation Biology, U.C. Davis, Dec. 6, 1993.

Alfalfa as wildlife habitat. California Alfalfa Symposium, Fresno, California, Dec. 9, 1993.

Management of pocket gophers in Sacramento Valley alfalfa. California Alfalfa Symposium, Fresno, California, Dec. 8, 1993.

Association analysis of raptors in a farming landscape. Plenary speaker at Raptor Research Foundation Meeting, Charlotte, North Carolina, Nov. 6, 1993.

Landscape strategies for biological control and IPM. Plenary speaker, International Conference on Integrated Resource Management and Sustainable Agriculture, Beijing, China, Sept. 11, 1993.

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Landscape Ecology Study of Pocket Gophers in Alfalfa. Alfalfa Field Day, U.C. Davis, July 1993.

Patterns of wildlife movement in a farming landscape. Spatial Data Analysis Colloquium, U.C. Davis, August 6, 1993.

Sound stewardship of wildlife. Veterinary Medicine Seminar: Ethics of Animal Use, U.C. Davis. May 1993.

Landscape ecology study of pocket gophers in alfalfa. Five County Grower's Meeting, Tracy, California. February 1993.

Turbulence and the community organizers: The role of invading species in ordering a turbulent system, and the factors for invasion success. Ecology Graduate Student Association Colloquium, U.C. Davis. May 1990.

Evaluation of exotic vertebrate pests. Fourteenth Vertebrate Pest Conference, Sacramento, California. March 1990.

Analytical methods for predicting success of mammal introductions to North America. The Western Section of the Wildlife Society, Hilo, Hawaii. February 1988.

A state-wide mountain lion track survey. Sacramento County Dept Parks and Recreation. April 1986.

The mountain lion in California. Davis Chapter of the Audubon Society. October 1985.

Ecology Graduate Student Seminars, U.C. Davis, 1985-1990: Social behavior of the mountain lion; Mountain lion control; Political status of the mountain lion in California.

Other forms of Participation at Professional Meetings

- Scientific Committee, Conference on Wind energy and Wildlife impacts, Berlin, Germany, March 2015.
- Scientific Committee, Conference on Wind energy and Wildlife impacts, Stockholm, Sweden, February 2013.
- Workshop co-presenter at Birds & Wind Energy Specialist Group (BAWESG) Information sharing week, Bird specialist studies for proposed wind energy facilities in South Africa, Endangered Wildlife Trust, Darling, South Africa, 3-7 October 2011.
- Scientific Committee, Conference on Wind energy and Wildlife impacts, Trondheim, Norway, 2-5 May 2011.
- Chair of Animal Damage Management Session, The Wildlife Society, Annual Meeting, Reno, Nevada, September 26, 2001.

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- Chair of Technical Session: Human communities and ecosystem health: Comparing perspectives and making connection. Managing for Ecosystem Health, International Congress on Ecosystem Health, Sacramento, CA August 15-20, 1999.

- Student Awards Committee, Annual Meeting of the Western Section of The Wildlife Society, Riverside, CA, January, 2000.

- Student Mentor, Annual Meeting of the Western Section of The Wildlife Society, Riverside, CA, January, 2000.

Printed Mass Media

Smallwood, K.S., D. Mooney, and M. McGuinness. 2003. We must stop the UCD biolab now. Op-Ed to the Davis Enterprise.

Smallwood, K.S. 2002. Spring Lake threatens Davis. Op-Ed to the Davis Enterprise.

Smallwood, K.S. Summer, 2001. Mitigation of habitation. The Flatlander, Davis, California.

Entrikan, R.K. and K.S. Smallwood. 2000. Measure O: Flawed law would lock in new taxes. Op-Ed to the Davis Enterprise.

Smallwood, K.S. 2000. Davis delegation lobbies Congress for Wildlife conservation. Op-Ed to the Davis Enterprise.

Smallwood, K.S. 1998. Davis Visions. The Flatlander, Davis, California.

Smallwood, K.S. 1997. Last grab for Yolo's land and water. The Flatlander, Davis, California.

Smallwood, K.S. 1997. The Yolo County HCP. Op-Ed to the Davis Enterprise.

Radio/Television

PBS News Hour,

FOX News, Energy in America: Dead Birds Unintended Consequence of Wind Power Development, August 2011.

KXJZ Capital Public Radio -- Insight (Host Jeffrey Callison). Mountain lion attacks (with guest Professor Richard Coss). 23 April 2009;

KXJZ Capital Public Radio -- Insight (Host Jeffrey Callison). Wind farm Rio Vista Renewable Power. 4 September 2008;

KQED QUEST Episode #111. Bird collisions with wind turbines. 2007;

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KDVS Speaking in Tongues (host Ron Glick), Yolo County HCP: 1 hour. December 27, 2001;

KDVS Speaking in Tongues (host Ron Glick), Yolo County HCP: 1 hour. May 3, 2001;

KDVS Speaking in Tongues (host Ron Glick), Yolo County HCP: 1 hour. February 8, 2001;

KDVS Speaking in Tongues (host Ron Glick & Shawn Smallwood), California Energy Crisis: 1 hour. Jan. 25, 2001;

KDVS Speaking in Tongues (host Ron Glick), Headwaters Forest HCP: 1 hour. 1998;

Davis Cable Channel (host Gerald Heffernon), Burrowing owls in Davis: half hour. June, 2000;

Davis Cable Channel (hosted by Davis League of Women Voters), Measure O debate: 1 hour. October, 2000;

KXTV 10, In Your Interest, The Endangered Species Act: half hour. 1997.

Reviews of Journal Papers (Scientific journals for whom I've provided peer review)

Journal	**Journal**
American Naturalist	Journal of Animal Ecology
Journal of Wildlife Management	Western North American Naturalist
Auk	Journal of Raptor Research
Biological Conservation	National Renewable Energy Lab reports
Canadian Journal of Zoology	Oikos
Ecosystem Health	The Prairie Naturalist
Environmental Conservation	Restoration Ecology
Environmental Management	Southwestern Naturalist
Functional Ecology	The Wildlife Society--Western Section Trans.
Journal of Zoology (London)	Proc. Int. Congress on Managing for Ecosystem Health
Journal of Applied Ecology	Transactions in GIS
Ecology	Tropical Ecology
Wildlife Society Bulletin	Peer J
Biological Control	The Condor

Committees

- Scientific Review Committee, Alameda County, Altamont Pass Wind Resource Area
- Ph.D. Thesis Committee, Steve Anderson, University of California, Davis
- MS Thesis Committee, Marcus Yee, California State University, Sacramento

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Other Professional Activities or Products

Testified in Federal Court in Denver during 2005 over the fate of radio-nuclides in the soil at Rocky Flats Plant after exposure to burrowing animals. My clients won a judgment of $553,000,000. I have also testified in many other cases of litigation under CEQA, NEPA, the Warren-Alquist Act, and other environmental laws. My clients won most of the cases for which I testified.

Testified before Environmental Review Tribunals in Ontario, Canada regarding proposed White Pines, Amherst Island, and Fairview Wind Energy projects.

Testified in Skamania County Hearing in 2009 on the potential impacts of zoning the County for development of wind farms and hazardous waste facilities.

Testified in deposition in 2007 in the case of O'Dell et al. vs. FPL Energy in Houston, Texas.

Testified in Klickitat County Hearing in 2006 on the potential impacts of the Windy Point Wind Farm.

Memberships in Professional Societies

The Wildlife Society
Raptor Research Foundation

Honors and Awards

Fulbright Research Fellowship to Indonesia, 1987
J.G. Boswell Full Academic Scholarship, 1981 college of choice
Certificate of Appreciation, The Wildlife Society—Western Section, 2000, 2001
Northern California Athletic Association Most Valuable Cross Country Runner, 1984
American Legion Award, Corcoran High School, 1981, and John Muir Junior High, 1977
CIF Section Champion, Cross Country in 1978
CIF Section Champion, Track & Field 2 mile run in 1981
National Junior Record, 20 kilometer run, 1982
National Age Group Record, 1500 meter run, 1978

Community Activities

District 64 Little League Umpire, 2003-2007
Dixon Little League Umpire, 2006-07
Davis Little League Chief Umpire and Board member, 2004-2005
Davis Little League Safety Officer, 2004-2005
Davis Little League Certified Umpire, 2002-2004
Davis Little League Scorekeeper, 2002
Davis Visioning Group member
Petitioner for Writ of Mandate under the California Environmental Quality Act against City of Woodland decision to approve the Spring Lake Specific Plan, 2002
Served on campaign committees for City Council candidates

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Representative Clients/Funders

Law Offices of Stephan C. Volker
Blum Collins, LLP
Eric K. Gillespie Professional Corporation
Law Offices of Berger & Montague
Lozeau | Drury LLP
Law Offices of Roy Haber
Law Offices of Edward MacDonald
Law Office of John Gabrielli
Law Office of Bill Kopper
Law Office of Donald B. Mooney
Law Office of Veneruso & Moncharsh
Law Office of Steven Thompson
Law Office of Brian Gaffney
California Wildlife Federation
Defenders of Wildlife
Sierra Club
National Endangered Species Network
Spirit of the Sage Council
The Humane Society
Hagens Berman LLP
Environmental Protection Information Center
Goldberg, Kamin & Garvin, Attorneys at Law
Californians for Renewable Energy (CARE)
Seatuck Environmental Association
Friends of the Columbia Gorge, Inc.
Save Our Scenic Area
Alliance to Protect Nantucket Sound
Friends of the Swainson's Hawk
Alameda Creek Alliance
Center for Biological Diversity
California Native Plant Society
Endangered Wildlife Trust
and BirdLife South Africa
AquAlliance
Oregon Natural Desert Association
Save Our Sound
G3 Energy and Pattern Energy
Emerald Farms
Pacific Gas & Electric Co.
Southern California Edison Co.
Georgia-Pacific Timber Co.
Northern Territories Inc.
David Magney Environmental Consulting
Wildlife History Foundation
NextEra Energy Resources, LLC
Ogin, Inc.
EDF Renewables
National Renewable Energy Lab
Altamont Winds LLC
Salka Energy
Comstocks Business (magazine)
BioResource Consultants
Tierra Data
Black and Veatch
Terry Preston, Wildlife Ecology Research Center
EcoStat, Inc.
US Navy
US Department of Agriculture
US Forest Service
US Fish & Wildlife Service
US Department of Justice
California Energy Commission
California Office of the Attorney General
California Department of Fish & Wildlife
California Department of Transportation
California Department of Forestry
California Department of Food & Agriculture
Ventura County Counsel
County of Yolo
Tahoe Regional Planning Agency
Sustainable Agriculture Research & Education Program
Sacramento-Yolo Mosquito and Vector Control District
East Bay Regional Park District
County of Alameda
Don & LaNelle Silverstien
Seventh Day Adventist Church
Escuela de la Raza Unida
Susan Pelican and Howard Beeman
Residents Against Inconsistent Development, Inc.
Bob Sarvey
Mike Boyd
Hillcroft Neighborhood Fund
Joint Labor Management Committee, Retail Food Industry
Lisa Rocca
Kevin Jackson
Dawn Stover and Jay Letto
Nancy Havassy
Catherine Portman (for Brenda Cedarblade)
Ventus Environmental Solutions, Inc.
Panorama Environmental, Inc.
Adams Broadwell Professional Corporation

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Representative special-status species experience

Common name	Species name	Description
Field experience		
California red-legged frog	*Rana aurora draytonii*	Protocol searches; Many detections
Foothill yellow-legged frog	*Rana boylii*	Presence surveys; Many detections
Western spadefoot	*Spea hammondii*	Presence surveys; Few detections
California tiger salamander	*Ambystoma californiense*	Protocol searches; Many detections
Coast range newt	*Taricha torosa torosa*	Searches and multiple detections
Blunt-nosed leopard lizard	*Gambelia sila*	Detected in San Luis Obispo County
California horned lizard	*Phrynosoma coronatum frontale*	Searches; Many detections
Western pond turtle	*Clemmys marmorata*	Searches; Many detections
San Joaquin kit fox	*Vulpes macrotis mutica*	Protocol searches; detections
Sumatran tiger	*Panthera tigris*	Track surveys in Sumatra
Mountain lion	*Puma concolor californicus*	Research and publications
Point Arena mountain beaver	*Aplodontia rufa nigra*	Remote camera operation
Giant kangaroo rat	*Dipodomys ingens*	Detected in Cholame Valley
San Joaquin kangaroo rat	*Dipodomys nitratoides*	Monitoring & habitat restoration
Monterey dusky-footed woodrat	*Neotoma fuscipes luciana*	Non-target captures and mapping of dens
Salt marsh harvest mouse	*Reithrodontomys raviventris*	Habitat assessment, monitoring
Salinas harvest mouse	*Reithrodontomys megalotus distichlus*	Captures; habitat assessment
Bats		Thermal imaging surveys
California clapper rail	*Rallus longirostris*	Surveys and detections
Golden eagle	*Aquila chrysaetos*	Numerical & behavioral surveys
Swainson's hawk	*Buteo swainsoni*	Numerical & behavioral surveys
Northern harrier	*Circus cyaeneus*	Numerical & behavioral surveys
White-tailed kite	*Elanus leucurus*	Numerical & behavioral surveys
Loggerhead shrike	*Lanius ludovicianus*	Large area surveys
Least Bell's vireo	*Vireo bellii pusillus*	Detected in Monterey County
Willow flycatcher	*Empidonax traillii extimus*	Research at Sierra Nevada breeding sites
Burrowing owl	*Athene cunicularia hypugia*	Numerical & behavioral surveys
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	Monitored success of relocation and habitat restoration
Analytical		
Arroyo southwestern toad	*Bufo microscaphus californicus*	Research and report.
Giant garter snake	*Thamnophis gigas*	Research and publication
Northern goshawk	*Accipiter gentilis*	Research and publication
Northern spotted owl	*Strix occidentalis*	Research and reports
Alameda whipsnake	*Masticophis lateralis euryxanthus*	Expert testimony

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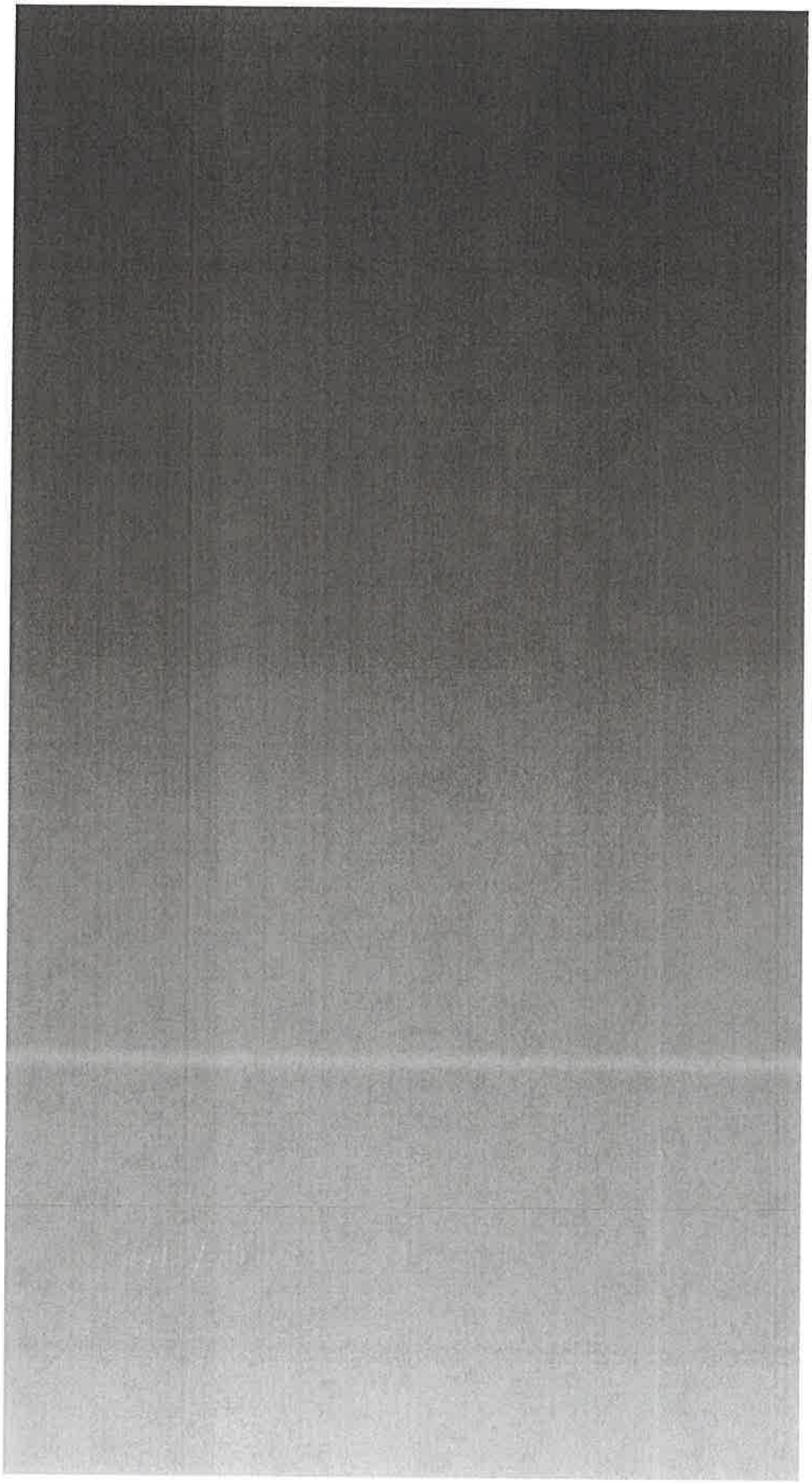

AIR SCIENCES INC.

DENVER • PORTLAND • LOS ANGELES

Heber 2 Application for Authority to Construct

PREPARED FOR:
ORMAT NEVADA INC.

PROJECT NO. 346-2-1
NOVEMBER 2019

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EXHIBIT C

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EXECUTIVE SUMMARY

ORMAT Nevada Inc. proposes to conduct a Re-Power Project which will replace six existing two-level geothermal power generation units at its Heber 2 facility in Imperial County, CA with two new units. The six units to be replaced are approaching the end of their useful lives while the two new units are expected to be more efficient, have lower maintenance requirements, and produce similar net combined power output. The Re-Power Project will affect volatile organic compound (VOC) air emissions at the facility and are not expected to affect emission rates of other regulated pollutants. Actual emission rates for all pollutants are expected to either remain unchanged or decrease. Therefore, ORMAT is confident and proposes to reduce the existing permitted emission levels.

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1.0 PROJECT DESCRIPTION

Second Imperial Geothermal Company, a subsidiary of ORMAT Nevada, Inc. (ORMAT), owns and operates the Heber 2 geothermal electric generation facility in the town of Heber in Imperial County, CA. Heber 2 operates under Authority to Construct (ATC) and Permit to Operate (PTO) #2217A-4 issued by Imperial County Air Pollution Control District (ICAPCD). Heber 2's PTO #2217A-4 includes the emission units at two adjacent, connected facilities known as Heber South and Goulds 2 which are also owned and operated by ORMAT. In this document, the terms Heber 2, Heber South, and Goulds 2 refer to the emission sources at each individual facility, while the general term Facility refers to all the sources at the combined facilities regulated under PTO #2217A-4. The Facility location is shown in Figure 1.

1.1 Existing Facility

Heber 2 currently consists of six ORMAT Energy Converters (OECs). They are integrated two-level units (ITLUs) and have a gross combined power output rating of 36 megawatts (MW). Goulds 2 and Heber South each consist of one OEC with gross outputs of 10 and 12 MW, respectively. Operation of the OECs is described below. Ancillary equipment for the Facility includes cooling towers, an evacuation skid/vapor recovery maintenance unit (VRMU), motive fluid (MF) above ground storage tanks, and diesel engines for emergency use.

The six OECs at Heber 2 are operationally interconnected to each other as well as to Goulds 2 and Heber South. The VRMU and MF storage tanks are shared by all the units and there is piping connecting the MF circuits between the units.

The existing OECs and storage tanks are shown in Figure 2 along with the locations for two proposed new OECs and storage tanks. All existing and proposed permitted emission units at the Facility are listed in Table 1.

1.2 Power Generation Process

All of the OECs at the Facility are binary units, meaning they use two separate fluid circuits to generate power. These units produce power by pumping geothermal fluid from the ground and use the heat from that fluid to vaporize liquid isopentane. This is done using heat exchangers; the two fluids remain isolated in separate circuits. The isopentane is the motive fluid, that is, the vaporized isopentane flows through and provides the motive force to the turbines. The turbines are connected to electric generators. The geothermal fluid, after transferring heat to the isopentane, is pumped back underground into the geological formation. The isopentane is cooled and condensed and begins the cycle again. The cooling is accomplished with a third fluid, cooling water, which cycles between the hot isopentane and cooling towers.

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Figure 1. Facility Location Map

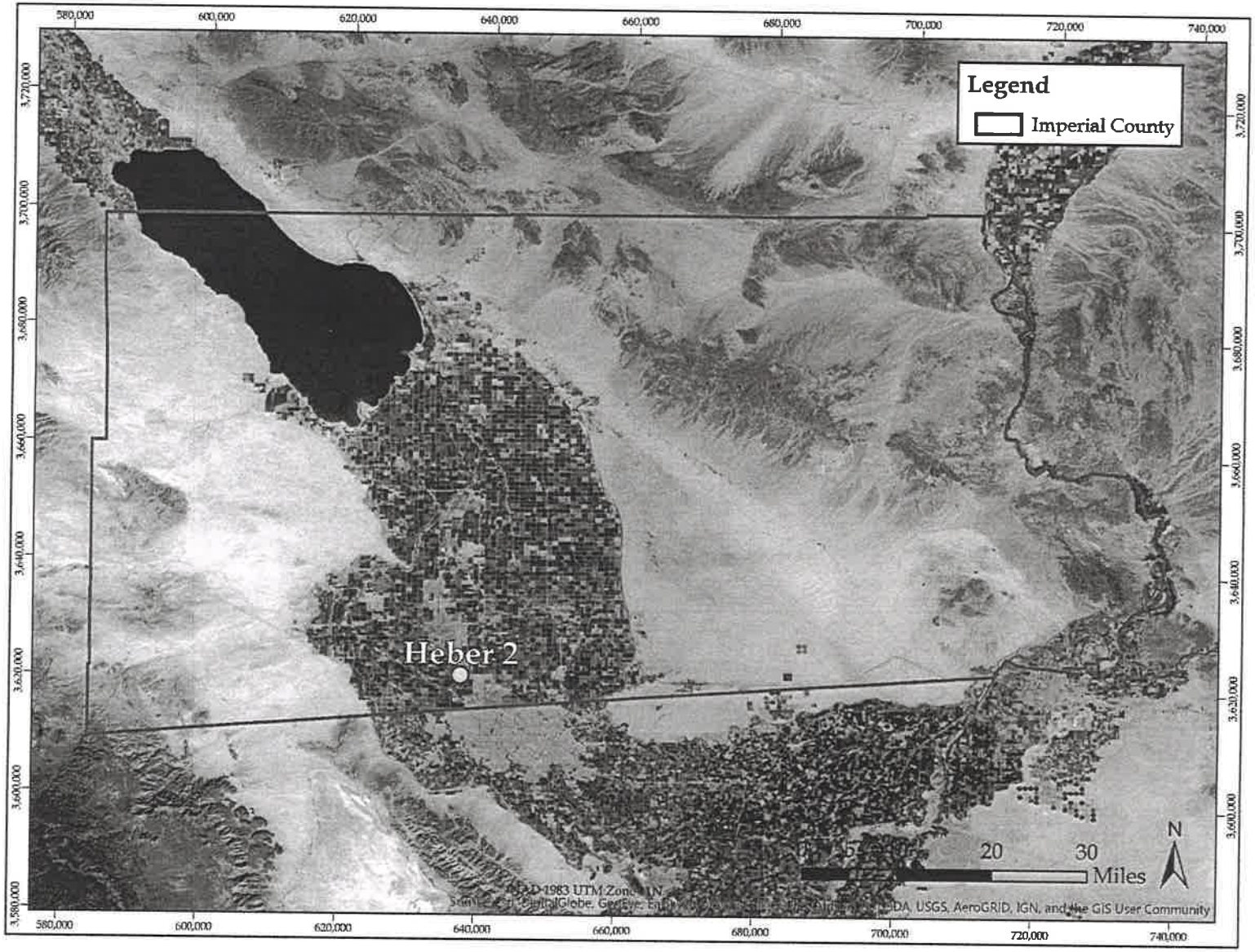

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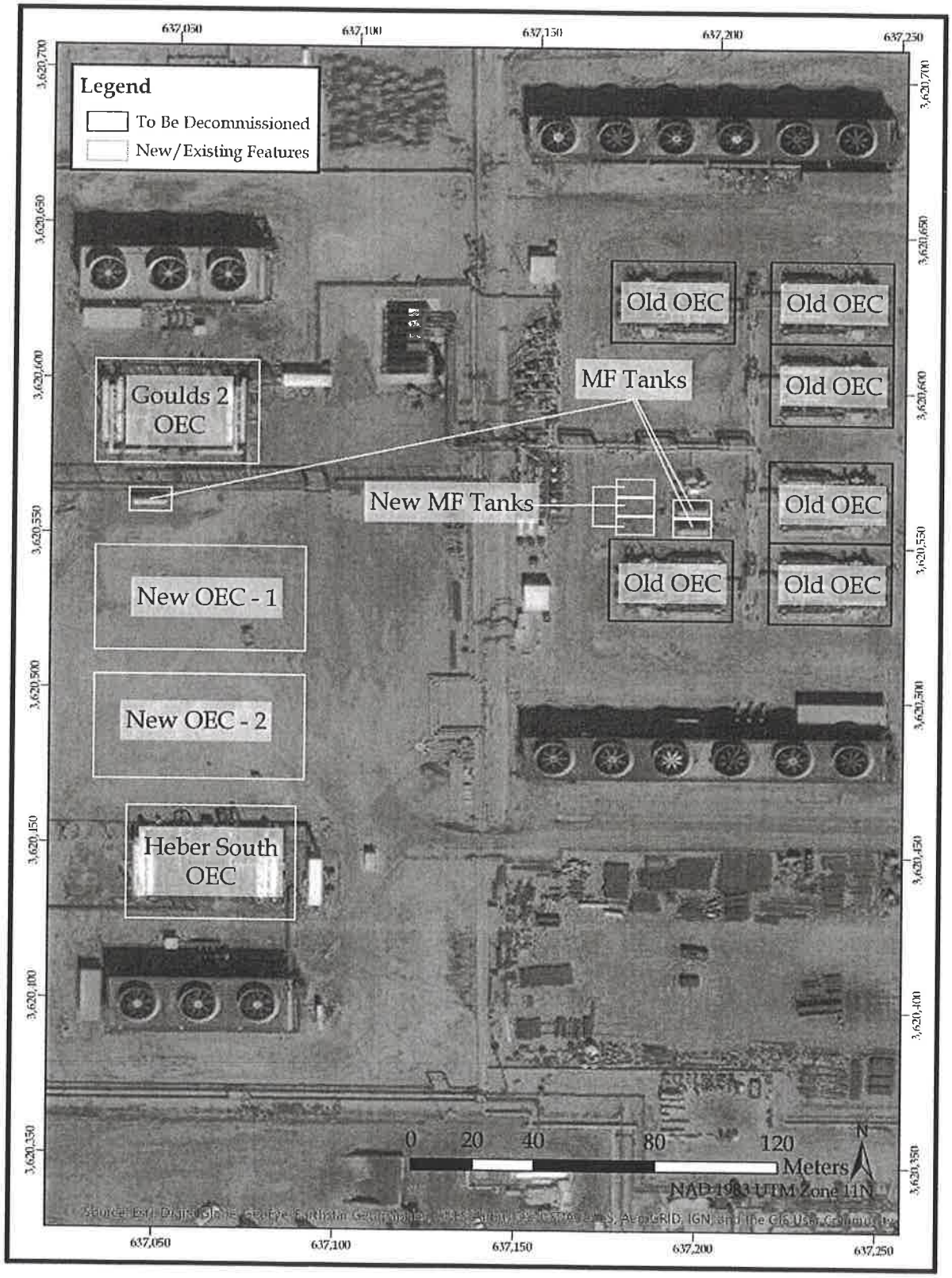
Figure 2. Facility Layout Showing Existing and Proposed Equipment



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1.3 Proposed Development

Development of the proposed Re-Power Project includes the installation of two new OEC units, manufactured by ORMAT, to replace all six existing OECs at Heber 2. The existing OECs will be deconstructed and removed from the Facility within 5 years per County of Imperial requirements.

The total disturbance will be approximately 2.5 acres, entirely within the existing Facility. The development site is completely devoid of vegetation and is actively disturbed as part of ongoing energy generation operations at the Facility. Considering its current condition, site preparation for the installation of the proposed facilities will be limited to light excavation and soil compaction. The locations of the new OECs and storage tanks are shown in Figure 2. Process flow diagrams for the new OECs are included in Appendix A.

ORMAT Energy Converter-1 (OEC-1)
The proposed OEC-1 is a two-turbine combined cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, vaporizer, water-cooled condensers, preheaters, and recuperators, with the OEC served by the existing portable VRMU for purging and maintenance events. The design capacity for the unit is 23.6 MW gross output.

ORMAT Energy Converter-2 (OEC-2)
The proposed OEC-2 is a two-turbine, two-cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, vaporizers, water-cooled condensers, and preheaters, with the OEC served by the existing portable VRMU for purging and maintenance events. The design capacity for the unit is 14.52 MW gross output.

Three Additional Isopentane Above Ground Storage Tanks
To support the new OEC units, three new above ground tanks for additional isopentane storage will be installed. There are two existing storage tanks at Heber 2 and one at Goulds 2. The new tanks will be sited adjacent to the existing Heber 2 tanks. Each tank has a capacity of 10,000 gallons.

The new OECs will utilize the two existing 6-cell Harmon cooling towers that are currently used by the six old OECs that will be decommissioned. No changes to the cooling tower operation or cooling water is anticipated, and therefore no change in emissions is expected.

The existing John Zink VRMU will continue to be used at the Facility and will service the new and existing equipment.

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Table 1. Existing and Proposed Equipment at Heber 2, Heber South, and Goulds 2

Equipment Description	Air Permitting Status
(6) 6 MW (each) ORMAT Energy Converters	Existing – To be shut down
10 MW ORMAT Energy Converter	Existing – No change
12 MW ORMAT Energy Converter	Existing – No change
(2) 6-cell Harmon cooling towers	Existing – No change
(2) 3-cell Marley Model F499A-5.91-3 cooling towers	Existing – No change
23.6 MW ORMAT Energy Converter	New
14.52 MW ORMAT Energy Converter	New
John Zink Series 2000 Vapor Recovery Unit	Existing – No change
Emergency Generator – Cummins (685 hp)	Existing – No change
Fire Pump – Clarke (443 hp)	Existing – No change
Emergency Pump – John Deere (350 hp)	Existing – No change
Fire Pump – Clarke (300 hp)	Existing – No change
(3) 10,000-gallon Motive Fluid Tanks	Existing – No change
(3) 10,000-gallon Motive Fluid Tanks	New

Re-Power Project Construction

Construction for the Heber 2 Re-Power Project will commence as soon as possible after issuance of all required pre-construction permits. Most construction activities will occur on an area approximately 2.5 acres in size. The active construction area will be watered on a regular basis as necessary to minimize dust emissions. Minor excavation will be conducted for equipment foundations as well as placement of underground pipes.

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2.0 AIR EMISSIONS

The Facility is a minor source of air pollution. The main pollutant of concern is isopentane, which is a VOC. Isopentane is the motive fluid used in the power generation process, as described above.

The Facility also has the potential to emit fugitive H_2S from geothermal fluid, particulates from cooling towers, and combustion emissions from emergency diesel engines. Emission calculations are provided in Appendix B.

2.1 Existing Air Emission Limits

Current facility-wide emission limits specified in PTO #2217A-4 are listed in Table 2.

Table 2. Facility-Wide Emission Limits

Pollutant	Emission Limit
Isopentane – 1st Quarter	185 lbs / day
Isopentane – 2nd Quarter	137 lbs / day
Isopentane – 3rd Quarter	137 lbs / day
Isopentane – 4th Quarter	218 lbs / day
H_2S	0.5 lbs / hour

In addition to the facility-wide limits, the Cummins diesel-fired emergency generator has emission limits of 14.32 pounds of NO_X per hour and 1.54 pounds per of CO per hour.

Due to maintenance activities that occur during the 1st and 4th quarters annually, isopentane emissions have the potential to exceed 137 pounds per day on average for those quarters. ORMAT purchases VOC emissions offsets on an annual basis as required by ICAPCD Rule 207 C.2.a.

2.2 Isopentane Emissions

Isopentane emissions at the Facility come from equipment maintenance, purging of non-condensable gases, and fugitive leaks.

Maintenance

Occasionally, the MF must be evacuated from a portion of an OEC for maintenance or repair. The OECs are divided into zones that can be isolated and evacuated for maintenance while MF remains in the rest of the system.

To evacuate MF from a zone for maintenance, the isopentane liquid and vapor are removed using the VRMU and held in the storage tanks. Any remaining vapors are purged from the zone

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using nitrogen and passed through the VRMU. The unit is not opened to the atmosphere until the vapor concentration is less than 20% of the lower explosion limit for isopentane.

Despite efforts to minimize isopentane release during maintenance operations, some small portion of the MF will be emitted to the atmosphere when an OEC zone is opened. Maintenance isopentane emissions occur due to:

- dilute vapors that remain in the evacuation zone.
- liquid pooling that can occur in low points or adjoining pipes that cannot be drained.
- emissions from the VRMU that are not captured by the 99%+ efficient emission controls.

Purging of Non-Condensable Gases

Over time impurities build up in the MF. These impurities include non-condensable gases (NCGs) which decrease the operating efficiency of the units. NCGs are purged from the system using the VRMU.

During purging, vapors from the OECs pass through a knock-out drum and chiller to separate the condensable gases from NCGs. The remaining gases are passed through an activated carbon bed to collect hydrocarbons before being vented to the atmosphere. The Facility's current air permit requires the VRMU to achieve 95% hydrocarbon capture efficiency. Annual testing indicates the VRMU at the Facility achieves greater than 99% capture and recovery.

Fugitive Leaks

Fugitive isopentane emissions occur due to leaks from seals, flanges, pumps, valves, and other components. The MF is pressurized above atmospheric pressure, and the MF will leak out of the system due to the pressure differential at any location that is not completely sealed. Operators check for leaks and other signs of damage or equipment failure every shift. Isopentane is a volatile, flammable fluid and sensors are located throughout the Facility to detect flammable gases for safety reasons.

The isopentane storage tanks are a source of potential fugitive emissions, however they are typically only used to store fluid that needs to be evacuated from the OECs during maintenance. Most of the time they remain empty.

It is not feasible to measure fugitive emissions directly, but fugitive leaks can be quantified based on the addition of isopentane to the system to make up for the lost fluid. ORMAT tracks fluid additions, and the fluid additions that are not attributable to known non-fugitive cause are counted as fugitive emissions.

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Quarterly actual MF make-up additions during 2017 and 2018 range from zero to approximately 1,700 gallons per quarter. The reported quarterly emission rates vary from zero to 95 pounds per day. This variability is not necessarily reflective of actual changes in fugitive emission rates, rather that additions of MF to make up for fugitive losses occur irregularly, and don't occur every calendar quarter. Actual fugitive emission rates are more consistent than the quarterly MF additions data imply.

Effect of Proposed Changes on Isopentane Emission Rates

The proposed changes will replace six old OECs with two new units. This will reduce the number of total geothermal power units at the Facility from eight to four, which also reduces the number of potential locations for leaks and equipment failures (e.g. the number of seals, flanges, pumps, valves, etc.). The new, simpler setup is likely to reduce isopentane emissions from fugitive leaks and the occurrence of failures requiring maintenance.

The proposed OECs have a more advanced design than the units that are being replaced. They have been designed with the knowledge that ORMAT has gained over the nearly three decades since the old OECs were designed. The design improvements include methods to decrease fugitive losses of MF such as redundant seals on pumps, minimizing joints in the system, better construction materials, and reducing low points in the system that cannot be drained prior to evacuation for maintenance.

The combined MF volume for the existing OECs is 120,000 gallons. The MF storage tanks add another 30,000 gallons for a total of 150,000 gallons. After the proposed changes, the OEC volume will decrease to 111,000 gallons; and the total volume including tanks will increase to 171,000 gallons. The reduced system capacity (excluding tanks) will reduce maintenance and purging emissions, while the increase in total capacity (including tanks) has the potential to increase fugitive emissions of isopentane. Including the storage tanks in fugitive emissions estimate is a conservative assumption since the tanks remain empty most of the time.

2.3 Method for Estimating Emissions for Proposed Development

The proposed modifications to the Facility will only affect emissions of isopentane. No changes are proposed for the sources of particulate, combustion, and H_2S emissions at the Facility.

Potential isopentane emissions for the proposed changes to Heber 2 were estimated based on site-specific emission factors derived from previous actual emissions data. No known publicly available emission factors exist for the proposed OECs or similar processes. However, ORMAT has isopentane emissions data for the existing Facility. ORMAT reports isopentane emissions from the Facility to ICAPCD on a quarterly basis. This data was used to derive site-specific emission factors which can be applied to the proposed changes with a higher degree of confidence than if more general emission factors were located and applied.

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Two years of previous emissions data (2017 & 2018) were used to determine appropriate emission factors and estimate emissions from the proposed OECs. Reported isopentane emissions are categorized based on their cause: maintenance, purging of NCGs, and fugitive leaks. The site-specific emission factors for each category of isopentane emissions are listed in Table 3.

Table 3. Site-Specific Isopentane Emission Factors

Emission Category	Emission Factor Basis	Actual Isopentane Emissions (lbs / day)	Existing System Volume (gallons)	Site-Specific Emission Factor (lbs / day / 1,000 gal)
Maintenance	Worst-case quarter	22.5	120,000 (OECs)	0.19
Purging	Worst-case quarter	0.0034	120,000 (OECs)	2.8×10^{-5}
Fugitive	Worst-case quarter	95.0	150,000 (OECs & storage tanks)	0.63

Isopentane emission factors were estimated based on the worst-case quarterly emissions from the previous two years for each emission category (maintenance, purging, and fugitive). These emission rates were divided by the system MF volume so estimated emissions could be scaled to account for changes to the size of the system. For maintenance and purging emissions, the existing combined volume for the OECs (120,000 gallons) was used. For fugitive emissions the existing MF tanks volume (30,000 gallons) was included as well.

An emission reduction factor, shown in Table 4, was applied to the isopentane emission estimates for the proposed changes to account for the reduced complexity of the system. The reduction in total number of geothermal power units from eight to four results in a corresponding reduction in the number of turbines, seals, valves, flanges, pumps, etc., which are the locations for potential leaks and equipment failures. Having a few large units rather than several small units means less potential for equipment leaks and failures. This in turn reduces fugitive and maintenance emission rates. As a reasonable approximation, an emission reduction factor was applied, equal to the ratio of existing units to proposed units (8 units: 4 units) equating to a 50% reduction. This factor was not applied to purging emissions.

Note that the emission estimates for the proposed development remain conservatively high. This is a result of using the worst-case quarterly emissions for each category (maintenance, purging, and fugitive) when deriving the emission factors, plus the significant design improvements (better seals, design for ease of maintenance, etc.) which will reduce emissions but are not accounted for in the emission estimates.

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2.4 Estimated Emissions for Proposed Development

Isopentane emissions for the proposed changes to the Facility were estimated using the site-specific emission factors described above and are listed below in Table 4. Emissions of other pollutants are not expected to be affected by the proposed changes. More detailed emission calculations can be found in Appendix B.

Table 4. Estimated Worst-Case Isopentane Emissions After Proposed Changes

Emission Category	MF Volume After Changes (gallons)	Emission Factor (lbs / day / 1,000 gal)	Emission Reduction Due to Reduced Complexity	Isopentane Emissions	
				(lbs / day)	(tons / year)
Maintenance	111,000	0.19	50%	10.4	1.9
Purging	111,000	2.8×10^{-5}	0%	0.0	0.0
Fugitive	171,000 (includes tanks)	0.63	50%	54.1	9.9
Facility Total				64.5	11.8

The total estimated isopentane emission rate is 64.5 pounds per day, which is well below currently permitted emission rates, listed in Table 5. Although emissions are expected to decrease, ORMAT is proposing permitted emission rates slightly below the currently permitted levels to account for the variability in emissions.

Table 5. Current and Proposed Isopentane Emission Limits

	Permitted Isopentane Emissions (lbs / day)	
Calendar Quarter	Current	Proposed
1st Quarter (Jan – Mar)	185	171
2nd Quarter (Apr – Jun)	137	137
3rd Quarter (Jul – Sep)	137	137
4th Quarter (Oct – Dec)	218	202

ORMAT is proposing a small reduction in the permitted emission rates for isopentane during the 1st and 4th calendar quarters. Emission rates during those two quarters tend to be higher because there is more planned maintenance activity during that half of the year. The two new OECs have a smaller total volume than the six old OECs they will replace; reducing total facility isopentane volume from 120,000 gallons to 111,000 gallons (excluding tanks). This is a 7.5% reduction in the total volume for the OECs at the facility. The smaller system volume will result in lower isopentane emissions for maintenance. ORMAT is requesting a reduction in the permitted emission rates, as shown in Table 5, for the two quarters with the highest maintenance activity of approximately 7.5% for each of those quarters.

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3.0 REGULATORY ANALYSIS AND PERMITTING

The Facility is a minor source for air pollution currently operating under PTO #2217A-4 issued by ICAPCD. This request for modification is being submitted as required under ICAPCD Rule 207. The facility is located in a nonattainment area for PM_{10}, $PM_{2.5}$, and ozone.

3.1 Rule Applicability

The following list summarizes the ICAPCD rules applicable to the requested changes to the Facility.

Rule 111 Equipment Breakdown
The Facility is required to comply with the notification and corrective action requirement described in Rule 111.

Rule 201 Permits Required
ORMAT is requesting to modify its existing Facility by decommission several pieces of existing, permitted equipment and upgrading with new units. These units have the potential to emit air pollutants and require an ATC and a PTO.

Rule 204 Applications
The Facility must submit an application to modify the current permit and provide the information required in the rule and requested by ICAPCD.

Rule 207 New and Modified Stationary Source Review
207(B) Definitions – Modification or Reconstructed Stationary Source
"A Reconstructed Stationary Source shall be treated as a new Stationary Source and not as a Modification." An analysis provided in Section 3.2 of this document demonstrates that the proposed changes to the Facility constitute a Modification rather than a Reconstructed Stationary Source.

207(C).1 Best Available Control Technology (BACT)
Application of BACT is required for new emission units that have the potential to emit 25 pounds per day or more of any non-attainment pollutant or its precursors. A BACT review for the new OEC units at the Facility is provided in Section 3.3.

207(C).2 Offsets
The Facility has the potential to emit more than 137 pounds per day of isopentane during the 1st and 4th quarters of the year and will continue to be required to purchase emission offsets.

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Rule 208 Permit to Operate
The ICAPCD may inspect the new equipment to confirm compliance with all requirements prior to issuing a PTO.

Rule 401 Opacity of Emissions
All emission sources at the Facility are subject to the opacity requirements in Rule 401.B.

Rule 403 General Limitations on the Discharge of Air Contaminants
Rule 403 establishes general emission standards for particulates and other pollutants that are applicable to emission sources at the Facility.

Rule 414 Storage of Reactive Organic Compound Liquids
The MF tanks store a reactive organic compound (ROC) with a vapor pressure greater than 0.5 pounds per square inch absolute (psia) and are therefore subject to the requirements of Rule 414. The existing and new tanks at the Facility satisfy the conditions of Rule 414 by utilizing a Vapor Recovery System with greater than 95% vapor loss control efficiency. Vapor pressure and other physical and chemical properties of isopentane are provided in the material safety data sheet in Appendix C.

Rule 417 Organic Solvents
Rule 417 applies to equipment that discharge organic solvents. The Facility uses isopentane as a process fluid and not as a solvent, although other applications for isopentane include use as an organic solvent. The applicant proposes that Rule 417 does not apply in this case because the facility does not "discharge" an organic solvent, such as by spraying onto a surface, but does have the potential for isopentane emissions as discussed above. Regardless of rule applicability, the proposed emission sources at the facility will utilize emission controls with greater than 85% capture and control efficiency and therefore satisfy the requirements of the rule.

3.2 Modification or Reconstruction Determination

The Re-Power Project will result in the replacement of several large pieces of equipment at the Facility. ICAPCD Rule 207 defines a Reconstructed Stationary Sources as "any Stationary Source undergoing physical Modification where the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable entirely new Stationary Source."

The new equipment at the Facility include:

- Two (2) ORMAT Energy Converters
- Three (3) 10,000-gallon Motive Fluid Storage Tanks

Existing equipment that will not be modified or replaced include:

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- Two ORMAT Energy Converters
- Two (2) Six-Cell Cooling Towers
- Two (2) Three-Cell Cooling Towers
- John Zink Series 2000 Vapor Recovery Unit
- Three (3) 10,000-gallon Motive Fluid Storage Tanks
- Four (4) Diesel Emergency Engines
- Existing process infrastructure including underground and above ground isopentane and coolant piping, flanges, valves, pumps, etc.
- Existing electrical equipment to condition power and connect to the power grid

The cost of the new equipment will be less than 50% of the cost of a comparable entirely new stationary source.

3.3 BACT Review

ICAPCD Rule 207(C) requires the implementation of BACT emission controls for any new source that has the potential to emit 25 pounds or more of any nonattainment pollutant or its precursors. The new OEC units are subject to this requirement because they have the potential to emit more than 25 pounds per day of VOC, which is an ozone precursor. The Facility is in an area classified nonattainment for ozone.

The BACT review process requires the determination of BACT on a case-by-case basis. The required review and BACT determination for the Facility follows the guidelines from Chapter B of the U.S. Environmental Protection Agency (EPA) guidance document, *New Source Review Workshop Manual, Prevention of Significant Deterioration and Nonattainment Area Permitting, Draft.* The review was conducted using the following five steps:

1. Identification of all possible control technologies
2. Elimination of technologically infeasible technologies
3. Ranking of the technologies by control effectiveness
4. Evaluation of the most effective control technology with consideration of economic, energy, and environmental impacts
5. Selection of BACT

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The review process above is consistent with the South Coast Air Quality Management District's *Best Available Control Technology Guidelines*.

Two databases were searched for possible control technologies that could be used at the Facility: the California Air Resources Board Statewide BACT Clearinghouse (CARB SBC) and the EPA RACT/BACT/LAER Clearinghouse (RBLC). Search results are summarized below.

The RBLC does not contain any determinations for the past ten years under process type 99.019 "Geothermal Power". The CARB SBC does not have a process category for geothermal power. In the absence of BACT determinations for geothermal power sources, a search was performed for other sources with VOC emissions from hydrocarbon fluid processes using pipes, flanges, valves, pumps, etc.

The RBLC was searched for determinations in the last ten years under process type code 50 "Petroleum/Natural Gas Production and Refining" for VOC emission sources. These results were filtered to include processes with similarities to the Heber 2 facility. The "Process Name" field from the RBLC results was filtered to include only sources with the words "leak", "fugitive", "vent", "tank", or "maintenance". After filtering the results, 61 determinations remained. An additional determination was found by searching the CARB SBC for "Oil and Gas: Fugitive Components". The results are summarized in Table 6.

Table 6. VOC Control Options for Hydrocarbon Handling Processes

Control Technology	Number of Determinations	Maximum Reported Control Efficiency
Thermal oxidizer	7	99.9%
Wet scrubber	1	99%
Vapor recovery	1	99%*
LDAR	26	97%
Good equipment design	5	Not listed
Compliance with applicable federal or state rules	12	Not listed
Good operation practices	6	Not listed
No control specified or No add-on control	4	Not listed

*ORMAT operates vapor recovery units at Heber 2 and other facilities and routinely achieves isopentane recovery efficiencies of 99%or higher. No control efficiency was listed for the vapor recovery determination found in the databases.

Additional possible controls for VOC emissions are vapor condensers and carbon adsorption filters.

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Of the possible VOC control options, a thermal oxidizer, such as a flare, is not feasible for the Heber 2 facility. While it effectively controls VOC emissions, it generates NO_X emissions, which is also an ozone precursor, along with other pollutants from combustion. Thermal oxidation often requires additional fuel for complete combustion of the pollutant, which increases operating costs and emissions. Additionally, ORMAT desires to capture, condense and reuse the isopentane vapors rather than destroy them through oxidation.

Another technically infeasible control method is a wet scrubber. The only RBLC determination for a wet scrubber was to control methanol emissions. Methanol is highly water soluble, whereas isopentane is not. A wet scrubber cannot effectively control isopentane emissions.

Of the remaining options, leak detection and repair (LDAR) and vapor recovery are the most effective controls. ORMAT has selected to use both of these control methods for the isopentane emission sources at Heber 2. Operators will continue to check for leaks during each shift and leaks will be repaired as quickly as possible and in accordance with its current LDAR procedures. ORMAT currently operates a John Zink VRMU that is considered BACT and will use it to control emissions from the new units associated with the Re-Power Project. The VRMU is a vapor recovery device which includes a condenser to recover isopentane fluid and activated carbon filter to remove any remaining organic compounds before release to the atmosphere. The VRMU at Heber 2 as well as similar units ORMAT operates at its other facilities are tested regularly and show total recovery of isopentane exceeding 99% efficiency during purging and maintenance operations.

3.4 Air Toxics Health Risk Assessment

The Facility was evaluated to determine if there are health risks associated with the proposed changes to operations. The Air Toxics "Hot Spots" Information and Assessment Act (AB 2588) requires stationary sources of toxic air contaminants to estimate the potential cancer and non-cancer risks due to toxic air emissions. The proposed changes to the Facility will affect emissions of isopentane, which is a VOC.

The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Appendix A lists all substances for which emissions must be quantified in a risk assessment. Isopentane has no known health risks and is not included in the list. Additionally, n-pentane and other similar substances, or larger groups of substances that include isopentane such as VOCs, are also not included in the list. Therefore, there are no quantifiable cancer or non-cancer public health risks associated with toxic air contaminant emissions from this project.

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Appendix A – Process Flow Diagram

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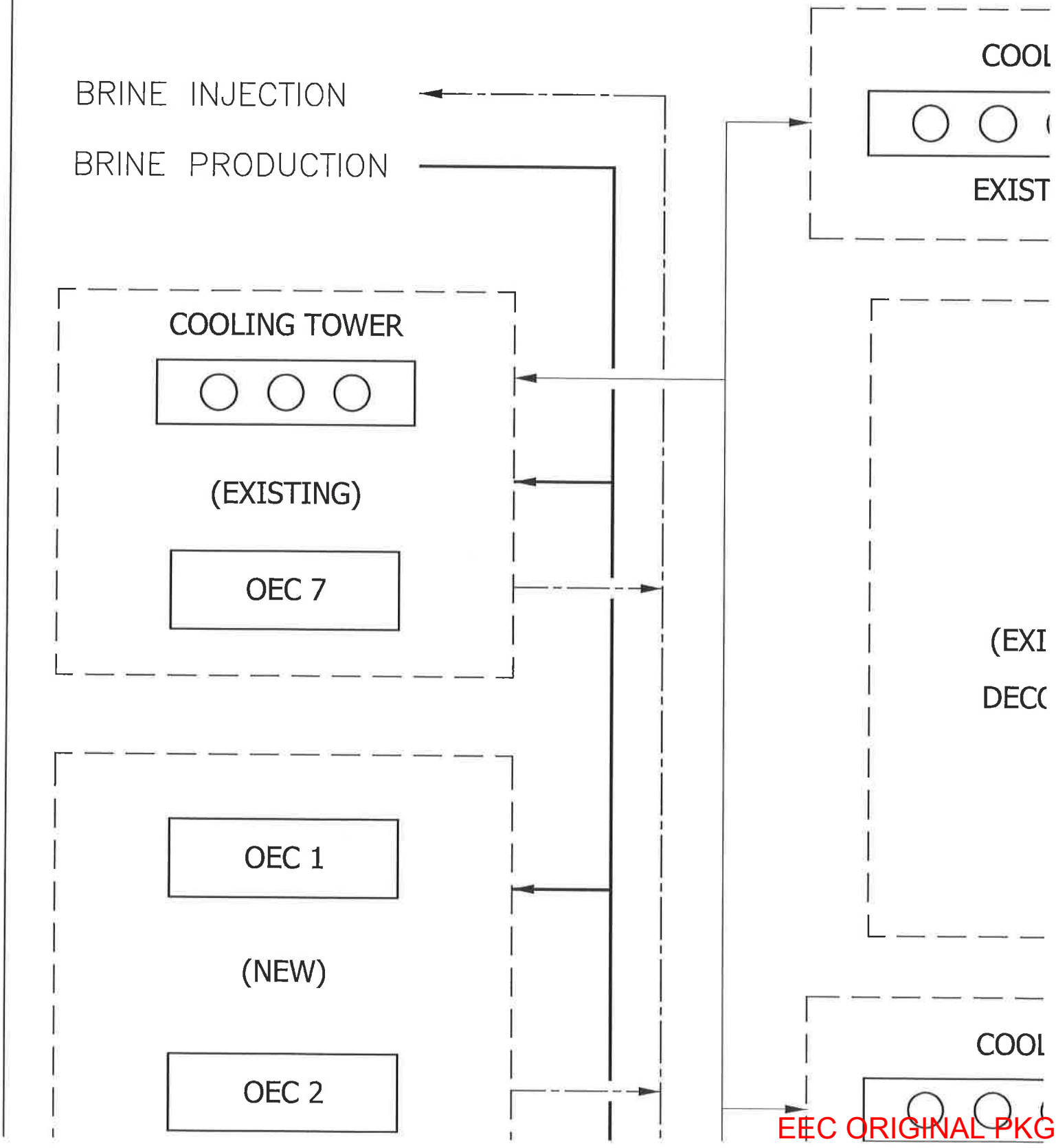
INTEGRATION OF HEBER II FACILITIES



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Appendix B – Emission Calculations

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 1 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: November 12, 2019

Ormat Heber 2: 2019 Re-Power Project - Facility-Wide Air Emissions Summary

Facility-wide Daily Emissions Estimate (lbs/day)

Emission Source	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC[1]	Isopentane[1]
OECs + Motive Fluid Tanks							64.5	64.5
Cooling Towers	76.9	9.2	9.2					
Diesel Engines[2]	1.3	1.3	1.3	29.0	5.6	0.016	3.7	
Facility Total Emissions	78	10.5	10.5	29.0	5.6	0.016	68.2	64.5

[1]Isopentane emissions are reported separately, but they are also included in the VOC emission estimate.
[2]Daily diesel engine emissions are based on one hour per day for maintenance and testing.

Facility-wide Annual Emissions Estimate (tons/year)

Emission Source	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC*	Isopentane*
OECs + Motive Fluid Tanks							11.8	11.8
Cooling Towers	14.0	1.7	1.7					
Diesel Engines	0.027	0.027	0.027	0.63	0.11	3.6E-4	0.068	
Facility Total Emissions	14.1	1.7	1.7	0.63	0.11	3.6E-4	11.8	11.8

*Isopentane emissions are reported separately, but they are also included in the VOC emission estimate.

Emissions Increase - Isopentane

	Facility Total Isopentane Emissions	
	lbs/day	*tons/year*
Previous Actual Emissions (worst-case, 2017-2018)	117.5	1.7
Projected Actual Emissions	64.5	11.8
Increase	-52.9	10.1

Isopentane Permitted Emission Limits - (Maintenance, Purging and Fugitive)

	Current Permit	Proposed Limits
	lbs/day	*lbs/day*
1st Quarter	185	171
2nd Quarter	137	137
3rd Quarter	137	137
4th Quarter	218	202

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 2 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: November 12, 2019

Isopentane Emission Calculations

Emission Units

OEC / ITLU	Rating (MW, each)	# of Units	Gross Power MW (total)	MF Volume* gallons (total)	GF Flow Rate* gal/hr	Permitting Status
Heber 2	6	6	36.0	72,000		Will be shut down and replaced by new OEC-1 and OEC-2
Goulds 2	10	1	10.0	22,500		Existing - no change
Heber South	12	1	12.0	25,500		Existing - no change
OEC-1	23.6	1	23.6	35,000	12,200	New unit
OEC-2	14.5	1	14.5	28,000	12,200	New unit
MF Tanks	Size (gal, each)			gallons (total)		
Existing	10,000	3		30,000		Existing - no change
New	10,000	3		30,000		New tanks

** MF is motive fluid (isopentane) and GF is geothermal fluid (brine)*

Actual Isopentane Emissions (Previous 2 Years)

	# of days	Maintenance gallons	Maintenance lbs/day	Purging gallons	Purging lbs/day	Fugitive gallons	Fugitive lbs/day	Facility Total lbs/day	Facility Total tons/year
2017 - 1st Qtr	90	300	17.2	0.02	0.001	1,636	94.1	111.3	
2017 - 2nd Qtr	91	240	13.6	0.04	0.002	123	7.0	20.7	
2017 - 3rd Qtr	92	400	22.5	0.05	0.003	1,616	90.9	113.4	
2017 - 4th Qtr	92	100	5.6	0.02	0.001	1,337	75.2	80.8	14.9
2018 - 1st Qtr	90	0	0.0	0	0.000	0	0.0	0.0	
2018 - 2nd Qtr	91	0	0.0	0	0.000	0	0.0	0.0	
2018 - 3rd Qtr	92	400	22.5	0.06	0.003	1,688	95.0	117.5	
2018 - 4th Qtr	92	250	14.1	0.02	0.001	770	43.3	57.4	8.0

Isopentane Density
620 mg/ml
0.00835 (lb/gal)/(mg/ml)
5.17 lb/gal

Site-Specific Isopentane Emission Factor Calculation

Previous 2 Years Emissions	Basis	Isopentane Emissions lbs/day	Isopentane Emissions tons/year	Existing Isopentane Volume gallons	Units Included	Calculated Site-Specific Emission Factor
Maintenance	worst-case quarter	22.5	1.7	120,000	OECs	0.19 *(lb/day)/1,000 gal MF*
Purging	worst-case quarter	0.0034	0.0002	120,000	OECs	2.8E-5 *(lb/day)/1,000 gal MF*
Fugitive	worst-case quarter	95.0	0.0	150,000	OECs + MF tanks	0.63 *(lb/day)/1,000 gal MF*
Total		117.5	1.7			

Heber 2 Re-Power Isopentane Emission Estimate - After proposed changes

OEC Units & MF Tanks	MF Volume (new) gallons	Emission Factor (lb/day)/1,000 gal	Expected Reduction Due to Fewer Emission Units	Isopentane Emissions lbs/day	Isopentane Emissions tons/year	Change in Emissions lbs/day	Change in Emissions tons/year
Maintenance	111,000	0.19	50%	10.4	1.9	-12.1	0.2
Purging	111,000	2.8E-5	0%	0.0	0.0	0.0	0.0
Fugitive	171,000	0.63	50%	54.1	9.9	-40.8	9.9
Total				64.5	11.8	-52.9	10.1

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 3 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: November 12, 2019

Cooling Towers Emission Calculations (Existing - no change)

Site Data		Reference
Total solids in recirculating water	3,950 ppm	Heber 1 OEC-14 ATC Application
Water Density at 84.9 F	8.31 lb/gal	
Droplets larger than 10 µm	88%	Heber 1 OEC-14 ATC Application
Droplets larger than 2.5 µm	88%	Heber 1 OEC-14 ATC Application

Cooling Tower Emissions

	Water Flow		PM		PM_{10}		$PM_{2.5}$	
Description	*gal/min*	Drift Rate	*lb/day*	*ton/yr*	*lb/day*	*ton/yr*	*lb/day*	*ton/yr*
3-Cell Cooling Tower	41,250	0.0010%	19.50	3.56	2.340	0.43	2.340	0.43
3-Cell Cooling Tower	41,250	0.0005%	9.75	1.78	1.170	0.21	1.170	0.21
6-Cell Cooling Tower	63,000	0.0008%	23.82	4.35	2.859	0.52	2.859	0.52
6-Cell Cooling Tower	63,000	0.0008%	23.82	4.35	2.859	0.52	2.859	0.52
Total			76.9	14.0	9.23	1.7	9.23	1.7

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 4 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: November 12, 2019

Diesel Engines Emission Calculations (Existing - no change)

Diesel Engines

Type	Engine Make & Model	Engine Power	Operating Hours	Emission Factors
Emergency Generator	Cummins KTA19G2	685 hp	50 hrs/yr	AP-42 Table 3.4-1, Existing Permit Limits
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	305 hp	35 hrs/yr	AP-42 Table 3.3-1
Emergency Pump	John Deere 6090HF485	350 hp	50 hrs/yr	EPA Certification Data
Fire Pump	Clarke JW6H-UF40 (John Deere 6081HF001)	300 hp	35 hrs/yr	CA Tier 2, Fire Pumps

Emission Factors

Reference	PM	PM_{10}	$PM_{2.5}$	NO_x	CO	SO_2	VOC	Units
PTO #2217A-4 Emission Limits - Cummins KTA19G2				14.3	1.5			*lb/hr*
AP-42 Table 3.4-1 (Diesel engines >600hp)	7.0E-4	7.0E-4	7.0E-4	0.024	0.0055	1.1E-5	7.1E-4	*lb/hp-hr*
AP-42 Table 3.3-1 (Diesel engines <600hp)	0.0022	0.0022	0.0022	0.031	0.0067	1.1E-5	0.0025	*lb/hp-hr*
EPA Cert. Data for JD Family 6JDXL09.0102	0.10	0.10	0.100	3.5	0.50	0.0049	0.10	*g/kW-hr*
CA Tier 2, Fire Pumps (300 ≤ hp < 600)	0.15	0.15	0.15	4.8	2.6	0.0049	4.8	*g/hp-hr*

SO_2 Emission Factor Calculation (mass balance):

7,000 Btu / 1 hp-hr	1 lb diesel / 19,300 Btu	15 lb S / 1,000,000 lb diesel	1.998 lb SO2 / 1 lb S	=	1.09E-05 lb SO_2/hp-hr

Diesel Properties	Typical CI Engine BSFC (AP-42)	Units Conversions
15 ppm S (ULSD)	7,000 Btu/hp-hr	1.341 hp/kW
7.1 lb/gal (AP-42)		453.592 g/lb
19,300 Btu/lb (AP-42)		1.998 g SO_2/g S

Diesel Engine Emissions - Daily (lbs/day)

Type	Engine Make & Model	PM	PM_{10}	$PM_{2.5}$	NO_x	CO	SO_2	VOC
Emergency Generator	Cummins KTA19G2	0.5	0.5	0.5	14.3	1.5	0.0074	0.48
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	0.7	0.7	0.7	9.5	2.0	0.0033	0.77
Emergency Generator	John Deere 6090H	0.1	0.1	0.1	2.0	0.29	0.0028	0.058
Emergency Pump	Clarke JW6H-UF40	0.1	0.1	0.1	3.2	1.7	0.0024	2.4
Total		1.3	1.3	1.3	29.0	5.6	0.016	3.7

*Daily diesel engine emissions are based on one hour per day for maintenance and testing.

Diesel Engine Emissions - Annual (tons/year)

Type	Engine Make & Model	PM	PM_{10}	$PM_{2.5}$	NO_x	CO	SO_2	VOC
Emergency Generator	Cummins KTA19G2	0.012	0.012	0.012	0.36	0.039	1.9E-4	0.012
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	0.012	0.012	0.012	0.17	0.036	5.8E-5	0.013
Emergency Generator	John Deere 6090H	0.0014	0.0014	0.0014	0.050	0.0072	7.1E-5	0.0014
Emergency Pump	Clarke JW6H-UF40	0.0017	0.0017	0.0017	0.056	0.030	4.3E-5	0.041
Total		0.027	0.027	0.027	0.63	0.11	3.6E-4	0.068

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Appendix C – Material Safety Data Sheet for Isopentane

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South Hampton Resources

Isopentane

Safety Data Sheet

According To Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules And Regulations And According To The Hazardous Products Regulation (February 11, 2015).

Revision Date: 4/05/2019 Date of Issue: 3/10/2019 Version: 4.0

Section 1. Substance name and company identification

1.1 Product identifier

Common name	Isopentane
Synonyms	2-Methylbutane
Chemical class	Alkane
REACH registration	This substance is derived from natural gas condensate and meets the criteria for exemption from REACH registration under Annex V.

1.2 Relevant identified uses of the substances or mixture and of the company/undertaking

Gasoline additive, solvent, blowing agent for polystyrene, chemical intermediate

1.3 Details of the supplier of the safety data sheet

Manufacturer	South Hampton Resources, Inc. 7752 FM 418 West Silsbee, Texas 77656 USA Tel: + 1 409-385-8300 E mail: customerservice@southhamptonr.com
EU Only Representative	TSGE Concordia House, St James Business Park, Grimbald Crag Court, Knaresborough, North Yorkshire, HG5 8QB, United Kingdom Tel: +44 (0) 1423 799 633 Fax: +44 (0) 1423 797 804

1.4 Emergency telephone number

In case of emergency	Tel. +1 703 527 3887 (CHEMTREC)

Section 2. Hazards Identification

2.1 GHS Classification

Flammable liquids, Category 1
Eye irritation, Category 2B
Specific target organ systematic toxicity-single exposure, Category 3
Aspiration hazard, Category 1
Chronic toxicity -- Category 2

2.2 GHS Label elements

Pictograms:

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Signal Word: Danger

Hazard Statements

H224 Highly flammable liquid and vapour
H304 May be fatal if swallowed and enters airways
H320 Causes eye irritation
H336 May cause drowsiness or dizziness.
H411 Hazardous to the aquatic environment, chronic toxicity -- Category 2
Toxic to aquatic life with long lasting effects.

Precautionary statements

P210 Keep away from heat/ sparks/open flames/hot surfaces. — No smoking.
P243+P240 Take precautionary measures against static discharge. Ground/bond container and receiving equipment.
P273 Avoid release to the environment.
P280 Wear protective gloves/protective clothing/eye protection/face protection
P301+P310+P331 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician. Do NOT induce vomiting.
P403+P235 Store in a well-ventilated place. Keep cool. Keep container tightly closed
P370+P378 In case of fire: Use foam, carbon dioxide or dry powder for extinction.
P501 Dispose of product/container in accordance with all applicable regulations.

Section 3. Composition

Name	EC No	CAS No	Concentration
n-Pentane	203-692-4	109-66-0	1 w% min
Isopentane	201-142-8	78-78-4	99 w% max

Section 4. First Aid Measures

4.1 Description of first aid measures

Inhalation
If breathing difficulties, dizziness, or light-headedness occur when working in areas with high vapor concentrations, remove victim to fresh air. If victim experiences continued breathing difficulties, keep patient warm and at rest, and seek medical attention. If breathing stops, begin artificial respiration and seek immediate medical attention.

Skin contact
If this product comes into contact with the skin, wash with soap and water. Seek medical attention if irritation persists. Remove and wash contaminated clothing before re-use.

Accidental eye contact

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If this product comes into contact with the eyes, flush with large quantities of water for several minutes, while gently holding the eyelids open. Seek medical attention if irritation persists.

Ingestion
If this product is swallowed, DO NOT INDUCE VOMITING. Give small quantities (<250 ml) of water to drink. Never give anything by mouth to an unconscious person. Seek immediate medical attention

Notes to doctor/physician
Aspiration of solvent may cause chemical pneumonitis.

4.2 Most important symptoms and effects, both acute and delayed

Inhalation: isopentane may cause dizziness and drowsiness if inhaled, and high concentrations may result in central nervous system depression, and loss of consciousness.

Ingestion: Symptoms of ingestion may include nausea, vomiting, as well as symptoms of dizziness, drowsiness and central nervous system depression. If vomiting occurs, isopentane may be aspirated into the lungs, with a risk of chemical pneumonitis.

4.3 Indication of any immediate attention and special treatment needed

If ingested or inhaled seek medical attention immediately.

Section 5. Firefighting Measures

5.1 Extinguishing media

Small fires: Use foam, carbon dioxide or dry powder extinguisher.

Large fires: Use foam to extinguish fires. Water spray should not be used, as n-pentane is lighter than water and may form pools of burning liquid on top of water. Keep adjacent containers cool using water spray.

5.2 Special hazards arising from the substance or mixture

Isopentane is extremely flammable. Remove all sources of ignition. Vapors are heavier than air and may travel considerable distances to a source of ignition and flash back. Vapor/air mixtures may be explosive. Electrostatic discharges may cause fire and/or explosion.

5.3 Advice for fire-fighters

Wear positive pressure Self-Contained Breathing Apparatus.

5.4 Evacuation

If tank, rail car, or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions, also, consider initial evacuation for 300 meters (1/2 mile) in all directions.

Section 6. Accidental Release Measures

6.1 Personal precautions, protective equipment and emergency procedures

Remove all ignition sources and evacuate unnecessary personnel from the area. Ventilate the area if possible. Wear suitable protective clothing including solvent resistant gloves and coveralls. If vapor concentrations are high, respiratory protective equipment may be required. See section 8 for more information.

6.2 Environmental precautions

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Prevent entry into sewers and watercourses. If product enters sewers or watercourses, inform the appropriate environmental authorities.

6.3 Method for cleaning up

Small spills: Remove all ignition sources. Use non-sparking hand tools. Take precautions to avoid electrostatic discharge. Absorb spillage in a non-combustible absorbent, e.g. sand or vermiculite, and place in a suitable container for disposal.

Large spills: Remove all ignition sources. Use non-sparking hand tools. Contain spill and cover if possible to reduce evaporation. Transfer to a suitable container by mechanical means. Take precautions to avoid static discharge, e.g. by grounding containers, etc. Consider initial downwind evacuation for at least 300 meters (1,000 feet).

6.4 Reference to other sections

Refer to section 8 of SDS for personal protection details.

Section 7. Handling and Storage

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Use only in well ventilated areas. isopentane is extremely flammable. Avoid contact with all ignition sources, including hot surfaces. Take precautions to avoid electrostatic discharges, such as grounding of containers and equipment, and restricting flow rates. Vapors are heavier than air and may accumulate in low lying areas and below ground areas such as ducts and sewers.

7.2 Condition for safe storage, including any incompatibilities

Store in a well ventilated area, away from all ignition sources. If stored in drums, keep out of direct sunlight.

Section 8. Exposure Controls/Personal Protection

8.1 Control parameters

Substance	TWA	Source, Type
n-Pentane	1000 ppm,3000 mg/m^3	OSHA
n-Pentane	600 ppm,1800 mg/m^3	ACGIH
Isopentane	600 ppm,1800 mg/m3	ACGIH

8.2 Exposure controls

Ensure there is sufficient ventilation of the area. The floor of the storage room must be impermeable to prevent the escape of liquids. General mechanical ventilation may be sufficient to keep product vapor concentrations within specified time-weighted TLV ranges. If general ventilation proves inadequate to maintain safe vapor concentrations, supplemental local exhaust may be required. Other special precautions such as respiratory masks or environmental containment devices may be required in extreme cases.

Respiratory protection
Use only in well ventilated area. If high exposure levels are likely, then suitable respiratory protection will be required. Very high vapor concentrations may result in oxygen displacement and self-contained breathing apparatus or airline may be required.

Hand Protection

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Wear suitable chemical resistant gloves recommended for use with hydrocarbon solvent. Nitrile gloves may be suitable, but glove manufacturers' specifications should always be checked first. Natural rubber gloves are not suitable. Change gloves in accordance with manufacturer recommendations. If gloves are damaged during use, remove immediately and wash hands before replacing with new gloves.

Eye protection

Wear suitable eye protection, safety glasses or goggles, when handling this product.

Skin protection

Aprons or coveralls made of fire retardant material are recommended. These should be changed after use or if contaminated. Wash before re-use.

Section 9. Physical and Chemical Properties

9.1 Information on basic physical and chemical properties

Appearance:	Colorless Liquid
Odor:	Gasoline-like odor
Molecular weight:	72
pH:	not applicable
Melting point/freezing point:	-256°F/-160°C
Approximate boiling range :	80-100°F/27-38°C
Flash point:	-70°F/-57°C
Evaporation rate:	not available
Flammability limits in air	
Lower:	1.4 v%
Upper:	8.3 v%
Reid vapor pressure at 100°F:	20.7 psia
Relative vapor density (Air=1.0)	2.6
Density at 60°F:	0.624 kg/l
Solubility in water:	negligible
Partition Coefficient: n-octanol/water:	2.72
Auto-ignition temperature:	788°F/402°C
Viscosity:	not available
Oxidizing properties:	none

Sources of Information:

1. Company product testing
2. Hawley's Condensed Chemical Dictionary revised by N. Irving Sax and Richard J. Lewis, and
3. CHRIS directory

Section 10. Stability and Reactivity

10.1 Reactivity

Stable under normal conditions.

10.2 Chemical stability

Stable under normal conditions.

10.3 Possibility of hazardous reactions

Hazardous polymerisation will not occur.

10.4 Conditions to avoid

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Keep away from sources of ignition.

10.5 Incompatible materials

This product is incompatible with strong oxidizing agents, strong acids and bases, and selected amines.

10.6 Hazardous decomposition products

None

Section 11. Toxicological Information

11.1 Information on toxicological effects

Acute Toxicity:
LC_{50} (Mouse) 450 mg/l/2 hour
Harmful when inhaled in high concentrations or ingested. n-pentane may cause dizziness and drowsiness if inhaled, and high concentrations may result in central nervous system depression, and loss of consciousness. Symptoms of ingestion may include nausea, vomiting, as well as symptoms of dizziness, drowsiness and central nervous system depression. If vomiting occurs, isopentane may be aspirated into the lungs, with a risk of chemical pneumonitis.
Irritation: isopentane can be irritating to the eye, may cause redness.
Corrosivity: Not corrosive
Sensitisation: Not known to be a sensitizer
Repeated dose toxicity:
NOAEL (90 day) 2250 ppm
Prolonged or repeated contact of this product will result in defatting of the skin, causing dryness and cracking.
Carcinogenicity: Not expected to be carcinogenic.
Mutagenicity: Not expected to be mutagenic
Toxicity for reproduction: Not expected to be toxic to reproduction.

Route of exposure: Inhalation and ingestion

Symptoms related to the physical, chemical and toxicological characteristics: isopentane may cause dizziness and drowsiness if inhaled, and high concentrations may result in central nervous system depression, and loss of consciousness. Symptoms of ingestion may include nausea, vomiting, as well as symptoms of dizziness, drowsiness and central nervous system depression. If vomiting occurs, isopentane may be aspirated into the lungs, with a risk of chemical pneumonitis.

Section 12. Ecological Information



GHS Classification:
H411 -- Hazardous to the aquatic environment, chronic toxicity -- Category 2
Toxic to aquatic life with long lasting effects.

12.1 Toxicity

EC50 (*Oncorhynchus mykiss,* rainbow trout) 3.1 mg/l (96 hour)
EC50 (*Daphnia magna*) 2.3 mg/l (48 hour)

Isopentane is classified as toxic to aquatic organisms and likely to cause long term effects in the environment.

Acute aquatic toxicity studies on samples of Isopentane show acute toxicity values greater than 1 mg/L and mostly in the range 1-10 mg/L. Isopentane will readily evaporate from the surface and would not be expected to have significant adverse effects in the aquatic environment.

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12.2 Persistence and degradability

Isopentane is readily biodegradable in aquatic systems, however, in view of its high evaporation rate, Isopentane is expected to volatilize rapidly from water sources into the atmosphere, where it will be degraded by photochemical reaction.

12.3 Bioaccumulative potential

The Log Kow value measured for Isopentane is 2.7 and it is expected to have a low potential for bioaccumulation.

12.4 Mobility in soil

Due to Isopentanes extreme volatility, air is the only environmental compartment in which this hydrocarbon will be found. In air, Isopentane can readily undergo photo degradation by reaction with hydroxyl radicals. The chemical half-life is approximately 4 days.

12.5 Results of PBT and vPvB assessment

No information available

12.6 Other adverse effects

No further details

Section 13. Disposal Considerations

13.1 Waste treatment methods

Recover and recycle product if possible. If recovery and recycling are not possible, isopentane may be disposed of by incineration.

Please follow all local, regional, national and international laws.

Section 14. Transport Information

14.1 UN number

1265

14.2 USDOT (United States Department of Transportation)(Domestic)

USDOT Proper Shipping Name: Pentanes
Hazard Classification: 3, Packing Group: 1
Label: Flammable Liquid
Placard: Flammable Liquid

14.3 IMO/IMDG (International Maritime Dangerous Goods)(Water)

IMO Proper Shipping Name: Pentanes
Hazard Classification: 3, Packing Group: 1
Label: Flammable Liquid

Special precautions for user: Container(s) greater than 5 liters (liquids) or 5 kilograms (solids), shipped by water mode and ALL bulk shipments may require the shipping description to contain the "Marine Pollutant" notation [49 CFR 172.203(l)] and the container(s) to display the [Marine Pollutant Mark] [49 CFR 172.322].

14.4 IATA (International Air Transport Association)

Proper Shipping Name: Pentanes
Hazard Classification: 3, Packing Group: 1
Label: Flammable Liquid

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14.5 ADR (Agreement on Dangerous Goods by Road (Europe))

Proper Shipping Name: Pentanes

Hazard Classification: 3, Packing Group: 1, Environmentally Hazardous

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code: Not applicable

Section 15. Regulatory Information

15.1 Clean Air Act

- This product neither contains nor was it manufactured with any class 1 or class 2 ozone depleting substances.
- Under Section 112 (r), 40 CFR Part 68, the threshold quantity for both n-pentane and isopentane is 10,000 lbs.

15.2 Emergency Planning and Community Tight-To –Know Act (EPCRA)

- Section 302 - This product does not contain any constituents that are classified as an extremely hazardous substance.
- Section 311/312 (Tier II) - This product is considered a fire hazard and an acute health hazard.
- Section 313 - This product contains no toxic chemicals.

15.3 California Office of Environmental Health Hazard Assessment

- Proposition 65 - This product contains none of the chemicals which may cause cancer or birth defects as listed in this legislation.

15.4 Coalition of Northeast Governors (CONEG)

- This product contains no lead, mercury, cadmium, or hexavalent chromium.

15.5 New Jersey Right-to-Know

- Normal pentane and isopentane both appear on this state's hazardous substance list.

15.6 Pennsylvania Right-to-Know

- Normal pentane and isopentane both appear on this state's hazardous substance list.

15.7 Toxic Substance Control Act (TSCA)

- All constituents of this product are listed in TSCA.

15.8 Other Inventories

- The constituents of this product are known to be listed on the following country inventories:
  - **Canada (DSL)**
  - **Japan (ENCS)**
  - **Australia (AICS)**
  - **Phillipines (PICCS)**
  - **China (IECSC)**
  - **Korea (KECI)**

Section 16. Other Information

Hazard Ratings:

GHS:		NFPA:		HMIS:	
Health:	4	Health:	1	Health:	1
Flammability:	1	Fire:	4	Flammability:	4
Reactivity:	5	Reactivity:	0	Reactivity:	0

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Specific Hazard: None

The above information is believed to be correct as of the date hereof. However no warranty of merchantability fitness for any use or any other warranty is expressed or is to be implied regarding the accuracy of this data, the results to be obtained from the use of the material, or the hazards connected with such use. Since the information contained herein may be applied under conditions beyond our control and with which we may be unfamiliar, and since data made available subsequent to the data hereof may suggest modification of the information, we do not assume responsibility for the results of its use. This information is furnished on the condition that the person receiving it shall make his own determination as to the suitability of the material for his particular purpose and on the condition that he assume the risk of his use thereof.

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RECEIVED

NOV 18 2019

AIR POLLUTION
CONTROL DISTRICT

ORMAT

November 15, 2019

VIA FedEx and Electronic Mail

Imperial County Air Pollution Control District
Attn: Israel Hernandez (israelhernandez@co.imperial.ca.us)
150 S. 9th Street
El Centro, CA 92243

RE: Heber 2 Repower Project
Application for Amendment to Authority to Construct Permit No. 2217A-4

Dear Mr. Hernandez,

Second Imperial Geothermal Co., a subsidiary of Ormat Nevada Inc., respectfully submits this application to amend ATC Permit No. 2217A-4 to support the repower activities at the Heber 2 facility. The repower involves replacing old equipment with new fewer units and better technology to increase the efficiency of the geothermal plant. We appreciate the APCD starting the review of this application while we proceed through the County Conditional Use Permit process.

If the Air Pollution Control District requires more information or has any questions regarding this application please feel free to contact me at 775.336.9029 Ext. 32288 or mwendt@ormat.com.

Best regards,

Melissa R. Wendt
Director, Project Development
Ormat Nevada Inc.

EEC ORIGINAL PKG

150 SOUTH NINTH STREET
EL CENTRO, CA 92243-2850

TELEPHONE: (442) 265-1800
FAX: (442) 265-1799

AIR POLLUTION CONTROL DISTRICT

September 25, 2019

RECEIVED
SEP 25 2019
IMPERIAL COUNTY
PLANNING & DEVELOPMENT SERVICES

Mr. Jim Minnick
Planning & Development Services Director
801 Main St.
El Centro, CA 92243

SUBJECT: Condition Use Permit 19-0017—Second Imperial Geothermal Company (Ormat)

Dear Mr. Minnick:

The Imperial County Air Pollution Control District ("Air District") would like to thank you for the opportunity to review Conditional Use Permit (CUP) 19-0017 that would allow for the installation of two new water-cooled ORMAT Energy Converters; three 10,000 gallon isopentane above ground storage tanks; and, additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy complex ("Project"). The new energy converters will replace the existing six converters while the three new isopentane storage tanks will complement the existing two storage tanks. The Project location is located at 855 Dogwood Road in Heber (APN 054-250-031-000).

Upon review, the Air District reminds the applicant that it will need to submit an application for a Modification of a Permit to Operate to the Engineering & Permitting Division of the Air District. During this process the applicant can discuss the emissions from the equipment to be used in the construction and installation of the energy converters and storage tanks. The applicant must adhere to the Air District's Regulation VIII which is designed to mitigate PM10 emissions during construction. Additionally, the applicant needs to submit a Construction Dust Control Plan and notify the Air District 10 days prior to the start of any construction activities.

Finally, the Air District requests a copy of the Draft CUP prior to recording.

The Air District's rule book can be accessed via the internet at http://www.co.imperial.ca.us/AirPollution. Click on "Rules & Regulations" under "Resources" on the left side of the page. Should you have questions, please call our office at (442) 265-1800.

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

EEC ORIGINAL PKG

Sincerely,

Curtis Blondell

Curtis Blondell
APC Environmental Coordinator

Reviewed by Monica Soucier
APC Division Manager

EEC ORIGINAL PKG

150 SOUTH NINTH STREET
EL CENTRO, CA 92243-2850

TELEPHONE: (442) 265-1800
FAX: (442) 265-1799

AIR POLLUTION CONTROL DISTRICT

June 18, 2020

RECEIVED
JUN 15 2020
IMPERIAL COUNTY
PLANNING & DEVELOPMENT SERVICES

Mr. Jim Minnick
Planning & Development Services Director
801 Main St.
El Centro, CA 92243

SUBJECT: Notice of Intent for a Negative Declaration of Initial Study 19-0020 for Condition Use Permit 19-0017—Heber 2 Geothermal Energy Complex (Ormat)

Dear Mr. Minnick:

The Imperial County Air Pollution Control District ("Air District") would like to thank you for the opportunity to review Initial Study 19-0020 regarding Conditional Use Permit (CUP) 19-0017 (collectively called "Project"). The Project would install two new Ormat Energy Converters (OECs) to replace the six existing Integrated Two-Level Units (ITLU) which would be demolished or abandoned in place. Additionally, three 10,000-gallon isopentane above ground storage tanks will be installed, along with additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex. An amendment to the existing CUP will renew the permitted life of the Heber 2 Geothermal Energy Complex (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049). The Project is located at 855 Dogwood Road in Heber, California, also identified as APN 054-250-031-000.

Upon review, the Air District has no comments, but politely requests a copy of the Draft CUP prior to recording.

The Air District's rule book can be accessed via the internet at https://apcd.imperialcounty.org. Click on "Rules & Regulations" at the top of the page. Please contact the Air District offices at (442) 265-1800 if you have any questions.

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

EEC ORIGINAL PKG

Sincerely,

Curtis Blondell

Curtis Blondell
APC Environmental Coordinator

Reviewed by,
Monica Soucier

EEC ORIGINAL PKG

Gabriela Robb

From: Krug, Robert@DTSC <Robert.Krug@dtsc.ca.gov>
Sent: Friday, May 15, 2020 3:27 PM
To: Gabriela Robb
Subject: RE: 05 28 20 EEC Meeting

CAUTION: This email originated outside our organization; please use caution.

Hi Gabriela,
Please forward my comments to David Black, Planner IV on these two projects:

Assessment #19-0018: Applicant: (CED) Con Edison Clean Energy Businesses
We request that prior to the start of business operations that the facility informs the DTSC Imperial CUPA of their operations and whether they will have hazardous materials, hazardous waste, underground storage tanks, aboveground storage tanks, or be a CalARP facility. If so, they are not allowed to operate without a permit.

Assessment # 19-0020: Applicant: Second Imperial Geothermal
We require the facility to update their CERS account information with the modifications made at their facility. This must be done within 30 days of the modification.

Robert Krug
Supervisor / Senior Environmental Scientist
DTSC Imperial CUPA
627 Wake Avenue
El Centro, CA 92243
Robert.Krug@dtsc.ca.gov
(760) 336-8919 Work
(760) 457-7376 Cell

RECEIVED
MAY 15 2020
IMPERIAL COUNTY
PLANNING & DEVELOPMENT SERVICES

Subject: 05 28 20 EEC Meeting

Good morning,

Please see attached agenda for the May 28, 2020 EEC meeting.
In an effort to increase the efficiency at which information is distributed and reduce paper usage, the EEC Hearing Package is available by clicking on the following link:
http://www.icpds.com/?pid=7530

Thank you,

EEC ORIGINAL PKG

Gabriela Robb

From: Krug, Robert@DTSC <Robert.Krug@dtsc.ca.gov>
Sent: Tuesday, August 27, 2019 3:23 PM
To: Gabriela Robb
Subject: RE: Request for Review and Comments for Ormat CUP19-0017

CAUTION: This email originated outside our organization; please use caution.

Hi Gabriela,
Regarding Heber 2 Geothermal Repower Project – Amendment to Conditional Use Permit No. 06-0006:
The DTSC Imperial CUPA requests that if Second Imperial Geothermal Company (SIGC) is currently regulated by the DTSC Imperial CUPA, that they update their California Environmental Reporting System (CERS) information when their activities and Haz Mat inventory changes. If they are just starting their business, then they need to evaluate their inventory for any Hazardous Materials (HM), if they will have any Hazardous Wastes (HW), if there will be any petroleum Aboveground Storage Tanks (ASTs) or Underground Storage Tanks (USTs), and lastly if they exceed the thresholds for the California Accidental Release Program (CalARP). If they determine they do have HM or HW as part of their business operation, then they need to notify the DTSC Imperial CUPA and we will evaluate and assist them in what they need to do, which will include creating a CERS account and the payment of annual CUPA fees. Any determination on their part is subject to validation by the DTSC Imperial CUPA, which may consist of an inspection of the facility and sampling wastes for HW criteria.
Bob

Robert Krug
Supervisor / Senior Environmental Scientist
DTSC Imperial CUPA
627 Wake Avenue
El Centro, CA 92243
Robert.Krug@dtsc.ca.gov
(760) 336-8919 Work
(760) 457-7376 Cell

RECEIVED
AUG 27 2019
IMPERIAL COUNTY
PLANNING & DEVELOPMENT SERVICES

From: Gabriela Robb <GabrielaRobb@co.imperial.ca.us>
Sent: Tuesday, August 27, 2019 2:58 PM
Subject: Request for Review and Comments for Ormat CUP19-0017

Good afternoon commenting agencies,

Please see attached Request for Review and Comments regarding CUP19-0017 as submitted by Second Imperial Geothermal Company/Ormat.
Comments are due by Thursday, September 26, 2019.

Should you have further questions, feel free to contact assigned planner, David Black at (442) 265-1736 Ext. 1746.

Thank you,

Gabriela Robb
Office Assistant III

EEC ORIGINAL PKG

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PLANNING & DEVELOPMENT SERVICES

September 18, 2019

RE: Conditional Use Permit #19-0017
Ormat, 855 Dogwood Road, Heber CA 92249 APN: 054-250-031

Imperial County Fire Department would like to thank you for the chance to review and comment on CUP #19-0017 for Ormat Facility Refurbishment, equipment installation, removal of existing facilities.

Imperial County Fire Department has the following comments and/or requirements for the Ormat Geothermal facility.

Comment received is requesting 3 additional 10,000 gallon isopentane above ground storage tanks will be installed adjacent to the existing 2 10,000 gallon isopentane above ground storage tanks.
Isopentane is highly flammable liquid that fire behavior can be highly volatile and vapors may explode when mixed with air. The amount of propose storage and the location rises concerns for Imperial County Fire Department and the surrounding community of Heber. The Emergency Response Guide:
Excerpt from ERG Guide 128 [Flammable Liquids (Water-Immiscible):
As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.
LARGE SPILL: Consider initial downwind evacuation for at least 300 meters (1000 feet).
FIRE: If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions. (ERG, 2016)
Firefighting
Fire Extinguishing Agents Not to Be Used: Water may be ineffective
Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide (USCG, 1999)
These precautions are required to be followed for all incidents including fire involving hazardous materials. To adequately protect the Imperial County Fire Department staff, facility staff, and citizens of the community of Heber and Imperial County ICFD is requesting the following mitigations measures:

- A certified fire protection engineer survey and analysis of current and proposed fire suppression and detection equipment be performed to evaluate the current systems performance and coverage of protection. Evaluate propose fire suppression and detection equipment in conjunction with existing equipment. A full report of findings must be provided to Imperial County Fire Department for review
- Isopentane leak or fire will require a large scale evacuation area and create a large scale hazardous material incident with a large operational zone. To minimize potential extremely dangerous condition to firefighters and hazardous material teams Imperial County Fire Department is requiring that a Drone be purchase for Imperial County Fire

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Department. The final cost, details, and equipment of the drone shall be determined prior the issuance of the building permit.

- Isopentane fire will require a large amount of dry chemical, foam or carbon dioxide to be effective in firefighting as water may be ineffective. For Imperial County Fire Department to be effective in our firefighting effort for the amount of storage Imperial County Fire Department is requiring a foam unit sized and equipment for the storage of isopentane be purchase for Imperial County Fire Department. The final cost, details, and equipment of the foam unit shall be determined prior the issuance of the building permits.
- All isopentane above ground storage tanks shall be protected by approved automatic fire suppression equipment. All automatic fire suppression shall be installed and maintained to the current adapted fire code and regulation.
- An approved automatic fire detection system shall be installed as per the California Fire Code. All fire detection systems shall be installed and maintained to the current adapted fire code and regulations.
- Fire department access roads and gates will be in accordance with the current adapted fire code and the facility will maintain a Knox Box for access on site.
- Compliance with all required sections of the fire code.
- Applicant shall provide product containment areas(s) for both product and water run-off in case of fire applications and retained for removal.

Imperial County Fire Department reserves the right to comment at a later time as we feel necessary.

If you have any questions, please contact the Imperial County Fire Prevention Bureau at 442-265-3020 or 442-265-3021.

Sincerely
Andrew Loper
Lieutenant/Fire Prevention Specialist
Imperial County Fire Department
Fire Prevention Bureau

Robert Malek
Deputy Chief
Imperial County Fire Department

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Kimberly Noriega

From: Ben Pogue <bpogue@ce.solutions>
Sent: Saturday, June 6, 2020 9:53 AM
To: Andrew Loper
Cc: David Black; Melissa Wendt; Sergio Cabanas; Shlomi Huberman
Subject: Heber 2 Geothermal Repower Project - Hazard Assessment

CAUTION: This email originated outside our organization; please use caution.

Good morning Lieutenant Loper,

I am following up on behalf of the Second Imperial Geothermal Co. (ORMAT) on your question regarding the analysis area for the Heber 2 Hazard Assessment (HA). As we understood, your question was why the HA used a 0.33 mile analysis area, as opposed to a 0.5 mile analysis area. I reached out to the consultant (Risk Mgt. Professionals) who performed the HA, and they provided the response below. We wanted to close the loop with you on this issue and I'd be glad to coordinate an online meeting or conference call to discuss if you have further questions. Thank you Lt. Loper, please let us know if this information resolves the issue and, if not, how you would like to proceed and I'll coordinate on this end.

Best regards, Ben

From HA Consultant:
For the alternative release scenario, the CalARP and EPA RMP regulations do not assign a radius for the alternative release scenario – the regulations only state the following regarding the alternative release scenario:

- CalARP Regulations (19 CCR § 2750.4) / EPA RMP Regulations (40 CFR §68.28):
    - (a) The owner or operator shall identify and analyze at least one alternative release scenario for each regulated toxic substance held in a covered process(es) and at least one alternative release scenario to represent all flammable substances held in covered processes.
    - (1) For each scenario required under section (a), the owner or operator shall select a scenario:
        - (A) That is more likely to occur than the worst-case release scenario under Section 2750.3;
        - (B) That will reach an endpoint offsite, unless no such scenario exists; and
        - (C) That will reach a public receptor, unless no such scenario exists.

There is not a prescribed distance the regulations assign. If you are a county within LEPC Region I (Los Angeles, Orange, San Luis Obispo, Santa Barbara, and Ventura Counties), there is a requirement that if the alternative release scenario radius is less than 0.5 miles, a map displaying a 0.5 mile radius with a list of sensitive receptors outlined on the map with the name, address and telephone number of each sensitive receptor is required. However, the Heber 2 facility is within Imperial County, which is part of LEPC Region VI. If the CUPA would like us to prepare a map in accordance with these LEPC Region I requirements, we will be happy to do so for you. Please let me know.

Ben Pogue, PMP, AICP
Director of Environmental Planning & Natural Resource Management
CELL (503) 477-2792 EMAIL bpogue@ce.solutions
WEBSITE www.ce.solutions

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Heber Public Utility District

1078 Dogwood Rd. Suite 103 • PO Box H
Heber CA 92249
Tel:(760)482-2440 • Fax (760)353-9951
www.heber.ca.gov

Mr. David Black, Planner IV
Imperial County Planning and Development Services
801 Main Street
El Centro, CA 92243

RE: COMMENT LETTER REGARDING CONDITIONAL USE PERMIT (CUP) #19-0017 HEBER II PROJECT

Dear Mr. Black:

Thank you for allowing us the opportunity to provide comments regarding the above-referenced project. The District understands the proposed amendment for the existing CUP #06-0006 to allow the installation of two (2) new water-cooled ORMAT Energy Converters and three (3) additional Isopentane above ground Storage Tanks. The proposed project is located within Heber Public Utility District's Sphere of Influence. The following comments are offered:

1. **Hazard Assessment:** The project description on the Request for Review and Comment Letter identifies the installation of three (3) additional isopentane storage tanks to be located adjacent to the existing two (2) isopentane storage tanks at 10,000 gallons each. The Hazard Assessment in the Mitigated Declaration is based on the release of a single 10,000-gallon isopentane tank. This same report states that the potential catastrophic failure of one of three 10,000-gallon isopentane tanks would have an impact of 0.3 miles, or 1,584 feet. There are residential units located within 3,500 feet to the northeast of the isopentane tanks. Please clarify how the release of three (3) additional isopentane tanks would affect the other adjacent tanks causing additional release and the impact that would occur.

2. **Miscellaneous:** ORMAT's internal pipelines are located within close proximity to Heber Public Utility District's (HPUD) domestic water pipeline along Dogwood Road, directly east of the project site. It is important to note that hot water running through ORMAT's pipeline has caused one of our pipelines, located on Pitzer Road, to burst. We encourage measures to be implemented for the proposed project to ensure protection for HPUD's domestic water pipeline.

3. **Annexation:** HPUD encourages and recommends the annexation of said property to be incorporated in HPUD's Boundary.

Once again, we thank you for the opportunity to comment. Should you have any questions, please feel free to contact me at (760)482-2440 or via email at lfischer@heber.ca.gov.

Sincerely,

Laura Fischer
General Manager

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COUNTY OF IMPERIAL

DEPARTMENT OF PUBLIC WORKS

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September 18, 2019

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Mr. Jim Minnick, Director
Planning & Development Services Department
801 Main Street
El Centro, CA 92243

Attention: David Black, Planner IV

SUBJECT: **CUP 19-0017 for Second Imperial Geothermal Company / Ormat;**
Located on 855 Dogwood Road, Heber, CA.
APN 054-250-031-000

Dear Mr. Minnick:

This letter is in response to your submittal received by this department on August 27, 2019 for the above mentioned project. The applicant is requesting a facility refurbishment, equipment installation and removal of existing facilities.

Department staff has reviewed the package information and the following comments shall be Conditions of Approval:

1. Prior to the issuance of grading, building, and encroachment permits, corner record is required to be filed with the county surveyor for monuments:

   8771. (b) When monuments exist that control the location of subdivisions, tracts, boundaries, roads, streets, or highways, or provide horizontal or vertical survey control, the monuments shall be located and referenced by or under the direction of a licensed land surveyor or licensed civil engineer legally authorized to practice land surveying, prior to the time when any streets, highways, other rights-of-way, or easements are improved, constructed, reconstructed, maintained, resurfaced, or relocated, and a corner record or record of survey of the references shall be filed with the county surveyor.

2. Prior to Certificate of Occupancy, a second corner record is required to be filed with the county surveyor for monuments:

   8771. (c) A permanent monument shall be reset in the surface of the new construction or a witness monument or monuments set to perpetuate the location if any monument could be destroyed, damaged, covered, disturbed, or otherwise obliterated, and a corner record or record of survey shall be filed with the county surveyor prior to the recording of a certificate of completion for the project. Sufficient controlling monuments shall be retained or replaced in their original positions to enable property, right-of-way and easement lines, property corners, and subdivision and tract boundaries to be reestablished without devious surveys necessarily originating on monuments differing from those that currently control the area.

3. An encroachment permit shall be secured from the Department of Public Works for any and all new, altered or unauthorized existing driveway(s) to access the property through surrounding County Roads.

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4. The applicant shall provide a drainage letter that takes into account the prevention of storm event run-off and sedimentation of damage to off-site properties and county road right-of-way(s).

5. Dogwood Road is classified as Prime Arterial - Six (6) lanes divided, requiring one hundred sixty four feet (164) of right of way, being eighty two (82) feet from existing centerline. It is required that sufficient right of way be provided to meet this road classification. **As directed by Imperial County Board of Supervisors per Minute Order #6 dated 11/22/1994 per the Imperial County Circulation Element Plan of the General Plan).**

INFORMATIVE:

The following items are for informational purposes only. The Developer is responsible to determine if the enclosed items affect the subject project.

- All solid and hazardous waste shall be disposed of in approved solid waste disposal sites in accordance with existing County, State and Federal regulations (Per Imperial County Code of Ordinances, Chapter 8.72).

- All on-site traffic areas shall be hard surfaced to provide all weather access for emergency vehicles.

- The project may require a National Pollutant Discharge Elimination System (NPDES) permit and Notice of Intent (NOI) from the Regional Water Quality Control Board (RWQCB) prior to County approval of onsite grading plan (40 CFR 122.28).

- As this project proceeds through the planning and the approval process, additional comments and/or requirements may apply as more information is received.

- A Transportation Permit may be required from road agency(s) having jurisdiction over the haul route(s) for any hauls of heavy equipment and/or large vehicles which impose greater than legal loads on riding surfaces, including bridges. (Per Imperial County Code of Ordinances, Chapter 10.12 – Overweight Vehicles and Loads).

Should you have any questions, please do not hesitate to contact this office. Thank you for the opportunity to review and comment on this project.

Respectfully,

By:

John A. Gay, PE
Director of Public Works

CY/dm

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KYLE C. JONES
RACHAEL E. KOSS
NIRIT LOTAN
WILLIAM C. MUMBY

MARC D. JOSEPH
Of Counsel

*Not admitted in California. Licensed in Colorado.

November 18, 2020

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Via Email Submission

Chairman Jim Minnick and Committee Members
Environmental Evaluation Committee
Imperial County
801 Main Street
El Centro, CA 92243
Email: JimMinnick@co.imperial.ca.us; icpdscommentletters@co.imperial.ca.us

David Black, Planner IV
Email: DavidBlack@co.imperial.ca.us

Re: **Assessment #19-0020: Second Imperial Geothermal; Negative Declaration for the Heber 2 Geothermal Repower Project (SCH No. 2020069002; CUP No. 19-0017)**

Dear Chairman Minnick and Committee Members, Mr. Black:

On behalf of California Unions for Reliable Energy ("CURE"), we submit these comments regarding Environmental Evaluation Committee ("EEC") Assessment #19-0020: Second Imperial Geothermal, including the Initial Study/Negative Declaration ("IS/ND") for the Heber 2 Geothermal Repower Project ("Project"). We urge the EEC to revise the IS/ND and recirculate it as an Environmental Impact Report ("EIR") to give the public and the County an opportunity to accurately assess the Project's significant environmental impacts.

The Staff Report submitted to the EEC recommends that the IS/ND be recirculated as a Mitigated Negative Declaration ("MND") to account for several impacts that are potentially significant unless mitigated, including impacts to biological resources, geology and soils, and health risks related to the Project's three new 10,000-gallon above-ground isopentane storage tanks. We concur that the Project poses potentially significant hazardous materials and public health risks from the proposed storage of isopentane, an extremely volatile and highly flammable liquid, as well as potentially significant impacts to biological resources

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and geology and soils, and that the IS/ND must be recirculated as a new CEQA document for further public assessment and comment. However, an MND is inadequate to address all of Project's potentially significant impacts, many of which were not analyzed at all, or were inadequately analyzed, in the IS/ND. The IS/ND also failed to include supporting evidence for many of its conclusions about the Project's air quality, valley fever, geologic and biological resources impacts. An EIR must be prepared and circulated for additional public comment to address these remaining inadequacies in the IS/ND. The EIR must include a detailed analysis which fully discloses the scope and severity of the Project's potential impacts to public health and the environment and must incorporate feasible and enforceable mitigation measures to minimize these risks to the greatest extent feasible.

On August 31, 2020, we submitted written comments on the IS/ND, supported by the technical comments of air quality and hazardous materials expert Phyllis Fox, Ph.D., PE and biological resources expert Shawn Smallwood, Ph.D.[1] Dr. Fox and Dr. Smallwood provided substantial evidence supporting a fair argument that the Project was likely to have numerous potentially significant impacts that were not adequately disclosed, analyzed, or mitigated in the IS/ND. The Staff Report did not directly respond to any of our comments. The Responses from the Applicant ("Responses"), address some of our comments, though not in any meaningful level of detail. Furthermore, both of the comment letters from Dr. Fox and Dr. Smallwood, went unanswered. Dr. Fox and Dr. Smallwood have provided letters indicating that the Staff Report and Responses lack evidence for their conclusions and calling for preparation of an EIR. We request that the County provide responses to all of our comments in an EIR.[2]

The Responses that do purport to address our comments lack any substantial evidence that the Project will not result in significant impacts, and fail to address the substantial evidence submitted by our experts. The Responses are largely non-responsive, and fail to provide the missing information, analysis, and mitigation called for in the entirety of our comment letter. Furthermore, the Responses are inconsistent with the revised MND that Staff recommends be adopted by the County. The revised MND, for instance, found that the Project will have potentially significant impacts on biological resources and geology and soils, and recommends

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[1] CURE's August 1, 2020 *Comments on the Negative Declaration for the Heber 2 Geothermal Repower Project (SCH No. 2020069002; CUP No. 19-0017)* are included in the Staff Report at Part 1, beginning at pdf. 71.

[2] Both Dr. Fox's and Dr. Smallwood's replies to the Staff Report and Responses are attached as **Attachment A** and **Attachment B**.

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mitigation measures to minimize these impacts. The Responses, however, state that the Project will result in no significant impacts in these areas. This is indicative of the lack of evidence for the conclusions made in both the Responses and the proposed MND, and underscores the necessity of an EIR to fully evaluate the Project's impacts.

Among the issues itemized in our comment letter that have not been addressed by the Responses are:

- Construction emissions estimations are based upon incomplete baseline information and are therefore inaccurate. The ATC application indicates that the increase in isopentane emissions was calculated using only emissions from the third quarter of 2018. Baseline emissions must be based on an average over a period.
- Our expert, Dr. Fox, found that emissions from construction would be significant, while the IS/ND does not support the conclusion that construction emissions would not contribute significantly to regional violations of ambient air quality standards.
- An updated inventory of air quality emissions containing new figures and a memorandum summarizing these calculations was included in the Staff Report. Any new analysis must be circulated as part of an EIR, not simply attached to the Staff Report.
- The Project may result in significant impacts to public health through valley fever. The IS/ND acknowledges that measures must be taken to avoid risks to worker safety and public health, but disguises these measures as "voluntary" practices undertaken by the applicant, thus failing to acknowledge a potentially significant risk that requires mitigation and the circulation of an EIR.
- The Project may result in significant impacts to biological resources, including six migratory bird species. The Staff Report acknowledges this, and includes several new mitigation measures in an attempt to minimize the potential impacts, but the Responses fail to disclose the impact as significant. Both the mitigation measures, and an updated analysis which discloses the severity of the impact, should be included in an EIR that is recirculated for public review to allow for meaningful consideration of their adequacy.
- The Responses fail to acknowledge that the Project may result in potentially significant impacts to geology and soils. The IS/ND

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explained that withdrawing geothermal fluid creates localized ground subsidence. Dr. Fox's comments explained that inflation and subsidence, if not controlled, can have adverse geologic impacts on farming operations, irrigation systems, roads, bridges and municipal sewer piping. The Responses are inconsistent with the revised MND, which recommends the preparation of a geotechnical investigation of the Project site prior to approval of a grading or building permit to minimize the potentially adverse effects due to the Project's location in a seismically active valley. As these adverse effects have the potential to be catastrophic, an EIR is required to properly assess mitigation.

- The Staff Report acknowledges that risks to public health and the environment involving the transport, use, and disposal of hazardous materials, as well as the risk of upset or accident involving these materials are potentially significant unless mitigated. Staff recommends incorporating mitigation measures that include protecting isopentane tanks with fire suppression equipment; installation of an automatic fire detection system; equipping tanks with water-suppression systems and flame and gas detectors; constructing a blast wall between isopentane tanks #4 and #5; and more. Due to the catastrophic nature of any adverse effects resulting from upset or accident involving hazardous materials, an EIR assessing these mitigation measures should be circulated.

While we agree with Staff that the IS/ND must be recirculated for additional public comment and to include mitigation measures to address impacts from several potentially significant impacts, we urge the Committee to require the County to prepare an EIR to sufficiently consider these impacts. We reserve the right to file comments on any revised CEQA document.

Sincerely,



Kendra Hartmann
Christina Caro

KDH:ljl
4847-015j

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ATTACHMENT A

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Phyllis Fox, Ph.D., PE
745 White Pine Ave.
Rockledge, FL 32955

November 18, 2020

Dear Ms. Hartmann,

I have reviewed the Staff Report and Responses to Comments ("Responses") on the Initial Study/Negative Declaration ("IS/ND") for the Heber 2 Geothermal Repower Project. While I agree that the IS/ND must be recirculated for further public review and comment, it must be revised as an environmental impact report ("EIR"), not a mitigated negative declaration ("MND").

Though Staff did not respond directly to my comment letter, some of the recommended revisions in the IS/ND, as well as some of the responses submitted by the Applicant, peripherally address issues raised in my letter.

Hazard Assessment

First, the Staff Report contains a revised Hazard Assessment. [1] However, it fails to address my comments. However, this revised analysis fails to address the majority of the issues that I raised in my comments on this issue.[2] A hazard analysis must be based on the worst-case scenario. The revised analysis selected a vapor cloud explosion as the most appropriate type of accident. However, a BLEVE is the worst case release scenario for very flammable materials such as isopentane because it combines both the mechanical effects of an explosion and the thermal effects of a fire. Due to these dual effects, it is one of the most severe accidents that can happen and typically results in mortalities.

The revised Hazard Assessment failed to evaluate a worst-case scenario, a BLEVE. It incorrectly asserts, with no support, that "BLEVEs are generally considered unlikely events and were therefore not considered a probable event for the Offsite Consequence Analysis."

[1] ORMAT, Heber 2 Geothermal Power Generation Facilities, Heber, California, Hazard Assessment, October 16, 2020, Prepared by Risk Management Professionals, Inc.
[2] Fox Comments, Comment 8: Hazards.

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However, my comments documented many BLEVE accidents at similar facilities. My comments also demonstrated that the impact radius for BLEVEs is substantially higher (up to 68 times) than the impact radius for the vapor cloud explosion cases evaluated in the IS[3] and the revised Hazard Assessment in the Staff Report. Assuming a 68 times higher impact radius, an explosion at the Project's storage tank facility based on the revised analysis could extend 3.5 miles (0.052x68=3.5 miles) from the tanks,[4] impacting numerous sensitive receptors.[5]

Further, the revised Hazard Analysis failed to consider Imperial County's recently adopted "specific plan area" that covers the Heber Known Geothermal Resource Area (KGRA). The Heber Specific Plan allows commercial, residential, industrial, and other employment-oriented development in a mixed-use orientation, which currently includes geothermal uses. This plan could place many sensitive receptors close to the Project.[6] Heber's annual report discloses:[7]

> geothermal uses. Several of the landowners from whom we hold geothermal leases have expressed an interest in developing their land for residential, commercial, industrial or other surface uses in accordance with the parameters of the Heber Specific Plan Area. Currently, Imperial County's Heber Specific Plan Area is coordinated with the cities of El Centro and Calexico. There has been ongoing underlying interest since the early 1990s to incorporate the community of Heber. While any incorporation process would likely take several years, if Heber were to be incorporated, the City of Heber could replace Imperial County as the governing land use authority, which, depending on its policies, could have a significant effect on land use and availability of geothermal resources.

Finally, the revised hazard analysis only considered "offsite sensitive receptors." However, one of the most at-risk populations is on-site workers, emergency responders, the Applicant's office/control room/shop building at the power plant, and agricultural workers in the surrounding fields. The impacts to these workers are significant and unmitigated.

The Imperial County Fire Department had similar concerns and requested specific mitigation measures. The Staff Report asserts mitigation HAZ-1 addresses these concerns. However, HAZ-1 is silent on the Fire Department's concerns.[8]

While I concur that it is necessary to include measures to minimize the potential harm from an accident involving the storage of isopentane, which is an extremely volatile and highly flammable liquid, these mitigation measures are not sufficient to prevent such harm. My comment letter discussed the problems with considering the worst-case scenario from the hypothetical catastrophic failure of only one of the 10,0000-gallon isopentane tanks. The Project proposes to install three of these tanks. The Staff Report attaches a new Hazard Assessment. This is a new study which presents new information and analysis that must be presented in an EIR, not merely attached to the Staff Report. Moreover, my

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[3] Worst-case BLEVE/Vapor Cloud Explosion = 6.8 mi/0.1 mi = 68.
[4] Revised impact radius = (0.3 mi)(68) = 20 mi. Project impact radius of 0.3 miles from IS, pdf 311, Table 6.
[5] Fox Comments, p. 49 (The nearest sensitive receptors are about 0.66 miles to the northeast.)
[6] U.S. Securities and Exchange Commission, Form 10-K, Ormat Technologies, Inc., Fiscal Year Ended December 31, 2019; https://sec.report/Document/0001437749-20-004072/. See also: Ormat Technologies, Inc., 2019 Annual Report, pdf 77; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.
[7] See, e.g. Ormat Technologies, Inc., 2019 Annual Report, pdf 77; http://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ORA_2019.pdf.
[8] Staff Report, pdf184

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preliminary review of the Hazard Assessment concludes that it remains inadequate because it fails to analyzes the impacts from all three tanks and continues to rely on the IS/ND's deficient worst-case release scenario. Due to the high risk to public health from these potential accidents, an EIR must be prepared and circulated to allow the public to review these impacts and mitigation measures.

Many more were not responded to at all, or provide inaccurate and cursory responses, including:

- Emissions of criteria pollutants such as NOx would be significantly higher depending on the equipment used during construction. Though the Applicant's responses state that the IS/ND checklist adequately describes the construction activities and equipment, neither the IS/ND nor its supporting Air Quality Report contain any information about which equipment will be used.
- The IS/ND did not include any supporting calculations for isopentane emissions estimates. Based on my calculations, as explained extensively in my comments on the IS/ND, these emissions are underestimated and will likely increase, not decrease, potentially resulting in a significant impact. The Responses do not provide evidence to support the County's conclusions.
- Operational air quality impacts from emissions of isopentane and other criteria pollutants will be significant. The IS/ND did not include supporting calculations for emissions estimates, and neither do the Responses.
- The IS/ND only estimates the change in ROG emissions for maintenance, purging, and fugitive components (valves, flanges, etc.) for the OEC units' emissions. The facility includes other equipment that emits pollutants, including four cooling towers, a vapor recovery unit, a diesel generator, and a fire pump. These all variously emit ROG, NOx, PM10, PM2.5, and HAPs. Because the facility is at the end of its useful life and is being repowered, it is reasonable to assume that the Heber 2 facility and all of this supporting equipment has not been operating at its design capacity in the baseline.
- The Project may result in significant impacts to public health, including increased incidence of valley fever, exposure to geothermal gases, increased emissions of hazardous air pollutants, and worsening air quality. The mitigation proposed in the Staff Report does not address Valley Fever spores, which are substantially smaller than the PM2.5 and PM10 emissions they were designed to control. My coments identify mitigation measures for Valley Fever developed by San Luis Obispo County specifically to control Valley Fever spores. The responses failed to acknowledge these important and essential mitigation measures.

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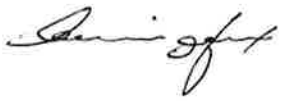
- Staff has recommended including in a mitigation measure in an MND to minimize the potential risks posed by upset and accident of hazardous materials related to the Project's three new 10,000-gallon above-ground isopentane storage tanks. The measure includes diking and impoundment of the isopentane tanks to minimize the magnitude and extent of a tank failure and relocating the tanks to prevent a catastrophic event.

Sincerely,



Phyllis Fox, Ph.D., PE

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ATTACHMENT B

EEC ORIGINAL PKG

Shawn Smallwood, PhD
3108 Finch Street
Davis, CA 95616

Attn: David Black, Planner IV
Imperial County Planning & Development Services Department
801 Main Street
El Centro, CA 92243

18 November 2020

RE: Heber 2 Geothermal Repower Project

Dear Mr. Black,

I write to reply to responses to my comments on the Initial Study and Mitigated Negative Declaration (IS/MND) prepared for the proposed Heber 2 Geothermal Repower Project. I note that whereas the County responded directly to comments provided by CURE, those comments were summaries of my comments. My qualifications for providing expert comments were provided with my letter of 1 July 2020.

Comment IV.b. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site — the County failed to make a reasonable effort to describe baseline biological conditions, and account for sensitive species on the site.

County Response: As noted by CURE, a comprehensive records search for biological resources, vegetation, and sensitive species was performed to identify species that could occupy the project site and surrounding area. All databases used in this research (e.g., IPac, CNDDB, etc.) are managed by public agencies and serve as the standard for determining the biological community present in/near a project site. After a review of the records, a wildlife biologist performed a reconnaissance-level survey of the Project Site, concurring that the site is completely void of any habitat and sensitive species. These efforts were recorded and provided as an Appendix B to the CUP. For a site that is a "dirt lot" by CURE's own admission, and confirmed with site photographs and supporting technical documentation, a reasonable effort was made to describe the baseline biological conditions and potentially occurring sensitive species. Further, as provided in the CUP Amendment Application, the Environmental Protection Measures section, "pre-construction surveys would occur to ensure the absence of any sensitive species".

As provided in the CURE letter, a Google Earth snapshot of a common crow flying by the Project site does not constitute evidence that sensitive species are likely present (14 C.C.R. 15064(f).) As documented through verifiable database research and a site-specific survey (as provided in Appendix B of the CUP), the site does not contain suitable habitat and no sensitive species occur on the site. Further, due to the industrialized nature of the site, avian species are likely to avoid the site. Again, the Project site would be surveyed prior to construction to verify the absence of any special status species.

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Reply: In dismissing species occurrence data that are available on eBird, the response implies that use of data managed by public agencies — specifically iPac and CNDDB — "serve as the standard for determining the biological community present in/near a project site." However, CNDDB was never intended to determine the biological community at or near a project site. CNDDB appropriately posts the following disclaimer: "We work very hard to keep the CNDDB and the Spotted Owl Database as current and up-to-date as possible given our capabilities and resources. However, we cannot and do not portray the CNDDB as an exhaustive and comprehensive inventory of all rare species and natural communities statewide. Field verification for the presence or absence of sensitive species will always be an important obligation of our customers. Likewise, your contribution of data to the CNDDB is equally important to the maintenance of the CNDDB. ..." Similarly, iPac makes no claim of perfect knowledge of species occurrences at or near a site.

CEQA does not include such an exclusionary standard over which data sources ought to be used to inform decision-makers and the public of potential project impacts to biological resources. An important CEQA objective is to publicly disclose potential environmental impacts of a proposed project so that decision-makers and the public can make more informed decisions over whether and how to proceed with a proposed project. To meet this objective, CEQA does not require use of CNDDB and iPac as the sole data bases upon which to inform the public. Nor do detection survey guidelines for any particular species suggest relying solely on CNDDB or iPac for determining habitat suitability at a site. The response asserts exclusionary use of CNDDB and iPac as a false standard.

Public participation with decision-making over proposed projects is another important CEQA objective, and one to which the public can contribute via their observations of special-status species on or near a project site. Members of the public have eyes, too. Observations of the public can be just as informative — and more so — as those of professional biologists, especially when biologists commit very little time and effort toward detecting special-status species at a site. eBird is a compilation of observations of the public. It is administered competently by Cornell University Laboratory of Ornithology — the most respected ornithological organization in North America and a leading authority in the world. Hundreds of scientific papers based on eBird records have been peer-reviewed and published (https://ebird.org/science/publications). eBird not only serves as a highly useful source of information for predicting the occurrence likelihoods of special-status species, but it helps to meet CEQA's objective of public participation.

The response repeats the IS/ND's claim that the lack of vegetation on site prevents the occurrence of any special-status species. But the response also repeats the IS/ND's neglect of airspace as a critical habitat component of volant species. Species that fly do so in the airspace above ground regardless of whether the ground is covered in grass, scrub or a suppressed "dirt lot." Many of these species fly at night, and thus pay little attention to groundcover. However, some special-status species happen to prefer bare ground, such as California horned lark (Photos 1 and 2).

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Photos 1 and 2. *A pair of California horned larks at their breeding site on bare ground in April 2020, in an agricultural field where safflower and wheat were cultivated to either side. Photos by K. Shawn Smallwood.*

The response goes on to claim, "...as provided in the CUP Amendment Application, the Environmental Protection Measures section, "pre-construction surveys would occur to ensure the absence of any sensitive species." This claim falsely characterizes the purpose and capability of preconstruction surveys. As I explained in my comment letter of 1 July 2020, "...preconstruction surveys cannot verify the absence of any species, as verification of absence is not what preconstruction surveys are designed to achieve. Preconstruction surveys are surveys intended to detect and salvage readily detectable individuals before they are destroyed by heavy machinery. The only type of survey that can verify absence is a 'detection survey.' Detection surveys are intended for providing the best means of detecting a particular species and for supporting determinations of absence when the species has not been detected despite implementation of detection surveys. Detection surveys are also intended to inform preconstruction surveys and to inform mitigation planning. The protocols for detection surveys have been developed by experts on the species, usually in coordination with natural resource agencies."

The response mischaracterizes information I provided in my comment letter. According to the County, "...a Google Earth snapshot of a common crow flying by the Project site does not constitute evidence that sensitive species are likely present (14 C.C.R. 15064(f).)." The crow was not a crow, but rather 4 common ravens. Nor were the common ravens just flying by, but the series of images available on Google Earth revealed they had been perched on project buildings before taking off. These distinctions are important because, as was explained in my comment letter, common ravens are the most prolific removers of bird and bat carcasses from places where collision fatalities are deposited. Common ravens occur where they have learned food

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can be reliably found. Birds and bats that collide with powerblocks and fences and powerlines become reliable food sources for common ravens.

Comment VI.e. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project – Avian fatality monitoring at nearby solar facilities show high levels of avian mortality.

County Response: See response above for Issue IV.b above. Additionally, as observed in the CUP project description, no new transmission lines (or solar facilities, as volunteered in the CURE comment) or changes to existing Heber 2 substation are proposed; therefore, baseline conditions would remain the same and the Project would not cause any significant impacts to avian species.

Reply: The proposed project would cause significant impacts to avian species, as amply demonstrated by fatality monitoring data collected in both Imperial County and neighboring counties (Smallwood 2020). In my comment letter of 1 July 2020, I predicted that after 30 years of operations of the existing structures and proposed new structures, the accumulated collision fatalities would total about 13,050 birds and 930 bats. In its response, the County does not dispute my predictions. Instead, the response characterizes the ongoing collision and entanglement mortality as baseline conditions that would remain unchanged for 30 more years. Whereas in 1992 little was known of the impacts to wildlife caused by powerblocks, fences and powerlines, the proliferation of solar energy projects and the wildlife fatality monitoring performed at those projects have provided the bases for predicting wildlife fatalities at the project that would be modified as proposed and operated for another 30 years. The project's impacts would be substantial, and significant.

Shawn Smallwood

Shawn Smallwood, Ph.D.

REFERENCES CITED

Smallwood, K. S. 2020. Comparison of bird and bat fatality rates among utility-scale solar projects in California. Report to undisclosed client.

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HEBER 2
DOCUMENTS & DATA

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Recorded in Official Records, Imperial County

Dolores Provencio
County Clerk / Recorder

4/25/2006
11:04 AM
IV

P Public

Doc#: 2006–020097

Titles: 1 Pages: 17

Fees	54.00
Taxes	0.00
Other	0.00
PAID	$54.00

Please return to:

Imperial County Planning & Dev. Services Department
801 Main Street
El Centro, California 92243

AGREEMENT FOR CONDITIONAL USE PERMIT #06-0006 ORCAL/HEBER FIELD COMPANY

This Agreement is made and entered into on this 12th day of April 2006, by and between ORCAL/Heber Field Company, hereinafter referred to as Permittee, and the COUNTY OF IMPERIAL, a political subdivision of the State of California, (hereinafter referred to as "COUNTY").

RECITALS

WHEREAS, Permittee is the owner, lessee or successor-in-interest in certain land in Imperial County located south of State Highway 86, east of Dogwood Road, north of Willoughby Road, and southeast of the townsite of Heber, California, described as a portion of the East half of Tract 45, APN 054-250-036-000, 20 acres, Township 16 South, Range 14 East, SBB&M; and,

WHEREAS, Permittee has applied to the County of Imperial for a Conditional Use Permit #06-0006 ("Project") for the following expansion project which supercedes the previous CUP #04-0026);

GENERALCONDITIONS:

The "GENERAL CONDITIONS" are shown by the letter "G". These conditions are conditions that are either routinely and commonly included in all Conditional Use Permits as "standardized conditions and/or are conditions that the Imperial County Planning Commission has established as a requirement on all CUP's for consistent application and enforcement. The Permittee is hereby advised that the General Conditions are as applicable as the SITE SPECIFIC conditions.

G-1 GENERAL LAW:

The Permittee shall comply with all local, state and/or federal laws, rules, regulations, ordinances, and/or standards as they may pertain to the Project whether specified herein or not.

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G-2 PERMITS/LICENSES:

The Permittee shall obtain any and all local, state and/or federal permits, licenses, and/or other approvals for the construction and/or operation of the Project. This shall include, but not be limited to, local requirements for Health, Building, Sanitation, ICAPCD, Public Works, County Sheriff, Fire/Office of Emergency Services, Regional Water Quality Control Board, California Division of Oil, Gas and Geothermal Resources (CDOGGR), among others. Permittee shall likewise comply with all such permit requirements and shall submit a copy of such additional permit and/or licenses to the Planning & Development Services Department within 30 days of receipt, as deemed necessary.

G-3 RECORDATION:

This permit shall not be effective until it is recorded at the Imperial County Recorders Office and payment of the recordation fee shall be the responsibility of the Permittee. If the Permittee fails to pay the recordation fee within six (6) months from the date of approval, this permit shall be deemed null and void. The Planning & Development Services Department will submit the executed CUP to the County Recorder's office for recordation purposes.

G-4 CONDITION PRIORITY:

The Project shall be constructed and operated as described in the Conditional Use Permit application, and as specified in these conditions.

G-5 INDEMNIFICATION:

As a condition of this permit, Permittee agrees to defend, indemnify, hold harmless, and release the County, its agents, officers, attorneys, and employees from any claim, action, or proceeding brought against any of them, the purpose of which is to attack, set aside, void, or annul the permit or adoption of the environmental document which accompanies it. This indemnification obligation shall include, but not be limited to, damages, costs, expenses, attorneys fees, or expert witness fees that may be asserted by any person or entity, including the Permittee, arising out of or in connection with the approval of this permit, whether there is concurrent, passive or active negligence on the part of the County, its agents, officers, attorneys, or employees. This indemnification shall include Permittee's actions involved in construction, operation or abandonment of the permitted activities.

G-6 INSURANCE:

The Permittee shall secure and maintain liability in tort and property damage, insurance at a minimum of $1,000,000 or proof of financial responsibility to protect persons or property from injury or damage caused in any way by construction and/or operation of the permitted facilities. The Permittee shall require that proper Workers' Compensation insurance cover all laborers working on such facilities, e.g. during construction and maintenance, as required by the State of California. The Permittee shall also secure liability insurance and such other insurance as may be

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required by the State and/or Federal Law. Evidence of such insurance shall be provided to the County prior to commencement of any activities authorized by this permit, e.g. a Certificate of Insurance is to be provided to the Planning & Development Services Department by the insurance carrier and said insurance and certificate shall be kept current for the life of the permitted project. Certificate(s) of insurance shall be sent directly to the Planning & Development Services Department by the insurance carrier and shall name the Department as a recipient of both renewal and cancellation notices.

G-7 INSPECTION AND RIGHT OF ENTRY:

The County reserves the right to enter the premises to make appropriate inspection(s) and to determine if the condition(s) of this permit are complied with. The owner or operator shall allow authorized County representative(s) access upon the presentation of credentials and other documents as may be required by law to:

(a) Enter at reasonable times upon the owner's or operator's premises where the permitted facilities are is located, or where records must be kept under the conditions of the permit;

(b) Have access to and copy, at reasonable times, any records that must be kept under the conditions of the permit;

(c) Inspect at reasonable times any facilities, equipment, or operations regulated or required under the permit, and,

G-8 SEVERABILITY:

Should any condition(s) of this permit be determined by a Court or other agency with proper jurisdiction to be invalid for any reason, such determination shall not invalidate the remaining provision(s) of this permit.

G-9 PROVISION TO RUN WITH THE LAND/PROJECT:

The provisions of this project are to run with the land/project and shall bind the current and future owner(s), successor(s) of interest, assignee(s) and/or transferee(s) of said project. Permittee shall not without prior notification to the Planning & Development Services Department assign, sell or transfer, or grant control of project or any right or privilege therein. The Permittee shall provide a minimum of sixty (60) days written notice prior to such proposed transfer becoming effective. The permitted use identified herein is limited for use upon the permitted properties described herein and may not be transferred.

G-10 TIME LIMIT:

Unless otherwise specified within the specific conditions, this permit shall be limited to a maximum of three (3) years from the recordation of the CUP. The CUP may be extended for successive three (3) year period(s) by the Planning Director upon a finding by the Planning & Development Services Department that the project is in

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compliance with all conditions of the CUP as stated herein and any applicable Land Use regulation of the County of Imperial. Unless otherwise specified herein, no Conditional Use Permit(s) shall be extended for more than four (4) consecutive periods by the Planning & Development Services Department. If an extension is necessary, or is requested beyond fifteen (15) years, the Permittee shall file a written extension request at least sixty (60) days prior to the expiration of the Permit. Such an extension request shall include the appropriate extension fee, pursuant to the Land Use Ordinance, Title 9, Division 9, Section 90901.03 et. seq., General Planning fees. If the original approval was granted by the Planning Commission and/or the Board of Supervisors, such an extension shall only be considered by the approving body, after a noticed public hearing. Nothing stated or implied within this permit shall constitute a guarantee that an extension will be granted. An extension may not be granted if the project is in violation of any one or all of the conditions or if there is a history of non-compliance with the permit conditions.

G-11 COST:

The Permittee shall pay any and all amounts determined by the County Planning & Development Services Department to defray any and all cost(s) for the review of reports, field investigations, monitoring, and other activities directly related to the enforcement/monitoring for compliance of this Conditional Use Permit, County Ordinance or any other applicable law as provided in the Land Use Ordinance, Section 90901.03 et. seq, General Planning fees. All County Departments, directly involved in the monitoring/enforcement of this project may bill Permittee under this provision, however said billing shall only be through and with the approval of the Planning & Development Services Department.

G-12 REPORTS/INFORMATION:

If requested by the Planning Director, Permittee shall provide any such documentation/report as necessary to ascertain compliance with the Conditional Use Permit. The format, content and supporting documentation shall be as required by the Planning Director.

G-13 DEFINITIONS:

In the event of a dispute the meaning(s) or the intent of any word(s), phrase(s) and/or conditions or sections herein shall be determined by the Planning Commission of the County of Imperial. Their determination shall be final unless an appeal is made to the Board of Supervisors within the required time, i.e. ten (10) calendar days, pursuant to the Land Use Ordinance, Title 9, Division 1, Chapter 4, Section 90104.05, Appeal from Decision.

G-14 MINOR AMENDMENTS:

The Planning Director may approve minor modifications to the Permit to accommodate minor changes or modifications to the design, construction, and/or operation of the Project provided said changes are necessary for the project to meet

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other laws, regulations, codes, or conditions of the CUP and provided further, that such changes will not result in any additional environmental impacts.

G-15 SPECIFICITY:

The issuance of this permit does not authorizes the Permittee to construct or operate the Project in violation of any state, federal, local law nor beyond the specified boundaries of the project as shown the application/project description/permit, nor shall this permit allow any accessory or ancillary use not specified herein. This permit does not provide any prescriptive right or use to the Permittee for future addition and or modifications to the Project.

G-16 NON-COMPLIANCE (ENFORCEMENT & TERMINATION):

Should the Permittee violate any condition herein, the County shall give notice of such violation. If Permittee does not act to correct the identified violation, and after having given reasonable notice and opportunity, e.g. typically at least thirty (30) days, the County may revoke the permit.

(a) If the Planning Commission finds and determines that the Permittee or successor-in-interest has not complied with the terms and conditions of the CUP, or cannot comply with the terms and conditions of the CUP, or the Planning Commission determines that the permitted activities constitute a public nuisance, the Planning Director shall provide Permittee with notice and a reasonable opportunity to comply with the enforcement or abatement order.

(b) If after receipt of the order (1) Permittee fails to comply, and/or (2) Permittee cannot comply with the conditions set forth in the CUP, then the matter shall be referred to the Planning Commission for permit modification suspension, or termination, or to the appropriate prosecuting authority.

G-17 GENERAL WELFARE:

All construction, drilling, testing, and operations shall be conducted with consistency with all laws, conditions, adopted County policies, plans and the application so that the project will be in harmony with the area and not conflict with the public health, safety, comfort, convenience, and general welfare.

G-18 PERMITS OF OTHER AGENCIES INCORPORATED:

Permits granted by other governmental agencies in connection with the Project are incorporated herein by reference. The County reserves the right to apply conditions of those permits, as the County deems appropriate; provided however, that enforcement of a permit granted by another governmental agency shall require concurrence by the respective agency. Permittee shall provide to the County, on request, copies and amendments of all such permits.

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G-19 HEALTH HAZARD:

If the County Health Officer determines that a significant health hazard exists to the public, the Health Officer may require appropriate measures and the Permittee shall implement such measures to mitigate the health hazard. If the hazard to the public is determined to be imminent, such measures may be imposed immediately and may include temporary suspension of permitted activities, the measures imposed by the County Health Officer shall not prohibit the Permittee from requesting a special Planning Commission meeting, provided Permittee bears all related costs.

G-20 EMPLOYMENT:

The Permittee shall use to the maximum extent possible local labor from Imperial County for both construction and operation of said project. Permittee shall give priority to the extent allowed by law to applicants from Imperial County. This provision shall apply to all levels of employment at the site from Senior Management, Technical to Laborer (collectively the work force). At a minimum, Permittee shall seek to secure 50% of the work force from Imperial County residents (County residents being defined as anyone who has resided within the County for at least 120 days). In the event Permittee is unable to meet this requirement due to lack of qualified applicants, a comprehensive report shall be provided to the Planning & Development Services Department. Said report shall include the description of position(s), the number and origin of all applicants, the reasons that Permittee cannot comply. In the event compliance cannot be attained, this matter shall be brought to the Planning Commission for direction and/or modification.

G-21 APPROVALS AND CONDITIONS SUBSEQUENT TO GRANTING PERMIT:

Permittee acceptance of this permit shall be deemed to constitute agreement with the terms and conditions contained herein. Where a requirement is imposed in this permit that Permittee conduct a monitoring program, and where the County has reserved the right to impose or modify conditions with which the Permittee must comply based on data obtained therefrom, or where Permittee is required to prepare specific plans for County approval and disagreement arises, the Permittee, operator and/or agent, the Planning Director or other affected party, to be determined by the Planning Director, may request that a hearing be conducted before the Planning Commission whereby they may state the requirements which will implement the applicable conditions as intended herein. Upon receipt of a request, the Planning Commission shall conduct a hearing and make a written determination. The Planning Commission may request support and advice from a technical advisory committee. Failure to take any action shall constitute endorsement of staff's determination.

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SITE SPECIFIC CONDITIONS:

S-1 AUTHORIZED SCOPE OF ACTIVITIES:

The Permittee has constructed and operated the following facilities in compliance with the County's General Plan, Geothermal/Transmission Element, Land Use Ordinance, and former CUP #04-0026, and all other applicable local, state, and federal laws, ordinances, regulations and standards:

(a) A production island containing eleven (11) wells;

(b) Piping from the wells to the power plant and from the plant to the injection islands;

(c) An injection island containing eight (8) wells and additional injection island containing two (2) wells;

(d) Pumps, tanks, valves, controls, flow monitoring, and other necessary appurtenances to the above wells and pipelines;

(e) Construct and maintain the proposed injection pipeline from Heber Geothermal Company (Heber 1) geothermal power plant to the Second Imperial Geothermal Company (Heber 2) injection facilities;

(f) Operation of pumps, valves, and other control mechanisms, associated with
the pipeline, flow monitoring and other necessary appurtenances to the above.

The proposed project will be constructed, operated and maintained as follows:

(a) Drill an injection well on the HGC production island, drill a blowdown well, and construct a one and one-half mile (1 1/2 mile) long 6" below-ground pipeline to transport brine from the HGC power plant to the Second Imperial Geothermal Company area;

(b) Except as specifically authorized in this permit to complete the above activities, supplemental activities which require additional major equipment or facilities will require separate permits. The County, in issuing this permit, in no way assures or otherwise vests any right, with respect to the issuance of a permit(s) for any supplemental activities and Permittee shall also comply with all applicable geothermal standards in the Land Use Ordinance.

S-2 AIR QUALITY AND DUST EMISSIONS:

The Permittee shall comply with the Imperial County Air Pollution Control District's (ICAPCD) air-monitoring criteria for PM-10 to control dust or other emissions by implementing the APCD Fugitive Dust Control conditions (Rule 800) and obtain an Authority to Construct and Amendment Permit to Operate prior to any

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construction/operation of any new or modified equipment or operation for the expansion project.

S-3 ARCHAEOLOGICAL, CULTURAL & PALEONTOLOGICAL RESOURCES:

The Permittee shall monitor the construction of expansion equipment and if any unusual specimens of bone, stone, or ceramic are discovered during construction of the permitted facilities, all construction affecting the discovery site, shall cease until a qualified archaeologist retained by the Permittee and approved by the County, reviews the specimens. The recommendations of the archaeologist shall be complied with prior to resuming construction.

S-4 BRINE CHEMISTRY:

Permittee shall conduct brine chemistry tests which shall include but not be limited to analysis for hydrogen sulfide, mercury, arsenic, fluoride, boron, ammonia, strontium, iron, zinc, barium, lithium, lead, copper, and chromium. The results of such tests shall be provided by the County upon request. To the extent information contained in test results are proprietary, such information shall not be released to the public

S-5 CONFORMITY:

The expansion project shall be designed, constructed, and operated in substantial conformance with the application.

S-6 CONSTRUCTION STANDARDS:

The expansion facilities shall be built in accordance with the County Building Code requirement applicable to "Seismic Zone 4". All structures and facilities shall be designed in accordance with the publication entitled "Recommended Lateral Force Requirements and Commentary by the Structural Engineers Association of California". The structural components of the permitted facilities shall be reviewed by the Building Official/Planning Director. Building permits shall be procured for the Project from the County prior to commencement of any construction.

S-7 EMERGENCY RESPONSE PLAN:

The existing Emergency Response Plan shall be maintained covering possible emergencies, e.g. blow-outs, major fluid spills, impacts due to earthquakes, and other emergencies. At all times, there shall be at least one employee "on call", i.e., available to respond to an emergency by reaching the facility within a short period of time, with the responsibility of coordinating all emergency response measures. The Emergency Coordinator shall be thoroughly familiar with all aspects of the Emergency Response Plan and have the authority to commit the resources needed to carry out the contingency plan. Adequate personnel and equipment shall be available to respond to emergencies and to insure compliance with the conditions of the permit, to include appropriate first aid provisions during project construction and operation with appropriate first aid training for project employees. The existing Hazardous Materials Business Plan submitted to the County Environmental Health

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Services Division, Health Department, shall be maintained by the Permittee and any applicable amendments provided as deemed necessary for this project.

S-8 GEOTECHNICAL:

Geotechnical investigations of soil characteristics affecting the expanded facilities shall be conducted by qualified people at the applicant's expense. The report therefrom shall be made available to the County on request.

S-9 GEOLOGIC HAZARDS:

No structure meant to be, or which actually is, regularly, habitually, or primarily, occupied by humans shall be placed across the trace of an active fault. Further, no such structure shall be placed within fifty (50) feet of the trace of an active fault, nor anywhere within a seismic special studies zone, unless a geologic report, satisfactory to the State Geologist, is prepared and shows that no undue hazard would be created by construction or placement of the structure.

S-10 NOISE:

Control measures shall include, but are not limited to, the following:

(a) Diesel equipment used for drilling within 1,000 feet of any residence shall have hospital-type mufflers. Well venting and testing at these wells shall be accompanied by the use of an effective muffling device or "silencer".

(b) Heavy truck traffic, well site preparation, and pipe stacking shall be limited to the hours of 7:00 a.m. and 7:00 p.m. for any wells within 1,000 feet of any residence.

(c) Hydroblasters used in descaling operations when used within 1,000 feet of a residence shall be limited to the hours of 7:00 a.m. to 7:00 p.m.

(d) The Permittee may propose and the Planning Director may approve modification of the above measures.

S-11 PROJECT DESIGN:

The following shall be followed in project design:

(a) All expansion loops in fluid lines shall be horizontal except where requested in writing by the owners of surface rights within five hundred (500) feet of a proposed expansion loop, or where design constraints require otherwise.

(b) Marking and lighting of drill rigs and permanent facilities shall be maintained in accordance with Federal Aviation Administration regulations.

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(c) On-site parking shall be provided for all employees, customers, clients, and visitors. All facility roads and parking areas shall be constructed and surfaced to County standards.

(d) Shrubs, trees and ground cover shall be planted and maintained to compliment the appearance of the project, in accordance with a landscaping plan approved by the Planning Director.

(e) Permittee shall submit architectural and landscaping plans, as required herein, for all facilities to be constructed as part of the project to the Planning Director, and shall receive the approval of said Director prior to the commencement of construction. The Director shall not unreasonably withhold approval of said plans.

(f) All lights shall be directed or shield to confine any direct rays to the site, and shall be muted to the maximum extent consistent with safety and operational necessity.

(g) The location of power pole lines adjacent to County roads shall be reviewed and approved by the Public Works Department prior to construction/installation of the power poles.

(h) The Planning Director may authorize minor relocation of the well sites, lines, and other minor adjustments to insure that the final facilities comply with the conditions of this permit and those required by other governmental agencies.

S-12 PROTECTION OF WILDLIFE:

Measures approved by the Planning Director shall be employed to discourage or prevent wildlife and avian entry into brine ponds. Well cellars shall be designed to prevent wildlife entry and entrapment. Pipelines shall be constructed so as not to become a barrier to wildlife movement.

S-13 REPORTING:

The Permittee shall furnish to the County, within a reasonable time, any relevant reports/information which the County requires for monitoring purposes to determine whether cause exists for revoking this permit, or to determine compliance with this permit, i.e. relevant reports are those defined within this Permit or requested by the County. The Permittee shall submit all required reports to the Planning Director, County Planning & Development Services Department, 801 Main Street, El Centro, CA 92243.

S-14 SUBSIDENCE:

Permittee shall participate in the County's subsidence detection program and, in connection therewith, submit a plan for Department of Public Works (ICPWD) approval, showing the proposed locations of benchmarks. Monuments shall connect with the County's geothermal subsidence detection network. Benchmarks installed

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shall conform to County standards. Surveying shall be performed to National Geodetic Survey (NGS) standards and all field surveying shall conform to such standards.

Permittee shall evaluate whether or not the recent abnormally high annual subsidence measurements may be continuing, or whether they may be the result of some mechanism not associated with geothermal operations and shall:

(a) Review the results of the precision level survey of the Heber subsidence monitoring network;

(b) Install and level as part of this new survey, a few additional subsidence monuments in the areas of greatest subsidence (near the intersection of Dogwood Road and Willoughby Road) at locations selected in consultation with ICPWD and CDOGGR.

(c) Within approximately six (6) months of this survey, a follow-up with another survey of the entire Heber subsidence monitoring network, including these new monuments;

(d) Prepare and submit to ICPBD, ICPWD, and CDOGGR, a specific plan for additional monitoring and the development of potential measures to mitigate (if determined necessary), the subsidence to uplift in the Heber geothermal field area which may be attributable to Project operations to include:

- Re-surveying at least the core sections of the Heber subsidence monitoring network every six (6) months;
- Continuing to re-survey the entire Heber subsidence monitoring network annually;
- Implementing a program to monitor selected key land surface features (such as major bridges and canal structures) for evidence of changes due to subsidence or uplift; and,
- Conducting geothermal reservoir modeling to evaluate what specific changes in the operation of the geothermal wellfield could be undertaken to alter the geothermal reservoir pressure distribution with the objective of reducing the rate of geothermal subsidence and/or uplift in the areas of greatest challenge.

(e) Monitor results of future surveys as per item (d) and, based on those results, develop a long term plan for submittal to ICPBD, ICDPW, and CDOGGR to reduce, or reverse if possible, any uplift in the Heber injection areas or any subsidence in the Heber production areas;

(f) Construct and operate, as soon as all the required permits and approvals have been obtained, the proposed expansion project.

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S-15 INDUCED SEISMICITY:

Permittee shall participate in the County's seismic monitoring program, and in connection therewith, submit a plan for Public Works Department approval, and shall implement the plan as approved. If evidence of detrimental seismicity induced by project operations is indicated, changes in operations, including possible cessation of operations, may be ordered by the Department of Public Works after consultation with the California Department of Oil, Gas and Geothermal Resources (CDOGGR) and Permittee.

S-16 SYSTEM SHUT DOWN AND SITE ABANDONMENT:

The Permittee shall prepare and implement a plan for when the operation of the permitted facilities herein authorized has ceased, that all HGC facilities shall be dismantled, and the land involved be made compatible with the surrounding uses, or as requested by the landowner and as agreed to by the County Planning Director. A Bond, or other acceptable surety, or other forms of security acceptable to Imperial County, in the amount of $500,000, in addition to any amount set by the California Division of Oil, Gas and Geothermal Resources, shall be filed with the County that guarantees restoration of the land to its condition prior to the injection pipeline development. Upon completion of such site restoration, the Bond or other surety shall be released by the County.

S-17 REINJECTION:

Fluids equivalent to 86% of produced fluids by mass, and on an annual basis, shall be injected back into the reservoir subject to the requirements of CDOGGR and information obtained from any monitoring programs and other sources.

If significant subsidence, loss of reservoir pressure, or other detriments attributable to this project occur, or substantial evidence of other undesirable changes in operations is revealed, corrective measures or changes may be ordered by the County. Corrective measures may be included, but are not limited to, a modified injection rate or altered injection depth, re-leveling of affected areas, or reduction or total cessation of geothermal activities.

S-18 SPILLS AND RUNOFF:

The expanded plant site shall be designed and constructed to prevent spills from endangering adjacent properties and waterways, and to prevent runoff from any source being channeled or directed in an unnatural way so as to cause erosion, siltation, or other detriments. A system of pressure and flow sensing devices and regular inspection of all lines, capable of detecting leaks and spills, shall be instituted and maintained. Blowout prevention equipment shall be used in accordance with the requirements of CDOGGR.

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S-19 MAINTENANCE OF WATER QUALITY:

A water quality monitoring program, acceptable to the Regional Water Quality Control Board (RWQCB) shall be instituted and maintained. If injection fluids intrude on shallow ground waters, a modification of the injection program may be ordered by the County in consultation with RWQCB and the Permittee. Any needed sumps and holding ponds shall be constructed and maintained so that permeability does not exceed 1 X 10-6 cm/sec.

S-20 TRAFFIC SAFETY:

The Permittee shall obtain all encroachment permits and consider traffic safety in transporting equipment and materials to the permitted facilities to include temporary signs warning motorists on adjacent roadways and flagmen shall be used when equipment is being brought to and from the Project site.

(a) The Permittee shall coordinate the movement of any required oversize loads on County roads with the DPW, on State Highways with CALTRANS as well as the El Centro CHP office and such transportation of oversized equipment should be minimized as much as possible.

(b) The Permittee shall be required to obtain any necessary rights-of-way on property under the lease and control of the Permittee and to provide any necessary road work as deemed necessary by the DPW.

(c) The Permittee shall coordinate with DPW for their requested dedication of rights-of-way needed for Pitzer Road for the consideration of existing and any future road needs.

(d) The Permittee shall file for an encroachment permit for any work or proposed work in the affected County road rights-of-way.

(e) The Permittee shall coordinate the maintenance of unpaved roads used for construction activities and obtain approvals from the County Department of Public Works.

S-21 WATER COURSE CROSSINGS:

The Permittee shall provide one or more of the following techniques to decrease the potential for spills on or near Imperial Irrigation District water courses, e.g. surface water canals and/or drains, as follows:

(a) Pipes shall be constructed of industrial standard designation of "extra heavy" with a thickness of at least 50% greater than that used for other sections of pipe.

(b) An automatic injection pump shut off and check valve system to immediately stop fluid flow shall be installed on the injection pipeline.

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(c) Design of facilities shall protect surface and groundwater, e.g. handling of on-site drainage shall not adversely affect adjacent properties.

(d) Other spill prevention measures approved by the County shall be implemented.

S-22 WASTE DISPOSAL:

The Permittee shall insure that any discharged wastes, liquid or solid, shall be disposed of in compliance with all appropriate local, state, and federal regulations, in effect or subsequently duly-enacted, i.e. discharge of wastes into surface water shall meet all requirements of the Regional Water Quality Control Board, e.g. National Pollution Discharge Elimination System permit restrictions, and solid wastes shall be disposed of in an approved solid waste disposal site in accordance with County regulations.

S-23 ODORS:

All harmful or noxious emissions and odors shall be controlled to insure that quantities of air contaminants released as a result of the facility operations do not exceed State standards, or constitute a public nuisance.

S-24 WATER USAGE:

The Permittee may use up to a total of 5,000 acre feet of irrigation water per year for up to five years from date of commencement of water usage. Any extension beyond the five-year period must be agreed to in writing by the Imperial Irrigation District. If the amount of water available to Imperial County is reduced by the Central Arizona project, the right to the irrigation water for the five years granted herein may be terminated. Permittee shall diligently pursue the development of alternate sources to replace the use of irrigation water.

S-25 PARTICIPATION IN GEOTHERMAL COMMITTEE:

Permittee shall participate in the "Geothermal Industrial Committee" formed by the County.

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S-26 ACCEPTANCE:

Acceptance of this permit shall be deemed to constitute agreement by Permittee with all terms and conditions herein contained.

NOW THEREFORE, County hereby issues the Conditional Use Permit #06-0006 and Permittee hereby accepts such upon the terms and conditions set forth herein.

IN WITNESS THEREOF, the parties hereto have executed this Agreement the day and year first written.

PERMITTEE

_____ _____

Gregory Griffith, Plant Manager Date
ORCAL/Heber Field Company

COUNTY OF IMPERIAL, a political subdivision of the STATE OF CALIFORNIA

_____ _____

Jurg Heuberger, AICP, CEP, CBO Date
Planning Director

EEC ORIGINAL PKG

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PERMITTEE

Gregory Griffith, Plant Manager
ORCAL/Heber Field Company

4/12/06
Date

COUNTY OF IMPERIAL, a political subdivision of the STATE OF CALIFORNIA

Jurg Heuberger, AICP, CEP, CBO
Planning Director

Date

EEC ORIGINAL PKG

PERMITTEE NOTARIZATION

Dated April 12, 2006

STATE OF CALIFORNIA

COUNTY OF Imperial } S.S.

On April 12, 2006 before me, Monica M. Leon a Notary Public in and for said County and State, personally appeared Gregory Griffith, personally known to me (or proved to me on the basis of satisfactory evidence) to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

WITNESS my hand and official seal

Signature Monica M. Leon

MONICA M. LEON
COMM. #1612967
Notary Public-California
IMPERIAL COUNTY
My Comm. Exp. Nov 12, 2009

ATTENTION NOTARY: Although the information requested below is OPTIONAL, it could prevent fraudulent attachment of this certificate to unauthorized document.

Title or Type of Document Conditional Use Permit #06-0006
Number of Pages 17 Date of Document 4/12/06
Signer(s) Other Than Named Above

Dated

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RECEIPT

ORIGINAL COPY

RECEIPT NUMBER: R0600336

APD #: CUP06-0006 TYPE: CONDITIONAL USE PERMIT
SITE ADDRESS: 895 PITZER RD CNTY
PARCEL: 054-250-036-001
RECEIPT NOTATION:

TRANSACTION DATE: 02/13/2006

TOTAL PAYMENT:	5,500.00
TOTAL PAID FROM TRUST:	.00
TOTAL PAID FROM CURRENCY:	5,500.00

TRANSACTION LIST:

Type	Method	Description	Amount
Payment	Check	028528	5,500.00
		TOTAL:	5,500.00

ACCOUNT ITEM LIST:

Description	Account Code	Current Pmts
GENERAL PLAN TRUST T/M	7086000-301000	500.00
TIME & MATERIAL PLANNING	7004000-301000	5,000.00
	TOTAL:	5,500.00

RECEIPT ISSUED BY: IRISD INITIALS: ID
ENTERED DATE: 02/13/2006 TIME: 03:02 PM

This is your original copy of the **receipt** for funds received by the Imperial County Planning and Development Services Department for the above identified ***PERMIT***.

Please make sure this receipt is accurate and reflects the payment amount and the permit information referenced.

If you request cancellation of your permit and/or a refund, please understand that we can only refund a maximum of 70% of the total minus all costs already incurred to date.

If you have questions please direct them to this office at (760) 482-4236.

Thank you for your cooperation!

Jurg Heuberger, AICP, CEP
Building Official / Director of Planning & Development Services

CC: Auditor/Controller
Permit File
Permitrc.doc

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150 SOUTH NINTH STREET
EL CENTRO, CA 92243-2850

TELEPHONE: (442) 265-1800
FAX: (442) 265-1799

AIR POLLUTION CONTROL DISTRICT

May 25, 2016

Second Imperial Geothermal Co.
947 Dogwood Road
Heber, CA 92249

Dear Mr. Paolo Alvarado:

Enclosed please find amended conditions, authority to construct along with permit to operate **#2217A-4** for a geothermal power plant located at 855 Dogwood Rd., Heber, CA.

Please sign and date both copies of the permits and return our copies to our office.

If you have any questions regarding this permit, please do not hesitate to contact **Linda Cedillo at 442-265-1800.**

Sincerely,

Norma A. Amavizca
Office Technician

EEC ORIGINAL PKG

150 SOUTH NINTH STREET
EL CENTRO, CA 92243-2850

TELEPHONE: (442) 265-1800
FAX: (442) 265-1799

AIR POLLUTION CONTROL DISTRICT

CONDITIONS FOR AUTHORITY TO CONSTRUCT AND PERMIT TO OPERATE #2217A-4

SECOND IMPERIAL GEOTHERMAL COMPANY
947 DOGWOOD ROAD
HEBER, CA 92249

LOCATIION: 855 DOGWOOD RD., HEBER, CA

A. General Conditions

A.1 Operation of this equipment shall be in compliance with all data and specifications submitted with the application under which this permit is issued unless otherwise noted below.
(General Conditions)

A.2 Operation of this equipment shall be in compliance with all applicable APCD Rules and Regulations.
(General Conditions)

A.3 This Permit does not authorize the emissions of air contaminants in excess of those allowed by USEPA (Title 40 of the Code of Federal Regulation), the State of California Division 26, Part 4, Chapter 3 of the Health and Safety Code, or the APCD (Rules and Regulations).
(General Conditions)

A.4 This permit cannot be considered permission to violate applicable existing laws, regulations, rules or statutes of other governmental agencies.
(General Conditions)

B. Facility H2S Emission Limitation

B.1 The facility shall not discharge into the atmosphere in excess of 0.5 lbs/hr of hydrogen sulfide.
(ICAPCD Rule 207)

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

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C. Isopentane Emissions

C.1 Under all normal operating conditions (maintenance, VRU purging, and fugitive daily emissions), the total isopentane emissions shall not exceed 185 lbs/day during the first quarter (January thru March), and 137 lbs/day second (April thru June) quarter and 137 lbs/day third (July thru September) quarter; from the entire facility, as determined by normal inventory and mass balance procedures.
(ICAPCD Rule 207)

C.2 Fourth quarter (October thru December) isopentane emissions shall not exceed 218 lbs/day.
(Permit Application; ICAPCD Rule 207)

C.3 Purging Emissions

C.3.a All non-condensable gas purging of any ORMAT Energy Converter (OEC) and/or Integrated Two-Level Unit (ITLU) shall be conducted through the Vapor Recovery Unit (VRU). The purging of gases through the VRU to the atmosphere shall be conducted only after the separation process of non-condensable gases and isopentane gases is completed. Purging of non-condensable gases to the atmosphere shall be conducted in a manner to minimize entrainment of isopentane gases with non-condensable gases.
(ICAPCD Rule 207; Permit Application)

C.3.b Isopentane emissions occurring during normal purging events shall be considered part of the daily average isopentane emissions for the total isopentane loss for the reporting quarter.
(ICAPCD Rule 207)

C.4 Maintenance Emissions

C.4.a The APCD shall be notified by telephone or fax at least 48 hours prior to the time which an OEC and/or ITLU containing isopentane will be opened to the ambient air for scheduled maintenance.
(ICAPCD Rule 207; Permit Application)

C.4.b Unscheduled maintenance and repairs of an OEC and/or ITLU containing isopentane may be conducted without prior APCD notification.
(ICAPCD Rule 207; Permit Application)

C.4.c Prior to conducting any scheduled or unscheduled maintenance or repairs to any OEC and/or ITLU where the isopentane may be exposed to the atmosphere, the isopentane in that portion of the unit shall be first

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transferred to the storage tank or any type of vessel that serves as a storage tank, and any residual isopentane evacuated through the VRU. The OEC and/or ITLU shall be evacuated of isopentane in a manner that results in the minimum practical amount of isopentane being emitted to the atmosphere.
(ICAPCD Rule 207; Permit Application)

C.4.d Venting isopentane from an OEC and/or ITLU to the atmosphere for the sole purpose of evacuation is prohibited. All isopentane shall be transferred to the storage tank through the VRU.
(ICAPCD Rule 207; Permit Application)

C.4.e Isopentane emissions occurring during normal repair and maintenance shall not be considered a breakdown and shall be considered part of the daily average isopentane emissions for the total isopentane loss for the reporting quarter.
(ICAPCD Rule 207)

C.5 Breakdown Emissions

C.5.a Any breakdown, malfunction, or upset occurrence which constitutes a breakdown condition resulting in the emission of any air pollutant to the atmosphere, shall be reported to the ICAPCD as soon as reasonably possible but no later than two (2) hours after its detection, and should identify the time, specific location, equipment involved, and to the extent known the cause of the occurrence, and immediate remedial measures shall be undertaken to correct the problem and prevent further emissions into the atmosphere. The completion of corrective measures or the shutdown of emitting equipment is required within (24) hours of occurrence of a breakdown condition.
(ICAPCD Rule 111)

C.5.b If the breakdown condition will require more than (24) hours to correct, the Permittee, in lieu of shutdown, shall submit a variance application to the Air Pollution Control Officer (APCO) requesting to commence the emergency variance procedure set forth in the ICAPCD Hearing Board Procedures.
(ICAPCD Rule 111)

C.5.c Within 10 days after a breakdown occurrence has been corrected, the owner or operator shall submit a written report to the APCO which includes:

C.5.c.1 A statement that the occurrence has been corrected, together with the date of correction and proof of compliance;

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C.5.c.2 A specific statement of the reason(s) or cause(s) from the occurrence sufficient to enable the APCO to determine whether the occurrence was a breakdown condition;

C.5.c.3. A description of the corrective measures undertaken and/or to be undertaken to avoid such an occurrence in the future;

C.5.c.4 An estimate of the emissions caused by the occurrence;

C.5.c.5 And pictures of the equipment or controls which failed, if available.
(ICAPCD Rule 111)

C.5.d Failure to comply, or comply in a timely manner, with the reporting requirements established in paragraph C.5.a shall constitute cause for enforcement action.
(ICAPCD Rule 111)

C.5.e Isopentane breakdown emissions and losses shall be deducted from the total isopentane loss for the reporting quarter before calculating the daily average emissions.
(ICAPCD Rule 111; ICAPCD Rule 207)

D. Isopentane Mitigation

D.1 The Permittee shall offset all isopentane excess emissions above 137 lbs/day, determined on a quarterly basis.
(ICAPCD Rule 207)

D.2 The Permittee shall secure Emission Reduction Credits (ERCs) of Total Organic Compounds (TOC), on an annual basis, from the Agricultural ERC Bank in the amount of 7.05 tons per year to offset first and fourth quarter excess emissions, or the Permittee can opt to secure Emission Reduction Credits (ERCs) of Reactive Organic Gases (ROG) from the Stationary ERC Bank, on a one time basis, in the amount of current calculations to offset yearly first and fourth quarter excess emissions.
(ICAPCD Rule 207)

D.3 The Emission Reduction Credits shall be secured and shall be submitted before January 31 of each operating year along with the corresponding yearly permit operating fees.
(ICAPCD Rule 207)

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E. Vapor Recovery Unit (VRU)

E.1 The VRU shall be maintained in good working order at all times and shall achieve a minimum 95% isopentane vapor recovery efficiency during the purging process of an OEC and/or ITLU.
(ICAPCD Rule 207)

E.2 The VRU shall be source tested at least once, on a yearly basis, to verify the isopentane vapor recovery efficiency. The source test method shall receive prior approval by the Air Pollution Control District (APCD). The VRU source test shall be witnessed by the APCD.
(ICAPCD Rule 109)

E.3 Any breakdown, malfunction, or maintenance of the VRU resulting in the emission of isopentane to the atmosphere, shall be reported to the ICAPCD as soon as reasonably possible but no later than two (2) hours after its detection, and immediate remedial measures shall be undertaken to correct the problem and prevent further emissions into the atmosphere. The completion of corrective measures or the shutdown of emitting equipment is required within (24) hours of occurrence of a breakdown condition.
(ICAPCD Rule 111)

E.4 If the breakdown condition will require more than (24) hours to correct, the Permittee, in lieu of shutdown, shall submit a variance application to the Air Pollution Control Officer (APCO) requesting to commence the emergency variance procedure set forth in the ICAPCD Hearing Board Procedures.
(ICAPCD Rule 111)

E.5 The Permittee shall install and maintain in good working order an in-line flow meter (cfm) at the inlet of the VRU. The flow meter shall be equipped with a totalizer.
(Permit Application)

E.6 A log shall be maintained on the premises showing the VRU hours of operation and/or purging events, and routine repairs. This log shall be made available for inspection by the ICAPCD.
(Permit Application; ICAPCD Rule 207)

F. Emergency Standby Equipment

F.1 The diesel-fueled emergency equipment shall be restricted to the following maintenance operating hours:

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- Emergency Electric Power Generator, Model DMT-500C2, 500 KW, powered by a Cummins diesel-fueled engine model KTA19G2, rated 685 hp shall be restricted to operate 50 hours per year.
- John Deere model 6090H diesel pump (emergency stand-by), 350 hp shall be restricted to operate 50 hours per year.

(ATCM 93115)

F.2 The listed Clarke Detroit Diesel-Allison emergency Fire Pump, powered by a Detroit Diesel engine model DDFP-LGAT-7017V, rated 443hp, and the Clarke model JW6H-UF40 diesel pump (emergency stand-by) 300 hp shall be restricted to operate a total of 35 (thirty-five) hours per year for maintenance and testing purposes each, and to comply with the requirements of the National Fire Protection Association (NFPA) 25.

F3. Operation of the emergency power generator for other than testing and maintenance purposes, shall be limited to provide backup power, in each instance, be documented to the satisfaction of the ICAPCD.

F4. All internal combustion engines shall not discharge into the atmosphere any visible air contaminant other than uncombined water vapor, for a period or periods aggregating more than three minutes in any one hour, which is 20% opacity or greater.

F5. Each unit, with an internal combustion engine rated greater than 50 horsepower, shall have installed a non-resettable hour meter. The device shall be kept in proper working condition at all times.

F6. The permittee shall maintain an operation engine log onsite for each listed unit with an internal combustion engine rated greater than 50 horsepower. The Permittee shall maintain all required records for a minimum of two (2) calendar years and make them available to the ICAPCD upon request. The log(s) shall include the following for each unit:

a. Engine manufacturer name, model number, brake horsepower output rating, and type of fuel combusted;
b. A manual of recommended maintenance as provided by the engine manufacturer or other maintenance procedure as approved in writing by the APCO;
c. Record of routine engine maintenance, including date(s) and type of maintenance performed;
e. For each emergency unit, the total daily recorded hours of operation for maintenance and testing purposes.

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f. For each emergency unit, the total daily recorded hours of operation for emergency events.

F7. The listed Cummins Model KTA19G2 diesel emergency generator, with engine rated 685hp, shall be limited to the following emission limits:

a. 14.32 lbs/hr of NOx.
b. 1.54 lb/hr of CO.

F8. The Permittee shall conduct a source test for the Cummins Model KTA19G2 emergency generator to demonstrate compliance with the emission limits once every 60 months thereafter.

F9. The Cummins Model KTA19G2 generator shall each be source tested at least at 80% of the total horse power rating to determine compliance with the emission limits. If the permittee demonstrates to the satisfaction to the APCO that a listed unit cannot operate at 80% capacity, then the source test shall be performed at the highest achievable continuous power rating. Compliance with the NOx emission limits shall be determined by using CARB Method 100 or US EPA Method 7E. Oxygen Content shall be determined by using CARB Method 100 or US EPA Method 3A. Compliance with the CO emission limits shall be determined by using CARB Method 100 or US EPA Method 10, or other approved method.

F10. The source test protocol for each required test shall be submitted to the ICAPCD for approval 30 days prior to commencing testing. The source test results shall be submitted to the ICAPCD within 60 days of the test being completed.

F11. Permittee shall maintain all records required by this Permit for a minimum of two (2) calendar years. These records shall be maintained with the units or at the company's office, and shall be made available to the District upon request.
ICAPCD Rule 400.3

G. Monitoring

G.1 The ICAPCD may, at any time, monitor emissions from any source within the facility.
(ICAPCD Rule 108; ICAPCD Rule 109)

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G.2 The ICAPCD may, at any time, but no more often than once per year, authorize third-party emissions testing and/or inventory of the facility. The cost of the emissions testing shall be borne by the Permittee. The ICAPCD shall give advance notification to the Permittee prior to any emissions testing or inventory required.
(ICAPCD Rule 108; ICAPCD Rule 109)

H. Reports

At the end of each calendar quarter, and not more than thirty (30) days thereafter, the facility shall submit a report to the ICAPCD which contains the following information:

H.1 The total amount of isopentane renewals brought to the facility during the reporting quarter and the previous quarters of that year. The facility shall include the isopentane supplier's name and address.

H.2 The total amount of isopentane present at the facility before renewals.

H.3 The number of VRU non-condensable gas purges that occurred during the reporting quarter.

H.4 The number of isopentane withdrawals and total amount of isopentane withdrawn from OECs and/or ITLU for hardware maintenance and repairs during the reporting quarter.

H.5 The combined daily total quantity of isopentane fugitive, purging and maintenance emissions from all OEC and ITLU units.

H.6 The number of rotating seals replaced or installed or any other OEC and/or ITLU seal or gasket failure that occurred during the reporting quarter.

H.7 The number of pressure relief rupture discs removed and replaced during the reporting quarter.

H.8 The total flow, in cubic feet, through the VRU during the reporting quarter.

H.9 The facility shall report to the APCD by telephone all non-normal (upset and breakdown) releases of isopentane or geothermal gases to the atmosphere as established on operating condition C.5.

At the end of February of each calendar year, and not more than 30 days thereafter, the Permittee shall submit to the APCD an annual report of the previous calendar year, consisting of the following:

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H.10 The monthly fuel consumption and hours operated per month of the emergency standby water pump, emergency electric power generator, and emergency fire pump.
(ICAPCD Rule 207)

Equipment Listed at the Facility:

6- ORMAT Integrated Two Level Units, 6 MW approx. each, for a total of 12 modular power generating units.
1- ORMAT Integrated Two Level Unit, 12 MW approx. each, for a total of 2 modular power generating units.
1- ORMAT Integrated Two Level Unit, 10 MW, 2 modular power generating units.
2- 6-cell Harmon mechanical draft counter flow cooling towers, 63,000 gpm/tower, framework and fan deck made of treated Douglas fir, fiberglass fan stacks and PVC drift eliminators, with a drift rate of 0.0008% of circulating water flow.
1- 3-cell Marley Model F499A-5.91-3, mechanical draft counter flow tower, 41,250 gpm, made of industrial fiberglass, with fire retardant pultruded reinforced polyester framing and polyvinyl chloride cellular drift eliminators, with a drift rate of 0.0010% of circulating water flow.
1- 3-cell Marley Model F499A-5.91-3, mechanical draft counter flow tower, 41,250 gpm, made of industrial fiberglass, with fire retardant pultruded reinforced polyester framing and polyvinyl chloride cellular drift eliminators, with a drift rate of 0.0005% of circulating water flow.
1- John Zink Series 2000 AC-400-4-10-4 Carbon Adsorption-Condensation (ADCON) Hydrocarbon Vapor Recovery Unit (VRU), 90 scfm, equipped with a 27 HP electric motor.
1- Emergency Electric Power Generator, Model DMT-500C2, 500 KW, powered by a Cummins diesel-fueled engine model KTA19G2, rated 685 hp.
1- Clarke Detroit Diesel-Allison Fire Pump, powered by a Detroit Diesel engine model DDFP-LGAT-7017V, rated 443hp.
1- John Deere model 6090H diesel generator (emergency stand-by), 350 hp
1- Clarke model JW6H-UF40 diesel pump (emergency stand-by) 300 hp

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IMPERIAL COUNTY

AIR POLLUTION CONTROL DISTRICT
2016 APCD PERMIT

Facility name and mailing address:

SECOND IMPERIAL GEOTHERMAL COMPANY SIGC
947 DOGWOOD ROAD
HEBER, CA 92249

FEE FOR THE YEAR	$180.50
LATE FEE / PENALTY	$0.00
ADJUSTMENTS	$180.50
TOTAL PAID	$0.00
BALANCE DUE	$0.00

Permit Number:	**2217 ATC**
PAID	**Active**
Permit Type	GEOTHERMAL
Location Address	855 DOGWOOD ROAD HEBER, CA 92249
Resp. Agent	PAOLO ALVARADO
Phone	760-353-8200
Issued:	**5/25/2016**
Expires:	**5/25/2016**

CERTIFICATION BY AUTHORIZED AGENT

The permit presented here is correct. The authorizations, certifications, and information from the application and permit being renewed, remain valid and will be kept with this ANNUAL PERMIT RENEWAL.

DATE _____ SIGNATURE _____

CERTIFICATION BY APC DIVISION MANAGER

This permit becomes valid when signed by authorized agent.

This permit, or an approved facsimile, shall be mounted so as to be clearly visible in an accessible place within 25 feet of the article, machine, equipment, or other contrivance, or maintained readily available at all times on the operating premises. (Rule 201D)

Return this copy with payment fees to Imperial County Air Pollution Control District

150 South 9th Street, El Centro, CA 92243-2801

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IMPERIAL COUNTY

AIR POLLUTION CONTROL DISTRICT
2016 APCD PERMIT

Facility name and mailing address:

SECOND IMPERIAL GEOTHERMAL COMPANY SIGC
947 DOGWOOD ROAD
HEBER, CA 92249

FEE FOR THE YEAR	$17,458.00
LATE FEE / PENALTY	$0.00
ADJUSTMENTS	$17,458.00
TOTAL PAID	$0.00
BALANCE DUE	$0.00

Permit Number:	**2217 PTO**
PAID	**Active**
Permit Type	GEOTHERMAL
Location Address	855 DOGWOOD ROAD HEBER, CA 92249
Resp. Agent	PAOLO ALVARADO
Phone	760-353-8200
Issued:	**5/25/2016**
Expires:	**12/31/2016**

CERTIFICATION BY AUTHORIZED AGENT

The permit presented here is correct. The authorizations, certifications, and information from the application and permit being renewed, remain valid and will be kept with this ANNUAL PERMIT RENEWAL.

DATE _____ SIGNATURE _____

CERTIFICATION BY APC DIVISION MANAGER

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This permit, or an approved facsimile, shall be mounted so as to be clearly visible in an accessible place within 25 feet of the article, machine, equipment, or other contrivance, or maintained readily available at all times on the operating premises. (Rule 201D)

Return this copy with payment fees to Imperial County Air Pollution Control District

150 South 9th Street, El Centro, CA 92243-2801

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SPECIAL PUBLICATION 42
Interim Revision 2007

FAULT-RUPTURE HAZARD ZONES IN CALIFORNIA

Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Fault Zones[1] Maps

[1] Name changed from Special Studies Zones January 1, 1994



DEPARTMENT OF CONSERVATION
California Geological Survey

STATE OF CALIFORNIA
ARNOLD SCHWARZENEGGER
GOVERNOR

THE RESOURCES AGENCY
MIKE CHRISMAN
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
BRIDGETT LUTHER
DIRECTOR

CALIFORNIA GEOLOGICAL SURVEY
JOHN G. PARRISH, *PH.D.*
STATE GEOLOGIST

EEC ORIGINAL PKG

SPECIAL PUBLICATION 42

FAULT-RUPTURE HAZARD ZONES IN CALIFORNIA

Alquist-Priolo Earthquake Fault Zoning Act With Index to Earthquake Fault Zones Maps

by

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Interim Revision 2007

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PREFACE

The purpose of the Alquist-Priolo Earthquake Fault Zoning Act is to regulate development near active faults so as to mitigate the hazard of surface fault rupture.

This report summarizes the various responsibilities under the Act and details the actions taken by the State Geologist and his staff to implement the Act.

This is the eleventh revision of Special Publication 42, which was first issued in December 1973 as an "Index to Maps of Special Studies Zones." A text was added in 1975 and subsequent revisions were made in 1976, 1977, 1980, 1985, 1988, 1990, 1992, 1994, and 1997. The 2007 revision is an interim version, available in electronic format only, that has been updated to reflect changes in the index map and listing of additional affected cities. In response to requests from various users of Alquist-Priolo maps and reports, several digital products are now available, including digital raster graphic (pdf) and Geographic Information System (GIS) files of the Earthquake Fault Zones maps, and digital files of Fault Evaluation Reports and site reports submitted to the California Geological Survey in compliance with the Alquist-Priolo Act (see Appendix E).

On January 1, 1994, the name of the Alquist-Priolo Special Studies Zones Act was changed to the Alquist-Priolo Earthquake Fault Zoning Act, and the name Special Studies Zones was changed to Earthquake Fault Zones as a result of a July 25, 1993 amendment.

Information on new and revised Earthquake Fault Zones maps will be provided as supplements until the next revision of this report.

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SUPPLEMENT NO. 1 TO SPECIAL PUBLICATION 42 (2007 Interim Edition)

NEW AND REVISED OFFICIAL MAPS OF EARTHQUAKE FAULT ZONES OF SEPTEMBER 21, 2012

Official Maps of new and revised Earthquake Fault Zones, indexed hereon, are issued pursuant to the Alquist-Priolo Earthquake Fault Zoning Act. Revised maps supersede earlier Official Maps.

Copies of these maps may be examined at the offices of affected cities and counties, at the Public Information offices of the California Geological Survey (CGS), and on the CGS website (**http://www.quake.ca.gov/gmaps/ap/ap_maps.htm).** Both GIS and pdf files can be downloaded from this website. Printed maps may be purchased from ARC-Bryant (formerly BPS Reprographic Services), 945 Bryant Street, San Francisco, California 94103, telephone (415) 495-8700.

For information on Official Maps of Earthquake Fault Zones previously issued, and for provisions of the Alquist-Priolo Earthquake Fault Zoning Act, the reader should consult the 2007 edition of Special Publication 42, "Fault-rupture Hazard Zones in California." This publication is available online only from the California Geological Survey at **ftp://ftp.consrv.ca.gov/pub/dmg/pubs/sp/Sp42.pdf**.

Official Maps issued September 21, 2012 (Map numbers keyed to index map):

1. Hayward.*
2. Piru
3. Mecca*
4. Mortmar*
5. Orocopia Canyon*
6. Salton*
7. Durmid*
8. Carrizo Mtn.*
9. Painted Gorge
10. Plaster City
11. Coyote Wells
12. Yuha Basin
13. Mount Signal

* Revised zone map

Cities and counties affected by new or revised Earthquake Fault Zones shown on Official Maps of September 19, 2012:

Cities	**Counties**
Hayward	Alameda
Oakland	Imperial
San Leandro	Riverside
	San Diego
	Ventura

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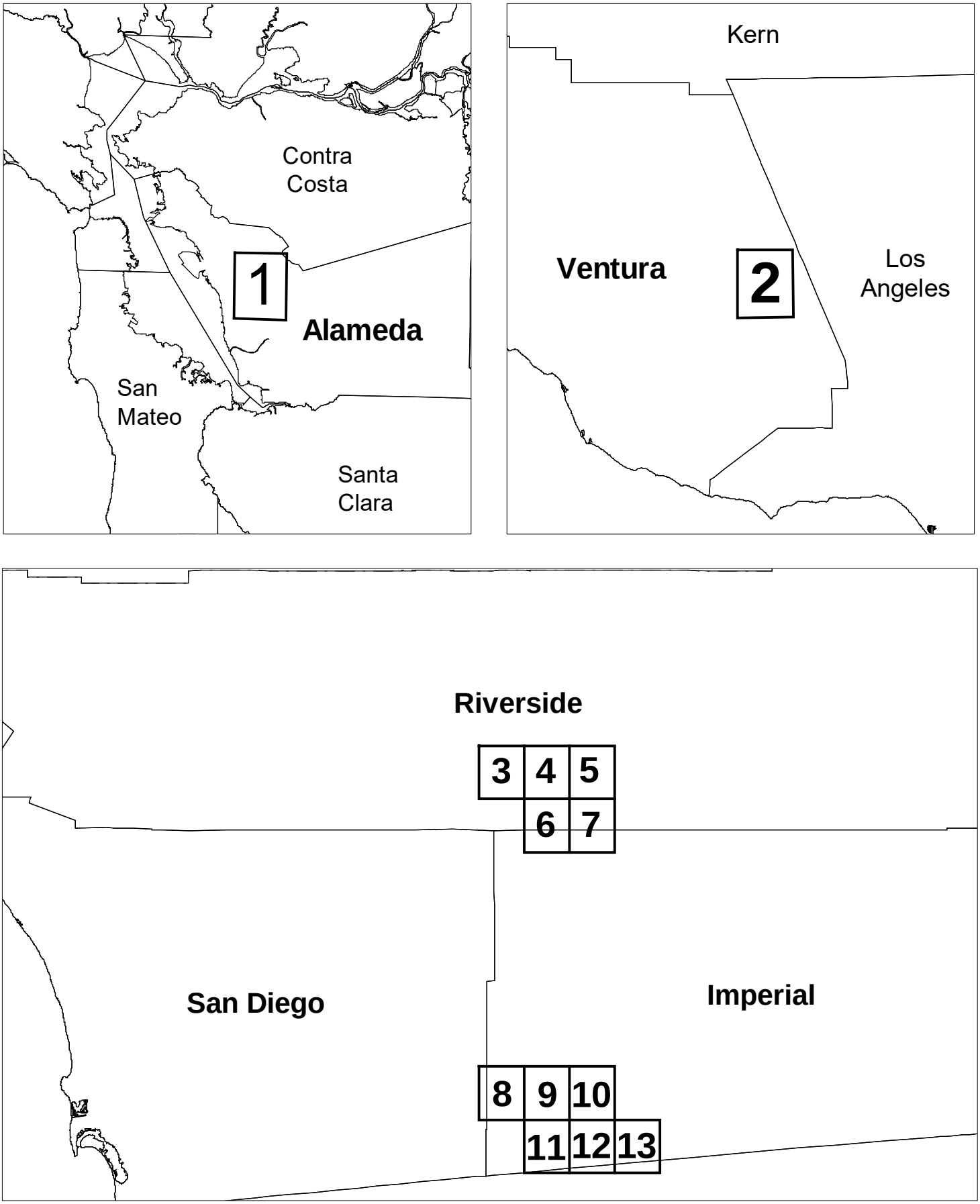

SUPPLEMENT NO. 1 INDEX MAP
NEW AND REVISED OFFICIAL MAPS OF EARTHQUAKE FAULT ZONES OF SEPTEMBER 21, 2012
(See List for Names of Maps)

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SUPPLEMENT NO. 2 TO SPECIAL PUBLICATION 42 (2007 Interim Edition)

NEW AND REVISED OFFICIAL MAPS OF EARTHQUAKE FAULT ZONES OF NOVEMBER 6, 2014

Official Maps of new and revised Earthquake Fault Zones, indexed hereon, are issued pursuant to the Alquist-Priolo Earthquake Fault Zoning Act. Revised maps supersede earlier Official Maps.

Copies of these maps may be examined at the offices of affected cities and counties, at the Public Information offices of the California Geological Survey (CGS), and on the CGS website (**http://www.conservation.ca.gov/CGS/Pages/Index.aspx).** Both GIS and pdf files can be downloaded from this website.

For information on Official Maps of Earthquake Fault Zones previously issued, and for provisions of the Alquist-Priolo Earthquake Fault Zoning Act, the reader should consult the 2007 edition of Special Publication 42, "Fault-rupture Hazard Zones in California." This publication is available online only from the California Geological Survey at **ftp://ftp.consrv.ca.gov/pub/dmg/pubs/sp/Sp42.pdf**.

Official Maps issued November 6, 2014 (Map numbers keyed to index map):

1. Hollywood.*
2. Azusa

* Revised zone map

Cities and counties affected by new or revised Earthquake Fault Zones shown on Official Maps of November 6, 2014:

Cities	**Counties**
Azusa	Los Angeles
Bradbury	
Duarte	
Glendora	
Irwindale	
Los Angeles	
Monrovia	
West Hollywood	

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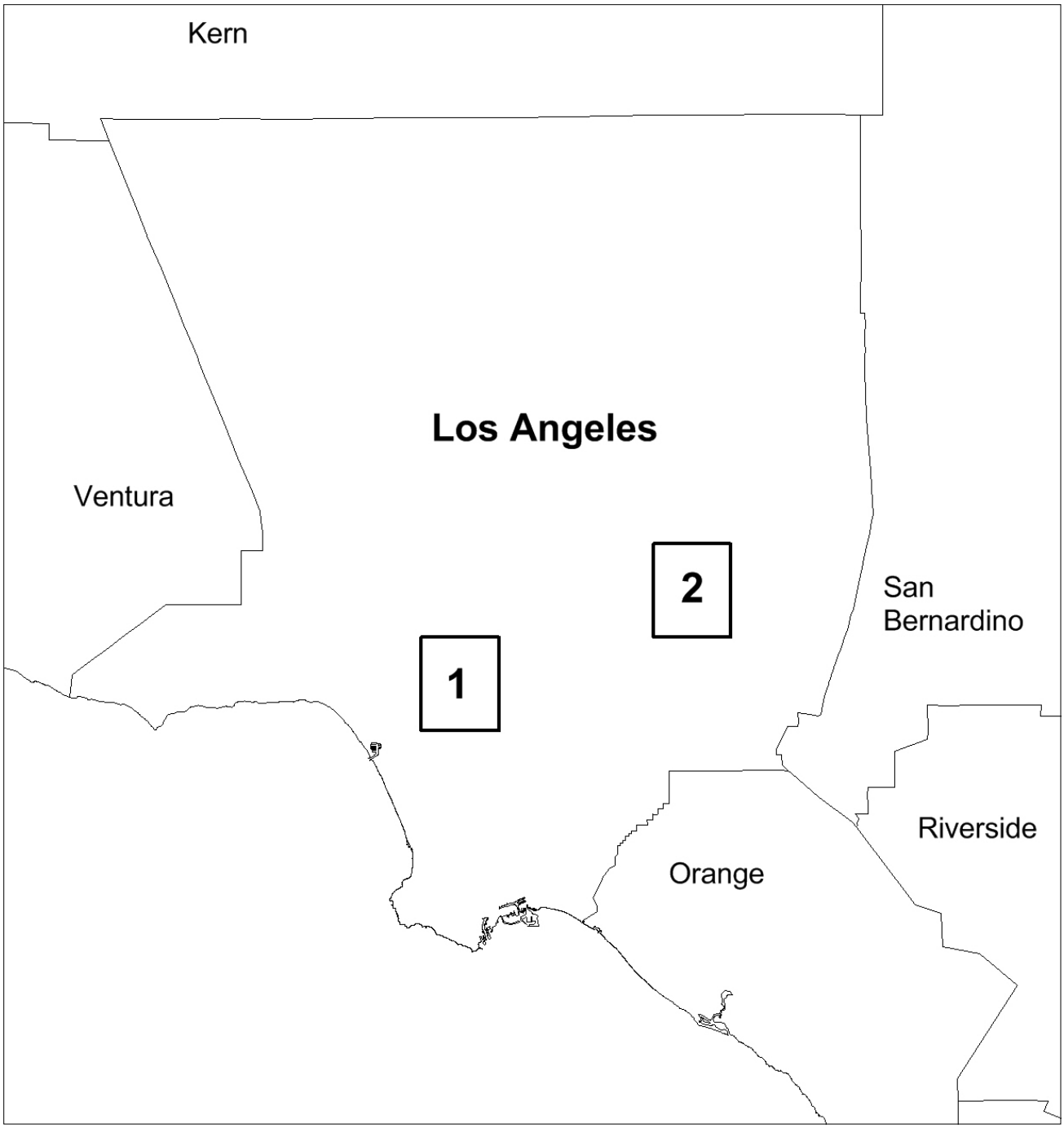

SUPPLEMENT NO.2 INDEX MAP

NEW AND REVISED OFFICIAL MAPS OF EARTHQUAKE FAULT ZONES OF NOVEMBER 6, 2014

(See List for Names of Maps)

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FAULT-RUPTURE HAZARD ZONES IN CALIFORNIA

By

William A. Bryant and Earl W. Hart

INTRODUCTION

The Alquist-Priolo Earthquake Fault Zoning Act was signed into law December 22, 1972, and went into effect March 7, 1973. The Act, codified in the Public Resources Code as Division 2, Chapter 7.5, has been amended ten times. A complete text of the Act is provided in Appendix A. The purpose of this Act is to prohibit the location of most structures for human occupancy across the traces of active faults and to thereby mitigate the hazard of fault rupture (Section 2621.5).

This law initially was designated as the Alquist-Priolo Geologic Hazard Zones Act. The Act was renamed the Alquist-Priolo Special Studies Zones Act effective May 4, 1975 and the Alquist-Priolo Earthquake Fault Zoning Act effective January 1, 1994. The original designation "Special Studies Zones" was changed to "Earthquake Fault Zones" when the Act was last renamed.

Under the Act, the State Geologist (Chief of the California Geological Survey [CGS]) is required to delineate "Earthquake Fault Zones" (EFZs) along known active faults in California. Cities and counties affected by the zones must regulate certain development "projects" within the zones. They must withhold development permits for sites within the zones until geologic investigations demonstrate that the sites are not threatened by surface displacement from future faulting. The State Mining and Geology Board provides additional regulations (Policies and Criteria) to guide cities and counties in their implementation of the law (California Code of Regulations, Title 14, Div. 2). A summary of principal responsibilities and functions required by the Alquist-Priolo Act is given in Table 1. The Policies and Criteria are summarized in Table 2, and the complete text is provided in Appendix B.

This publication identifies and describes (1) actions taken by the State Geologist to delineate Earthquake Fault Zones, (2) policies used to make zoning decisions, and (3) Official Maps of Earthquake Fault Zones issued to date. A continuing program to evaluate faults for future zoning or zone revision also is summarized. Other aspects of the Alquist-Priolo Earthquake Fault Zoning Act and its implementation are discussed by Hart (1978 and 1986). The effectiveness of the AP Act and program was evaluated by Reitherman and Leeds (1990). The program is implementing many of the recommendations in that report.

Information presented here is based on various in-house documents and publications of the authors and others of the CGS (see Appendix E).

Table 1. Summary of responsibilities and functions under the Alquist-Priolo Earthquake Fault Zoning Act (see Appendix A for full text of Act).

State Mining and Geology Board

1. Formulates policies and criteria to guide cities and counties (Sec. 2621.5 and 2623). (See Appendix B.)
2. Serves as Appeals Board (Sec. 673).

State Geologist

1. Delineates Earthquake Fault Zones; compiles and issues maps to cities, counties, and state agencies (Sec. 2622).
   a. Preliminary Review Maps.
   b. Official Maps.
2. Reviews new data (Sec. 2622).
   a. Revises existing maps.
   b. Compiles new maps.
3. Approves requests for waivers initiated by cities and counties (Sec. 2623).

Cities and Counties

1. Must adopt zoning laws, ordinances, rules, and regulations; primary responsibility for implementing Act (Sec. 2621.5).
2. Must post notices of new Earthquake Fault Zones Maps (Sec. 2621.9 and 2622).
3. Regulates specified "projects" within Earthquake Fault Zones (Sec. 2623).
   a. Determines need for geologic reports prior to project development.
   b. Approves geologic reports prior to issuing development permits.
   c. May initiate waiver procedures. (See Appendix F.)

Other

1. *Seismic Safety Commission* - advises State Geologist and State Mining and Geology Board (Sec. 2630).
2. *State Agencies* - prohibited from siting structures for human occupancy across active fault traces (Sec. 2621.5).
3. *Disclosure* - prospective buyers of any real property located within an Earthquake Fault Zone must be notified of that fact (Sec. 2621.9).

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Table 2. Summary of policies and criteria adopted by the State Mining and Geology Board and codified in California Code of Regulations (see Appendix B for full text).

Policies
1. Defines active fault (equals potential hazard) as a fault that has had surface displacement during Holocene time (last 11,000 years) (Sec. 3601).
2. Defines "structure for human occupancy" and other terms (Sec. 3601).
3. Requires cities and counties to notify property owners within proposed new and revised Earthquake Fault Zones (Sec. 3602).
4. Provides opportunity for public to comment on Preliminary Review Maps of Earthquake Fault Zones (Sec. 3602).
5. Provides for comments and recommendations to State Geologist regarding Preliminary Review Maps (Sec. 3602).
Specific Criteria for Lead Agencies (Sec. 3603)
1. No structure for human occupancy defined as a "project" is permitted on the trace of an active fault. Unless proven otherwise, the area within 50 feet of an active fault is presumed to be underlain by active branches of the fault.
2. Requires disclosure of Earthquake Fault Zones to the public.
3. Requires that buildings converted to structures for human occupancy comply with provisions of the Act.
4. Requires geologic reports directed at the problem of potential surface faulting for all projects defined by the Act.
5. Requires cities and counties to review geologic reports for adequacy.
6. Requires that geologic reports be submitted to the State Geologist for open-file.

PROGRAM FOR ZONING AND EVALUATING FAULTS

Requirements of the Act

Section 2622 of the Alquist-Priolo Earthquake Fault Zoning Act (Appendix A) requires the State Geologist to:

1. "Delineate ... appropriately wide earthquake fault zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults, and such other faults, or segments thereof, as the State Geologist determines to be sufficiently active and well-defined as to constitute a potential hazard to structures from surface faulting or fault creep."

2. Compile maps of Earthquake Fault Zones and submit such maps to affected cities, counties, and state agencies for their review and comment. Following appropriate reviews, the State Geologist must provide Official Maps to the affected cities, counties, and state agencies.

3. Continually review new geologic and seismic data to revise the Earthquake Fault Zones or delineate additional zones.

These requirements constitute the basis for the State Geologist's fault-zoning program and for many of the policies devised to implement the program.

Initial Program for Zoning Faults

As required under the Act, the State Geologist initiated a program early in 1973 to delineate Earthquake Fault Zones to encompass potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults, and to compile and distribute maps of these zones. A project team was established within the CGS to develop and conduct a program for delineation of the zones.

Initially, 175 maps of Earthquake Fault Zones were delineated for the four named faults. These zone maps, issued as Preliminary Review Maps, were distributed for review by local and state government agencies on December 31, 1973. Following prescribed 90-day review and revision periods, Official Maps were issued on July 1, 1974. At that time, the Earthquake Fault Zones became effective and the affected cities and counties were required to implement programs to regulate development within the mapped zones. A second set of Official Maps -- 81 maps of new zones and five maps of revised zones -- was issued on January 1, 1976 to delineate new and revised zones. Additional Official Maps of new and revised zones were issued in succeeding years, as summarized in Table 3.

Table 3. Official Maps of Earthquake Fault Zones issued 1974 through August 2007.

DATE OF ISSUE	NEW MAPS	REVISED MAPS	WITHDRAWN MAPS
July 1, 1974	175	-	-
January 1, 1976	81	5	-
January 1, 1977	4	3	-
January 1, 1978	1	-	-
July 26, 1978	2	-	-
January 1, 1979	4	7	-
January 1, 1980	21	9	-
January 1, 1982	13	27	2
July 1, 1983	18	12	-
January 1, 1985	33	10	-
July 1, 1986	18	14	-
March 1, 1988	58	4	-
January 1, 1990	60	25	-
November 1, 1991	46	8	-
July 1, 1993	1	10	2
June 1, 1995	8	13	-
May 1, 1998	2	1	-
May 1, 1999	3	1	-
May 1, 2003	3	11	-
August 16, 2007	-	1	-
Totals	551	161	4

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As of August 16, 2007, 551 Official Maps of Earthquake Fault Zones have been issued. Of these, 161 have been revised since their initial issue and four have been withdrawn. The maps are identified by quadrangle map name and the date of issue or revision on the Index to Maps of Earthquake Fault Zones (Figure 4).

The maps delineate regulatory zones for the faults generally identified in Figure 1. Additional faults will be zoned in the future, and some zones will be revised. Thirty-six counties and 104 cities are affected by the existing Earthquake Fault Zones. These jurisdictions are listed in Table 4.

Definitions, Policies, Rationale

For the State Geologist to carry out the mandate to establish regulatory zones, certain terms identified in Section 2622 of the Act had to be defined and policies had to be developed to provide a consistent and reasonable approach to zoning. After the zoning program was underway and the surface fault-rupture process was better understood, other terms were defined and some zoning policies were modified.

Fault and Fault Zone

A *fault* is defined as a fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. Most faults are the result of repeated displacement that may have taken place suddenly and/or by slow creep. A fault is distinguished from those fractures or shears caused by landsliding or other gravity-induced surficial failures. A *fault zone* is a zone of related faults that commonly are braided and subparallel, but may be branching and divergent. A fault zone has significant width (with respect to the scale at which the fault is being considered, portrayed, or investigated), ranging from a few feet to several miles.

*Table 4. Cities and counties affected by Earthquake Fault Zones as of August 16, 2007**

CITIES (104)**			COUNTIES (36)	
American Canyon	Hayward	Rosemead	Alameda	Stanislaus
Arcadia	Hemet	San Bernardino	Alpine	Ventura
Arcata	Highland	San Bruno	Butte	Yolo
Arvin	Hollister	San Diego	Contra Costa	
Bakersfield	Huntington Beach	San Fernando	Fresno	
Banning	Indio	San Jacinto	Humboldt	
Barstow	Inglewood	San Jose	Imperial	
Beaumont	La Habra	San Juan Bautista	Inyo	
Benicia	La Habra Heights	San Leandro	Kern	
Berkeley	Lake Elsinore	San Luis Obispo	Lake	
Bishop	Livermore	San Marino	Lassen	
Brea	Loma Linda	San Pablo	Los Angeles	
Calimesa	Long Beach	San Ramon	Marin	
Camarillo	Los Angeles	Santa Clarita	Mendocino	
Carson	Malibu	Santa Rosa	Merced	
Cathedral City	Mammoth Lakes	Seal Beach	Modoc	
Chino Hills	Milpitas	Signal Hill	Mono	
Coachella	Monrovia	Simi Valley	Monterey	
Colton	Moorpark	South Pasadena	Napa	
Compton	Moreno Valley	South San Francisco	Orange	
Concord	Morgan Hill	Temecula	Riverside	
Corona	Murrieta	Trinidad	San Benito	
Coronado	Oakland	Twentynine Palms	San Bernardino	
Culver City	Pacifica	Union City	San Diego	
Daly City	Palmdale	Upland	San Luis Obispo	
Danville	Palm Springs	Ventura (San Buenaventura)	San Mateo	
Desert Hot Springs	Palo Alto	Walnut Creek	Santa Barbara	
Dublin	Pasadena	Whittier	Santa Clara	
El Cerrito	Pleasanton	Willits	Santa Cruz	
Fairfield	Portola Valley	Windsor	Shasta	
Fontana	Rancho Cucamonga	Woodside	Siskiyou	
Fortuna	Redlands	Yorba Linda	Solano	
Fremont	Rialto	Yucaipa	Sonoma	
Gardena	Richmond	Yucca Valley		
Glendale	Ridgecrest			

* To inquire about local government policies and regulations or to consult (obtain) copies of specific Earthquake Fault Zones maps, address the Planning Director of each county or city. Some jurisdictions have replotted the EFZ boundaries on large-scale parcel maps.

** Additional cities may be affected by the zones as new cities are created, city boundaries are expanded, or new zones are established

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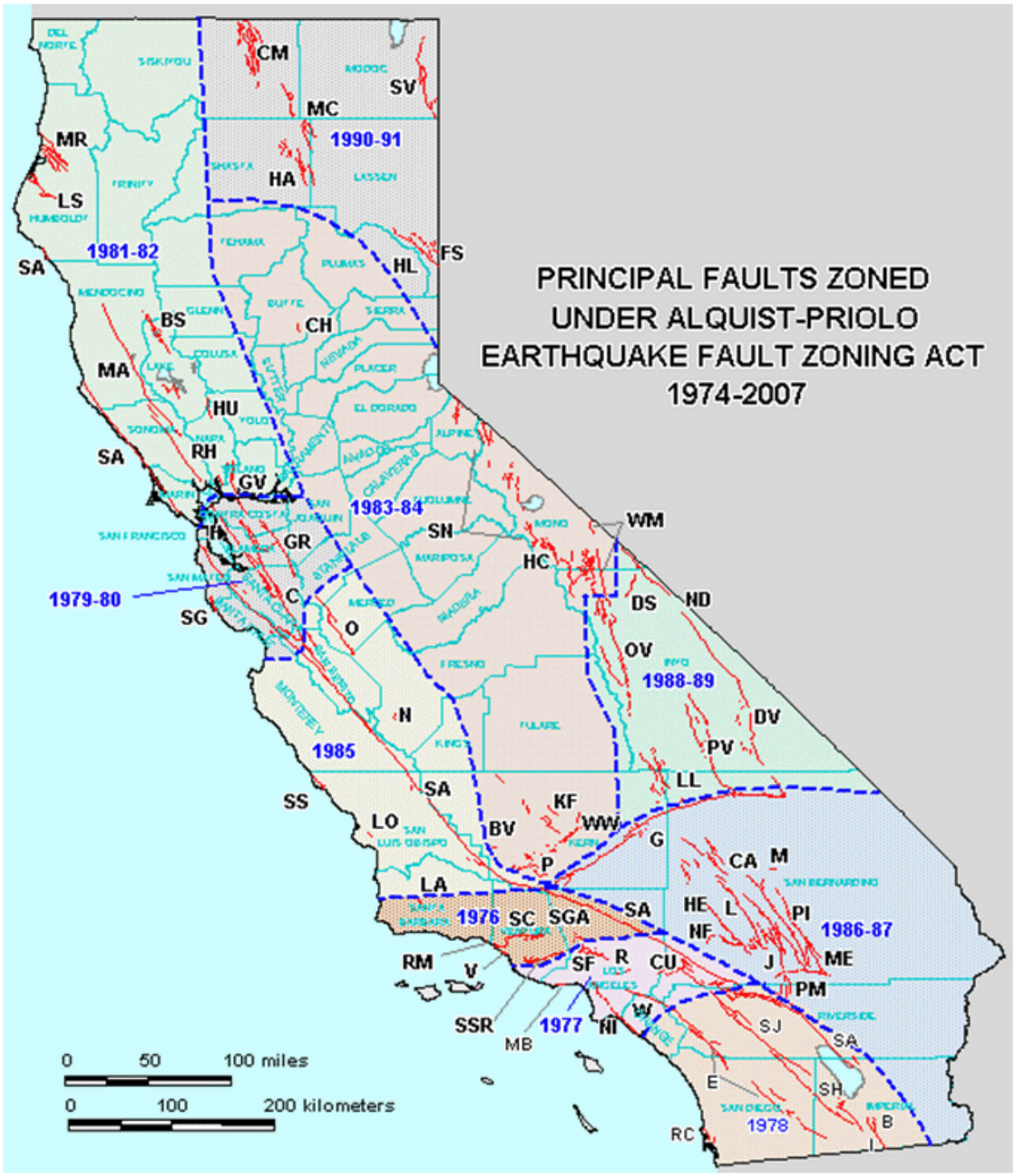
MAP SYMBOL	NAME OF PRINCIPAL FAULT
B	*Brawley
BS	Bartlett Springs
BV	*Buena Vista
C	*Calaveras
CA	Calico
CH	*Cleveland Hill
CM	Cedar Mtn.
CU	Cucamonga
DS	Deep Springs
DV	Death Valley
E	Elsinore
FS	*Fort Sage
G	*Garlock
GR	*Greenville
GV	*Green Valley and Concord
H	*Hayward
HA	Hat Creek
HC	*Hilton Creek & related
HE	Helendale
HL	Honey Lake
HU	Hunting Creek
I	*Imperial
J	*Johnson Valley & related
KF	*Kern Front & related
L	Lenwood
LA	Los Alamos
LL	*Little Lake
LO	Los Osos
LS	Little Salmon
M	*Manix
MA	*Maacama
MB	Malibu
MC	McArthur
ME	Mesquite Lake
MR	Mad River
N	*Nunez
ND	Northern Death Valley
NF	North Frontal
NI	*Newport-Inglewood
O	Ortigalita
OV	*Owens Valley
P	Pleito & Wheeler Ridge
PI	*Pisgah-Bullion
PM	Pinto Mountain
PV	Panamint Valley
R	Raymond Hill
RC	Rose Canyon
RH	Rodgers Creek-Healdsburg
RM	Red Mountain
SA	*San Andreas
SC	San Cayetano
SF	*San Fernando
SG	San Gregorio
SGA	San Gabriel
SH	*Superstition Hills
SJ	*San Jacinto
SN	Sierra Nevada (zone)
SS	San Simeon
SSR	Simi-Santa Rosa
SV	Surprise Valley
W	Whittier
WM	*White Mtns
WW	*White Wolf
V	Ventura



Faults zoned through August 2007

Approximate boundaries of work-plan regions and year studied

Note: Other faults may be zoned in the future and existing zones may be revised when warranted by new fault data

Figure 1. Principal active faults in California zoned under the Alquist-Priolo Earthquake Fault Zoning Act. Asterisk indicates faults with historic surface rupture.

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Fault Trace

A *fault trace* is the line formed by the intersection of a fault and the earth's surface. It is the representation of a fault as depicted on a map, including maps of the Earthquake Fault Zones.

Active Fault

For the purposes of this Act, an *active fault* is defined by the State Mining and Geology Board as one which has "had surface displacement within Holocene time (about the last 11,000 years)" (see Appendix B, Section 3601). This definition does not, of course, mean that faults lacking evidence for surface displacement within Holocene time are necessarily inactive. A fault may be presumed to be inactive based on satisfactory geologic evidence; however, the evidence necessary to prove inactivity sometimes is difficult to obtain and locally may not exist.

Potentially Active Fault

Because the Alquist-Priolo Act requires the State Geologist to establish Earthquake Fault Zones to encompass all "potentially and recently active" traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults, additional definitions were needed (Section 2622). Initially, faults were defined as *potentially active*, and were zoned, if they showed evidence of surface displacement during Quaternary time (last 1.6 million years, Figure 2). Exceptions were made for certain Quaternary (i.e., Pleistocene) faults that were presumed to be inactive based on direct geologic evidence of inactivity during all of Holocene time or longer. The term "recently active" was not defined, as it was considered to be covered by the term "potentially active." Beginning in 1977, evidence of Quaternary surface displacement was no longer used as a criterion for zoning. However, the term "potentially active" continued to be used as a descriptive term on map explanations on EFZ maps until 1988.

Sufficiently Active and Well-defined

A major objective of the CGS's continuing Fault Evaluation and Zoning Program is to evaluate the hundreds of remaining potentially active faults in California for zoning consideration. However, it became apparent as the program progressed that there are so many potentially active (i.e., Quaternary) faults in the state (Jennings, 1975) that it would be meaningless to zone all of them. In late 1975, the State Geologist made a policy decision to zone only those potentially active faults that have a relatively high potential for ground rupture. To facilitate this, the terms "sufficiently active" and "well-defined," from Section 2622 of the Act, were defined for application in zoning faults other than the four named in the Act. These two terms constitute the present criteria used by the State Geologist in determining if a given fault should be zoned under the Alquist-Priolo Act.

Sufficiently active. A fault is deemed sufficiently active if there is evidence of Holocene surface displacement along one or more of its segments or branches. Holocene surface displacement may be directly observable or inferred; it need not be present everywhere along a fault to qualify that fault for zoning.

Well-defined. A fault is considered well-defined if its trace is clearly detectable by a trained geologist as a physical feature at or just below the ground surface. The fault may be identified by direct observation or by indirect methods (e.g., geomorphic evidence; Appendix C). The critical consideration is that the fault, or some part of it, can be located in the field with sufficient precision and confidence to indicate that the required site-specific investigations would meet with some success.

Determining if a fault is sufficiently active and well-defined is a matter of judgment. However, these definitions provide standard, workable guidelines for establishing Earthquake Fault Zones under the Act.

The evaluation of faults for zoning purposes is done with the realization that not all active faults can be identified. Furthermore, certain faults considered to be active at depth, because of known seismic activity, are so poorly defined at the surface that zoning is impractical. Although the map explanation indicates that "potentially active" (i.e., Quaternary) faults are identified and zoned (with exceptions) on the Official Maps of Earthquake Fault Zones until 1988, this is basically true only for those maps issued July 1, 1974 and January 1, 1976. Even so, all of the principal faults zoned in 1974 and 1976 were active during Holocene time, if not historically. Beginning with the maps of January 1, 1977, all faults zoned meet the criteria of "sufficiently active and well-defined."

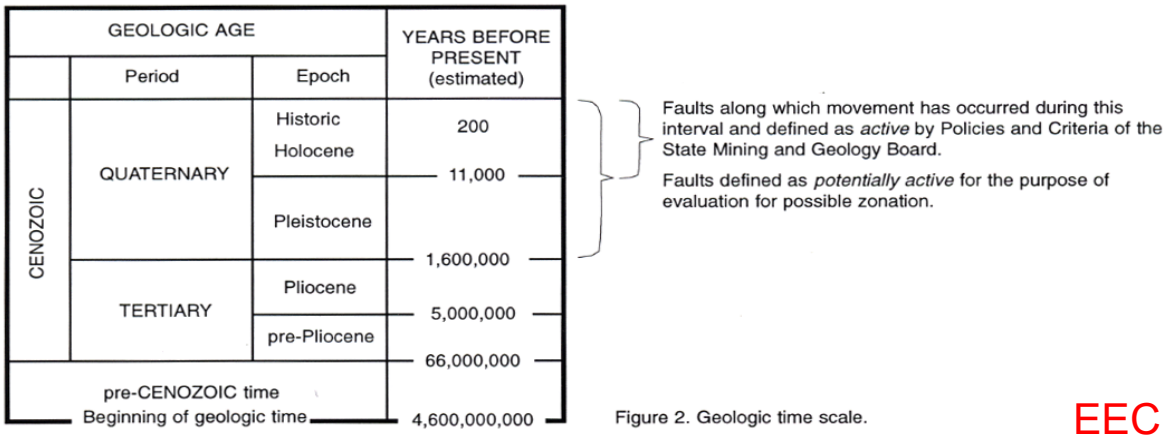

Figure 2. Geologic time scale.

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Delineating the Earthquake Fault Zones

Earthquake Fault Zones are delineated on U.S. Geological Survey topographic base maps at a scale of 1:24,000 (1 inch equals 2,000 feet). The zone boundaries are straight-line segments defined by turning points (Figure 3). Most of the turning points are intended to coincide with locatable features on the ground (e.g., bench marks, roads, streams). Neither the turning points nor the connecting zone boundaries have been surveyed to verify their mapped locations.

Locations of Earthquake Fault Zone boundaries are controlled by the position of fault traces shown on the Official Maps of Earthquake Fault Zones. With few exceptions, the faults shown on the 1974 and 1976 Earthquake Fault Zones maps were not field-checked during the compilation of these maps. However, nearly all faults zoned since January 1, 1977 have been evaluated in the field or on aerial photographs to verify that they do meet the criteria of being sufficiently active and well-defined.

Zone boundaries on early maps were positioned about 660 feet (200 meters) away from the fault traces to accommodate imprecise locations of the faults and possible existence of active branches. The policy since 1977 is to position the EFZ boundary about 500 feet (150 meters) away from major active faults and about 200 to 300 feet (60 to 90 meters) away from well-defined, minor faults. Exceptions to this policy exist where faults are locally complex or where faults are not vertical.

Fault Evaluation and Zoning Program

The Fault Evaluation and Zoning Program was initiated in early 1976 for the purpose of evaluating those "other faults" identified in the Act as "sufficiently active and well-defined" (see definition above) after it was recognized that effective future zoning could not rely solely on the limited fault data of others. Justification of this program is discussed in more detail in Special Publication 47 of the Division of Mines and Geology (1976; also see Hart, 1978).

The program was originally scheduled over a 10-year period. The state was divided into 10 regions or work areas (Figure 1), with one region scheduled for evaluation each year. However, the work in some regions was extended due to heavy workloads. Fault evaluation work includes interpretation of aerial photographs and limited field mapping, as well as the use of other geologists' work. A list of faults to be evaluated in a target region was prepared and priorities assigned. The list included potentially active faults not yet zoned, as well as previously zoned faults or fault-segments that warranted zone revisions (change or deletion). Faults also were evaluated in areas outside of scheduled regions, as the need arose (e.g., to map fault rupture immediately after an earthquake). The fault evaluation work was completed in early 1991. The work is summarized for each region in Open-File Reports (OFR) 77-8, 78-10, 79-10, 81-3, 83-10, 84-52, 86-3, 88-1, 89-16, and 91-9 (see Appendix E). Appendix E is a complete list of publications and products of the Fault Evaluation and Zoning Program.

For each fault evaluated, a Fault Evaluation Report (FER) was prepared, summarizing data on the location, recency of activity, and sense and magnitude of displacement. Each FER contains recommendations for or against zoning. These in-house reports are filed at the CGS Sacramento Regional Office at 801 K Street, MS 12-31, Sacramento, 95814, where they are available for reference. Reference copies of the FERs are filed in the CGS's Los Angeles and San Francisco Bay regional offices. An index to FERs prepared 1976 to April 1989 is available as OFR 90-9 (see Appendix E). This list and an index map identify the faults that have been evaluated. Digital files of all FER's are available in pdf format (CGS CD 2002-01; CD 2002-02; CD 2002-03) (see Appendix E).

Under the AP Act (Sec. 2622), the State Geologist has an on-going responsibility to review "new geologic and seismic data" in order to revise the Earthquake Fault Zones and to delineate new zones "when warranted by new information."

As a result of the fault evaluations made since 1976, 295 new and 155 revised Earthquake Fault Zones Maps have been issued and four maps have been withdrawn (Table 3). The faults zoned since 1976 are considered to meet the criteria of "sufficiently active and well-defined" (see Definitions above). Many other faults did not appear to meet the criteria and were not zoned. It is important to note that it is sometimes difficult to distinguish between slightly active faults and inactive ones, because the surface features formed as a result of minor, infrequent rupture are easily obliterated by geologic processes (erosion, sedimentation, mass wasting) or people's activities. Even large scale fault-rupture can be obscured in complex geologic terranes or high-energy environments. Recent fault-rupture also is difficult to detect where it is distributed as numerous breaks or warps in broad zones of deformation. As a consequence of these problems, it is not possible to identify and zone all active faults in California. For the most part, rupture on faults not identified as active is expected to be minor.

Since zones were first established in 1974, there have been 25 earthquakes or earthquake sequences associated with surface faulting in various parts of California (Table 5). This is an average of 0.75 fault-rupture events per year. Most of the recent surface faulting has been relatively minor; either in terms of amount of displacement or length of surface rupture (Table 5). However, one foot (30 cm) or more displacement occurred during seven events. Earlier records (incomplete) suggest that displacements of 3 feet (one meter) or more occur at least once every 15 to 20 years in California (Bonilla, 1970; Grantz and Bartow, 1977). Many of the recent coseismic events occurred on faults that were not yet zoned, and a few were on faults not considered to be potentially active or not even mapped. However, coseismic rupture also occurred on faults mostly or entirely within the Earthquake Fault Zones in nine of the rupture events (Table 5). A sequence of four rupture events occurred in the Lompoc diatomite quarry and presumably was triggered by quarrying (see event #10, Table 5). In addition, aseismic fault creep has occurred on many zoned faults in the last 30 years (see footnote, Table 5). Most fault creep is tectonically induced, although some is induced by people (mainly by fluid withdrawal).

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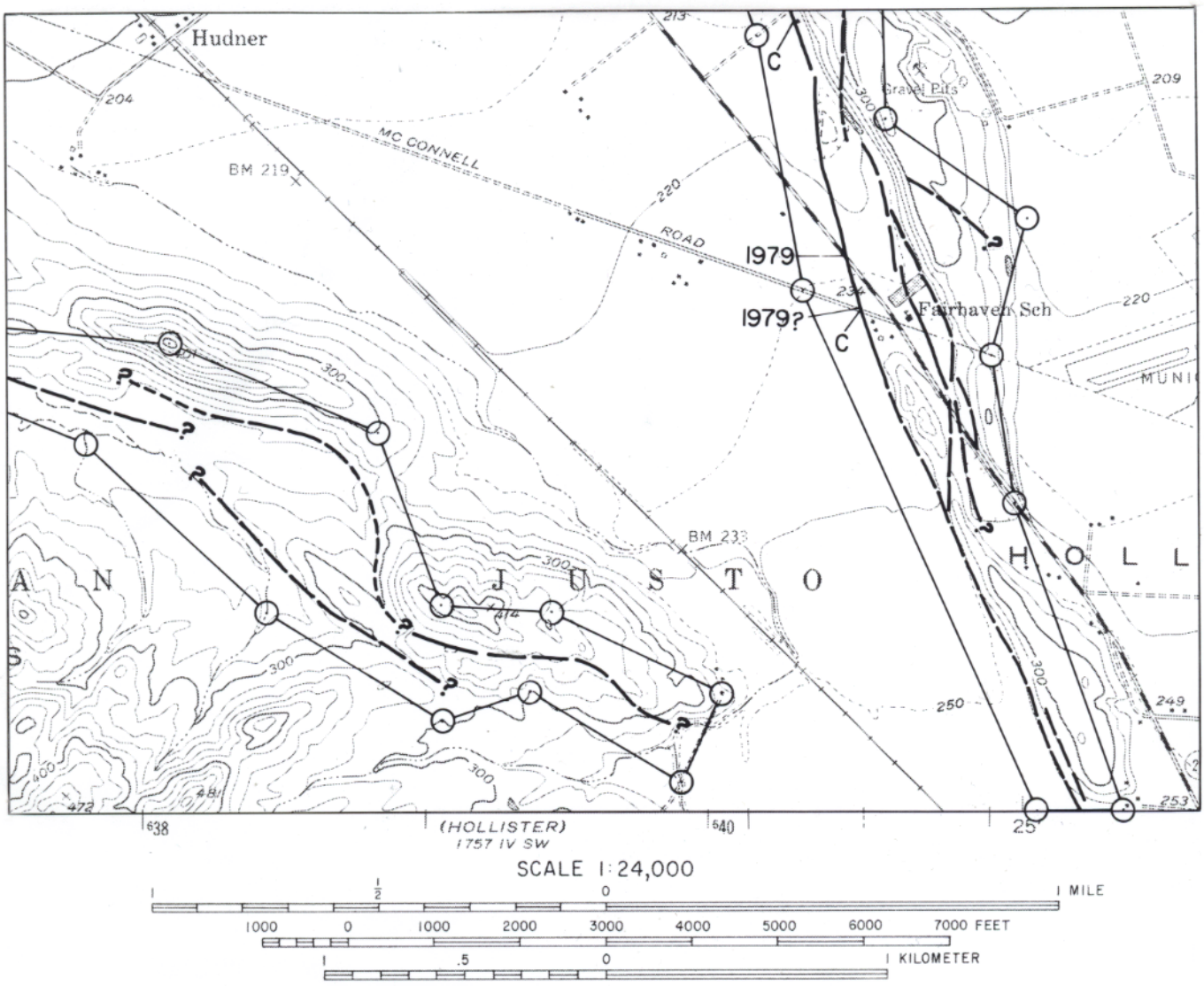

MAP EXPLANATION

Active Faults

1906 C

Faults considered to have been active during Holocene time and to have a relatively high potential for surface rupture; solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed; query (?) indicates additional uncertainity. Evidence of historic offset indicated by year of earthquake-associated event or C for displacement caused by creep or possible creep.

Earthquake Fault Zone Boundaries

These are delineated as straight-line segments that connect encircled turning points so as to define earthquake fault zone segments.

Seaward projection of zone boundary.

Figure 3. Example of Earthquake Fault Zones map and explanation of map symbols.

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Table 5. Surface faulting associated with earthquakes in California, 1974-June 2007. List excludes fault creep and faulting triggered by shaking or movement on a different fault[1]. See Bonilla (1970), Jennings (1985), and Grantz and Bartow (1977) for earlier faulting events.

Fault (County where located)	Year of rupture	Magnitude of associated earthquake	Surface rupture[2] Max. displacement (cm)	Total length[2] (km)	Main sense of displacement[3]	Comments
1. Brawley (Imperial)	1975	4.7	20	10.4	N	Also ruptured in 1940 and 1979, fault creep in part.
2. Galway Lake (San Bernardino)	1975	5.3	1.5	6.8	RL	Fault previously unknown.
3. Cleveland Hill (Butte)	1975	5.7	5	5.7	N	Fault not previously known to be Holocene-active.
4. Stephens Pass (Siskiyou)	1978	4.3	30	2+	N	Fault previously unknown.
5. Homestead Valley (San Bernardino)	1979	5.2	8	3.3	RL	Also minor rupture on Johnson Valley fault.
6. *Calaveras (San Benito, Santa Clara)	1979	5.9	1	39 (?)	RL	Minor, discontinuous rupture mostly in creep-active segment.
7. *Imperial *Brawley (Imperial) Rico	1979	6.6	55 15 10	30 13 1	RL N N	Creep triggered on San Andreas and Superstition Hills faults; also ruptured in 1940. Rico fault not previously known.
8. Greenville (Alameda)	1980	5.6	3	6.5	RL	Minor left-lateral slip also occurred on Las Positas fault.
9 . Hilton Creek-Mammoth Lakes (Mono)	1980	6.0-6.5	30	20	N	Rupture on many minor faults, may relate to volcanic activity. Minor ruptures also in 1981.
10. "Lompoc quarry" (Santa Barbara)	1981	2.5	25	0.6	R	Flexural slip on flank of syncline triggered by quarrying; do not plan to zone. Similar earthquake-associated ruptures occurred in 1985, 1988, and 1995.
11. Little Lake (Kern)	1982	5.2	0+	10	RL/N	Fracture zones on monoclines.
12. "Coalinga Nose" (Fresno)	1983	6.7	5	.005	R	Secondary fault (?) associated with 43 cm of anticlinal uplift; too minor to zone.
13. Nunez (Fresno)	1983	5.2-5.9	60	3.3	R	Aftershocks associated with event (12) above.
14. *Calaveras (Santa Clara)	1984	6.1	20 (?)	1.2	RL	Questionable faulting; triggered afterslip in 15-km long creep-zone to south.
15. *Banning (Riverside)	1986	5.9	7	9	RL	Minor slip also triggered locally on Garnet Hill and Desert Hot Springs (?) faults as well as more distant faults.
16. *White Mountains (Mono, Inyo)	1986	6.4	11	13	RL/N	Also extensional cracks on faults in Volcanic Tableland in 40km x 12km area.
17. Elmore Ranch (Imperial)	1987	6.2	12	12	LL	Also lesser left-lateral rupture on nearby faults.
18. *Superstition Hills (Imperial)	1987	6.6	90	28	RL	Much of rupture occurred as afterslip; associated with event 17.
19. *San Andreas (Santa Cruz)	1989	7.1	2.5	1?	RL	Surface rupture possibly triggered slip; slip also triggered on nearby Calaveras and San Andreas faults outside of aftershock zone. Secondary faulting may have occurred with ridgetop spreading fissures.
20. *Johnson Valley *Homestead Valley *Emerson (San Bernardino) *Camp Rock	1992	7.3	460-600	85	RL	Most significant fault rupture since 1906; ruptures connected several separate faults; triggered slip also occurred on at least 10 other faults.
21. "Eureka Valley" (Inyo)	1993	6.1	2	5+	RL/N	Two zones of left-stepping fractures along pre-existing fault scarps; incompletely mapped; remote area, not zoned.
22. "Stevenson Ranch" (Los Angeles)	1994	6.7	19	0.6	R	Flexural slip faults on limb of fold near Newhall; related to blind thrust faulting. Minor slip also triggered on Mission Wells fault, which ruptured in 1971.
23. Airport Lake (Kern and Inyo)	1995	5.4-5.8	1	2.5	RL/N	Discontinuous cracks along pre-existing scarp.
24. Lavic Lake *Bullion *Mesquite Lake (San Bernardino)	1999	7.1	525	45	RL	Bullion and Mesquite Lake faults previously zoned; Lavic Lake had not ruptured in Holocene.
25. *San Andreas (Monterey, San Luis Obispo)	2004	6.0	15	32	RL	Parkfield section of San Andreas fault zone; also ruptured in 1966. Much of rupture occurred as afterslip.

[1] Tectonic (aseismic) fault-creep and triggered slip have occurred along various segments of the San Andreas, Hayward, Calaveras, Concord, Green Valley, Imperial, Superstition Hills, Maacama, Garlock, and more than 10 other faults. People-induced fault-creep has been reported on at least 12 other faults due to withdrawal of groundwater or oilfield fluids. See Jennings (1994) for map locations.
[2] Includes some afterslip. Rupture length measured from distal ends of rupture, which often is discontinuous.
[3] N=normal displacement; R=reverse displacement; RL=right-lateral displacement; LL=left-lateral displacement.
* Coseismic surface faulting occurred mostly or entirely within existing Earthquake Fault Zones during eight events

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In addition to evaluating and zoning faults, program staff also perform other functions necessary to the implementation of the APEFZ Act. Regulations (Section 3603, Appendix B) require that cities and counties file geologic reports for "project" sites in Earthquake Fault Zones with the State Geologist. By the middle of 2006, over 4000 site-specific geologic reports investigating the hazard of surface-fault rupture had been filed for public reference. Site reports on file with CGS through 2000 are available as digital images in pdf format (CGS CD 2003-01; CD 2003-02). Reports filed after 2000 are available for reference at the Geologic Information and Publications Office in Sacramento (see Appendix E).

In order to improve the quality of site investigations and reports, guidelines were prepared in 1975 to assist others in evaluating faults. These guidelines have been revised and appear as Appendix C.

General guidelines for reviewing geologic reports for adequacy, required by Section 3603 of the regulations, are provided in Appendix D.

If a city or county considers that a geologic investigation of a proposed "project" is unnecessary, it may request a waiver from the State Geologist (Section 2623, Appendix A). A waiver form detailing the procedures used is provided in Appendix F. Through 2006, 84 waiver requests have been processed by program staff.

Another important activity is to provide information on the APEFZ Act, the Division's Fault Evaluation and Zoning Program, and fault-rupture hazards to both the public and private sectors. Program staff responds to about 1,500 inquiries each year from geologists, planners, building officials, developers, realtors, financial institutions, and others.

Uses and Limitations of Earthquake Fault Zones Maps

The Earthquake Fault Zones are delineated to define those areas within which fault-rupture hazard investigations are required prior to building structures for human occupancy. Traces of faults are shown on the maps mainly to justify the locations of zone boundaries. These fault traces are plotted as accurately as the sources of data permit; yet the plots are not sufficiently accurate to be used as the basis for building set-back requirements, and they should not be so used.

The fault information shown on the maps is not sufficient to meet the requirement for fault-rupture hazard investigations. Local governmental units must require developers to have project sites within the Earthquake Fault Zones evaluated to determine if a potential hazard from any fault, whether heretofore recognized or not, exists with regard to proposed structures and their occupants.

The surface fault-ruptures associated with historic earthquake and creep events are identified where known. However, no degree of relative potential for future surface displacement or degree of hazard is implied for the faults shown. Surface ruptures resulting from the secondary effects of seismic shaking (e.g., landsliding, differential settlement, liquefaction) are omitted from the map and do not serve as a basis for zoning.

Active faults may exist outside the Earthquake Fault Zones on any zone map. Therefore, fault investigations are recommended for all critical and important developments proposed outside the Earthquake Fault Zones.

INDEX TO MAPS OF EARTHQUAKE FAULT ZONES

The following pages (Figures 4A to 4J) indicate the names and locations of the Official Maps of Earthquake Fault Zones delineated by the California Geological Survey under the Alquist-Priolo Earthquake Fault Zoning Act (Appendix A). These index pages identify all Official Maps of Earthquake Fault Zones released by the State Geologist through August 2007. The official maps are compiled on U.S. Geological Survey 7.5-minute topographic quadrangle maps at a scale of 1 inch equals 2,000 feet (Figure 3). Cities and counties affected by these maps are listed in Table 4.

Because Earthquake Fault Zones maps are issued every year or two to delineate revised and additional zones, users of these maps should check with the California Geological Survey for up-to-date information on new and revised Earthquake Fault Zones maps. A change in zones also may affect different local governments. This index to Official Maps of Earthquake Fault Zones (Figures 4A to 4J) will be revised in future years as new maps are issued.

The Earthquake Fault Zones maps are available for purchase as indicated under Availability of Earthquake Fault Zones Maps. Also, they may be consulted at any office of the California Geological Survey and at the planning departments of all cities and counties affected locally by Earthquake Fault Zones (Table 4).

Availability of Earthquake Fault Zones Maps

Reproducible masters, from which copies of local Earthquake Fault Zones maps (scale 1:24,000) can be made, have been provided to each of the cities and counties affected by the zones. Requests for copies of

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particular Earthquake Fault Zones maps of local areas should be directed to the Planning Director of the appropriate city or county. Refer to the index of Earthquake Fault Zones maps for the quadrangle names of the maps needed.

Arrangements also have been made with ARC-Bryant (formerly BPS Reprographic Services), San Francisco, to provide paper copies of the Earthquake Fault Zones maps to those who cannot get them conveniently from the cities and counties.

ARC-Bryant
945 Bryant Street
San Francisco, CA 94103
Telephone: (415) 495-8700

Each map must be ordered by quadrangle name as shown on the index map. The cost of the maps is nominal; handling and C.O.D. charges are extra. These maps are not sold by the California Geological Survey.

Digital files of the maps can be obtained from the California Geological Survey in both digital raster (pdf) and Geographic Information System (GIS) format. Refer to Appendix E for more information on obtaining digital files of the maps.

REFERENCES

(See Appendix E for Complete List of AP Products)

Bonilla, M.G., 1970, Surface faulting and related effects, *in* Wiegel, R.L, editor, Earthquake Engineering: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, p. 47-74.

California Division of Mines and Geology, 1976, Active fault mapping and evaluation program -- 10-year program to implement Alquist-Priolo Special Studies Zones Act: California Division of Mines and Geology Special Publication 47, 42 p.

Grantz, A. and Bartow, A., 1977, Active faults of California: U.S. Geological Survey pamphlet, 15 p.

Hart, E.W., 1978, Zoning for the hazard of surface fault rupture in California: International Conference on Microzonation, 2nd, San Francisco, 1978, Proceedings, v. 2, p. 635-646.

Hart, E.W., 1986, Zoning for the hazard of surface faulting in California, *in* Proceedings Conference XXXII -- Workshop on future directions in evaluating earthquake hazards in southern California, November 12-13, 1985: U.S. Geological Survey Open-File Report 86-401, p. 74-83.

Jennings, C.W., 1975, Fault map of California with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology Data Map No. 1, scale 1:750,000.

Jennings, C.W., 1985, An explanatory text to accompany the 1:750,000 scale Fault and Geologic Maps of California: Division of Mines and Geology Bulletin 201, 197 p., 2 plates.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology Geologic Data Map No. 6, scale 1:750,000 (appendices).

Reitherman, R. and Leeds, D.J., 1990, A study of the effectiveness of the Alquist-Priolo program: California Division of Mines and Geology Open-File Report 90-18, 131 p.

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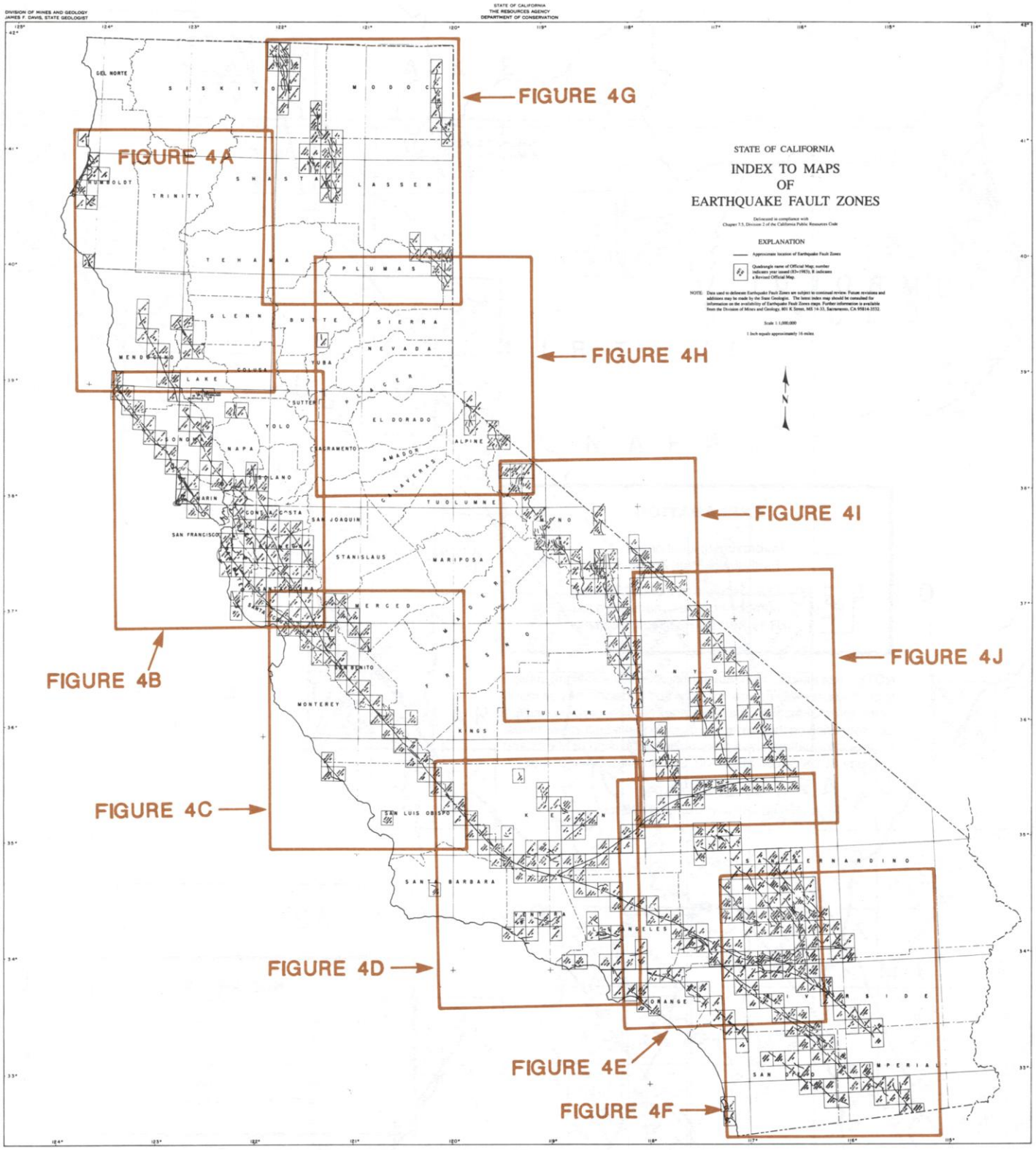

Data used to delineate Earthquake Fault Zones are subject to continual review. Future revisions and additions may be made by the State Geologist. Future supplements to this report should be consulted for information on the availability of Earthquake Fault Zones maps.
These Earthquake Fault Zones maps are delineated in compliance with Chapter 7.5, Division 2 of the California Public Resources Code.

Figure 4. Index to Official Maps of Earthquake Fault Zones.

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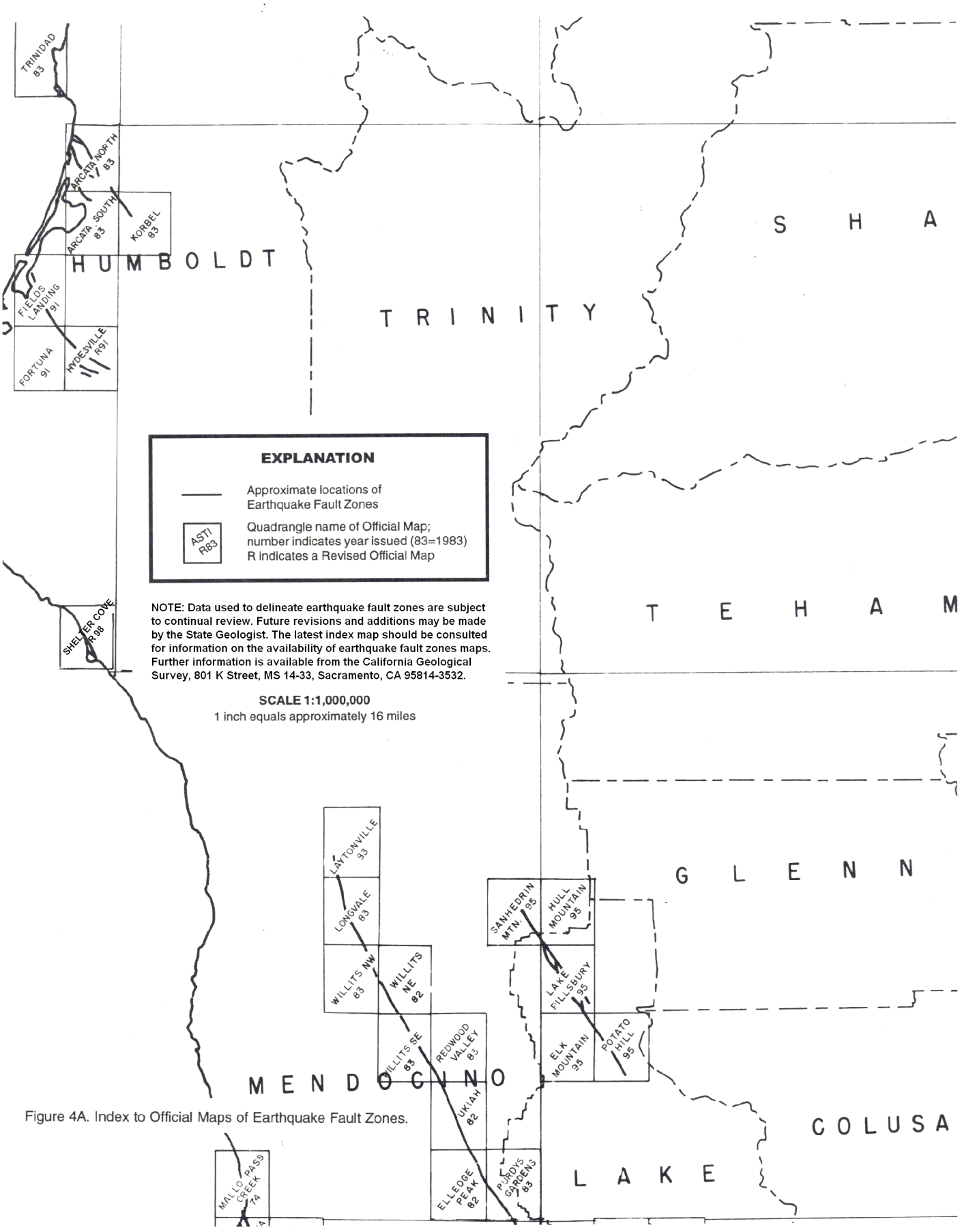

Figure 4A. Index to Official Maps of Earthquake Fault Zones.

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Figure 4B. Index to Official Maps of Earthquake Fault Zones.

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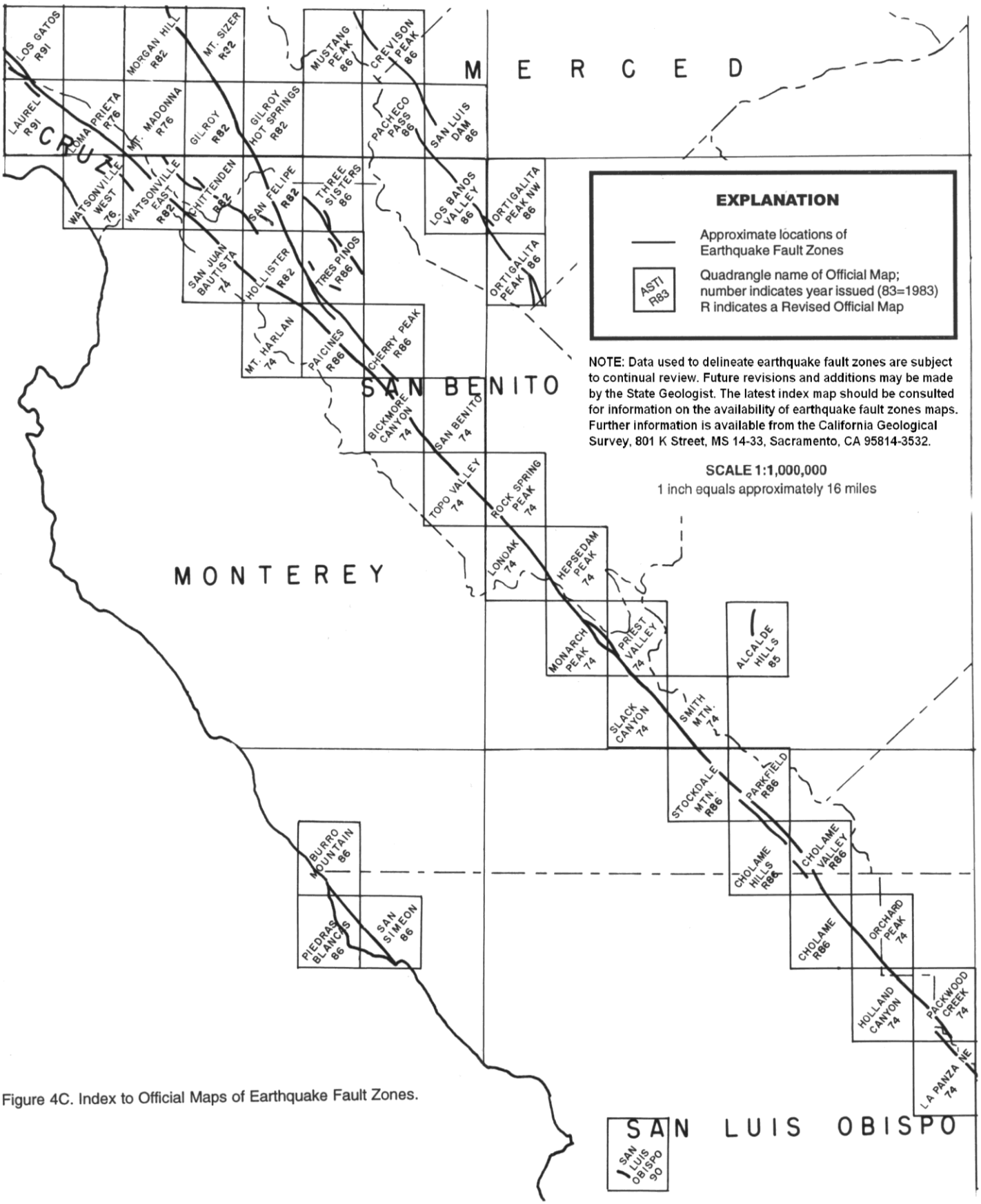

Figure 4C. Index to Official Maps of Earthquake Fault Zones.

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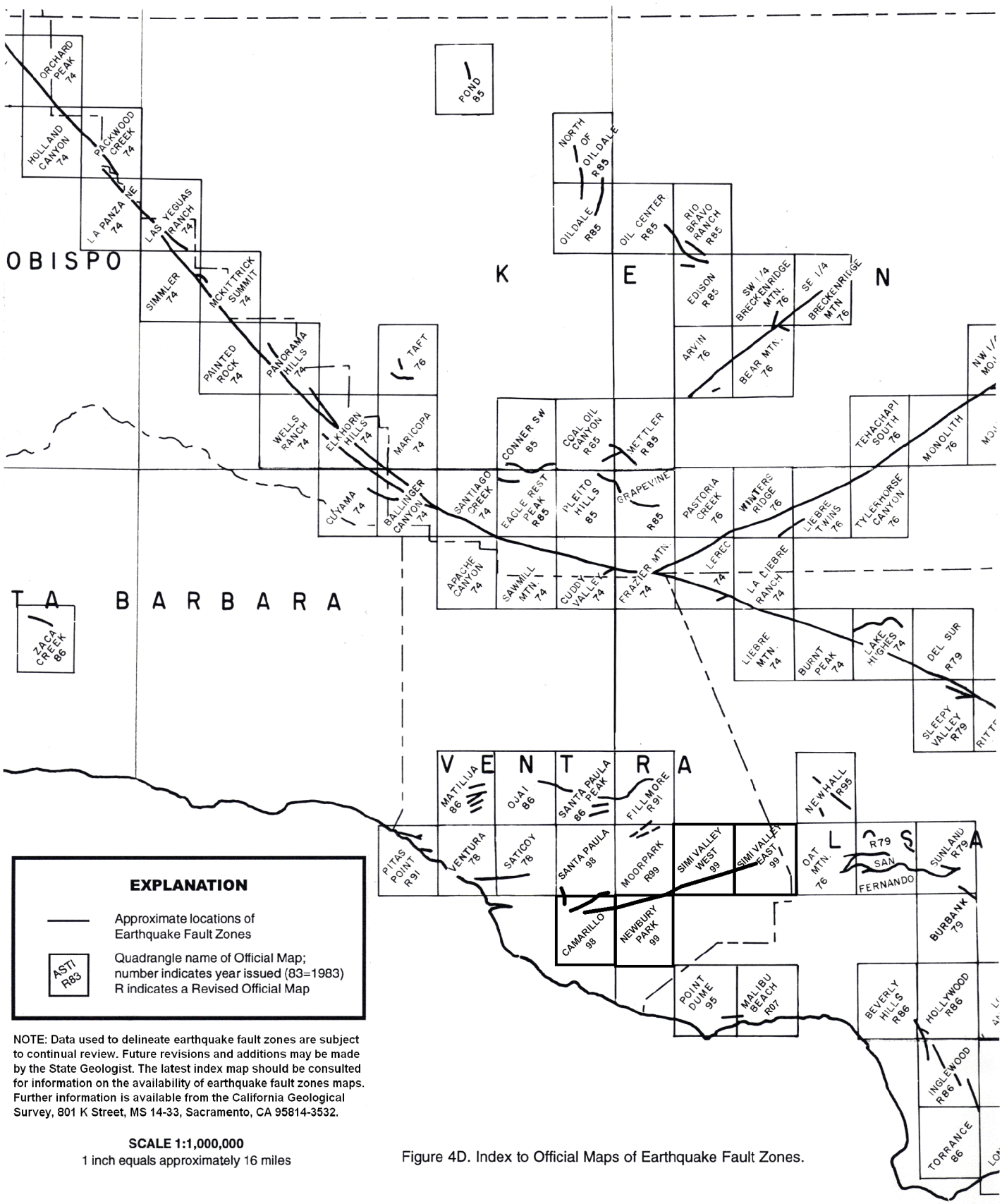

EXPLANATION

Approximate locations of Earthquake Fault Zones

ASTI R83 — Quadrangle name of Official Map; number indicates year issued (83=1983) R indicates a Revised Official Map

NOTE: Data used to delineate earthquake fault zones are subject to continual review. Future revisions and additions may be made by the State Geologist. The latest index map should be consulted for information on the availability of earthquake fault zones maps. Further information is available from the California Geological Survey, 801 K Street, MS 14-33, Sacramento, CA 95814-3532.

SCALE 1:1,000,000
1 inch equals approximately 16 miles

Figure 4D. Index to Official Maps of Earthquake Fault Zones.

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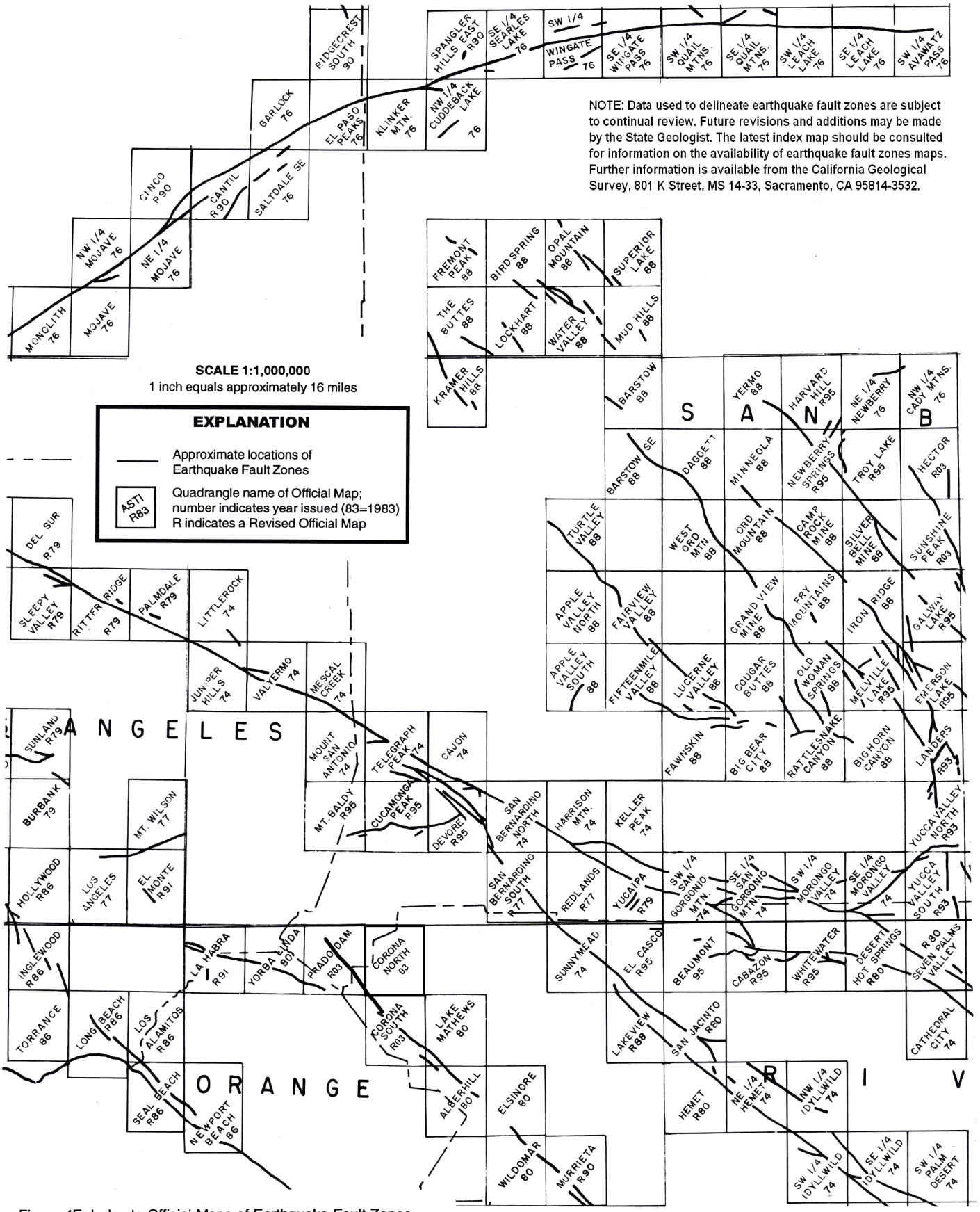

Figure 4E. Index to Official Maps of Earthquake Fault Zones.

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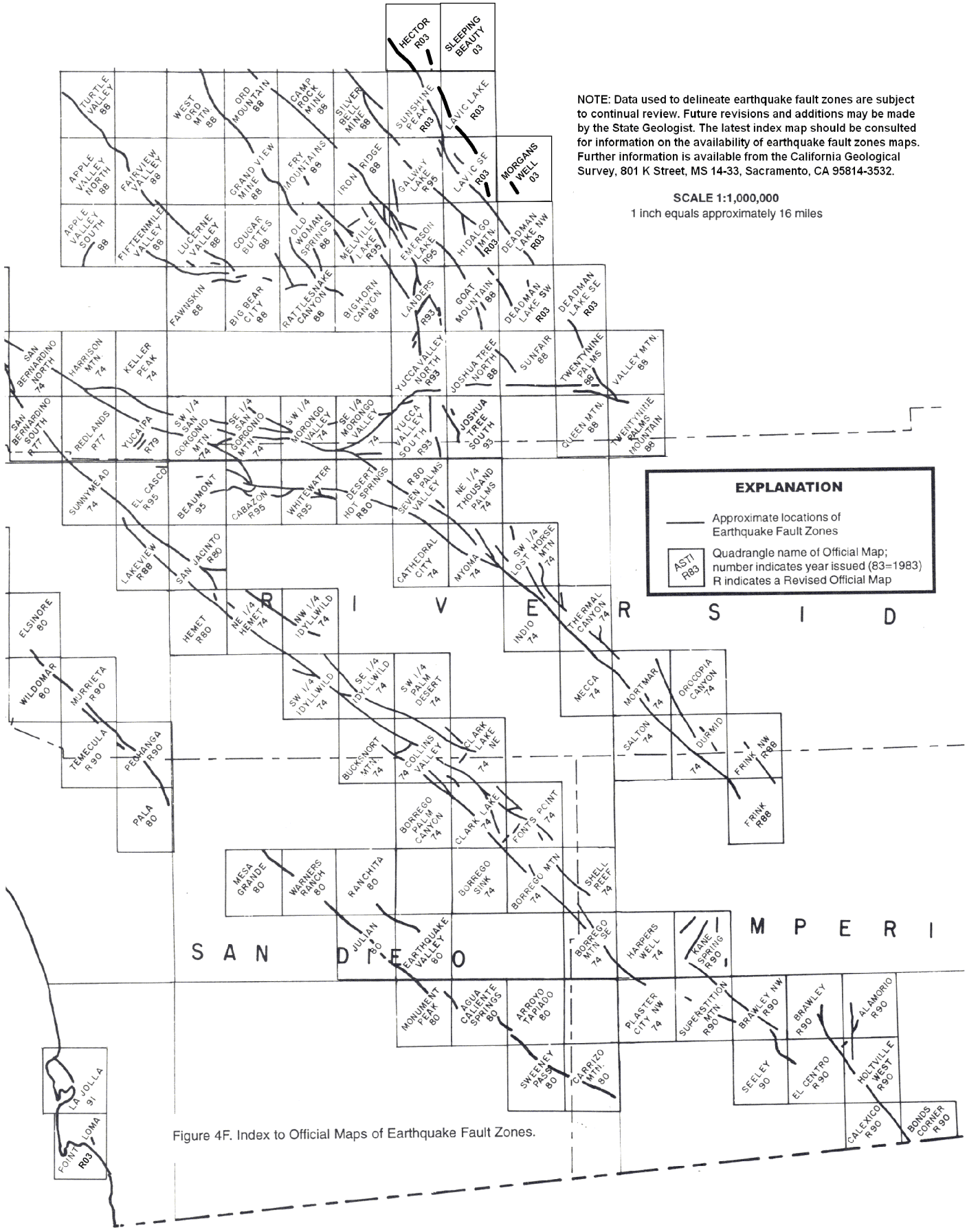

Figure 4F. Index to Official Maps of Earthquake Fault Zones.

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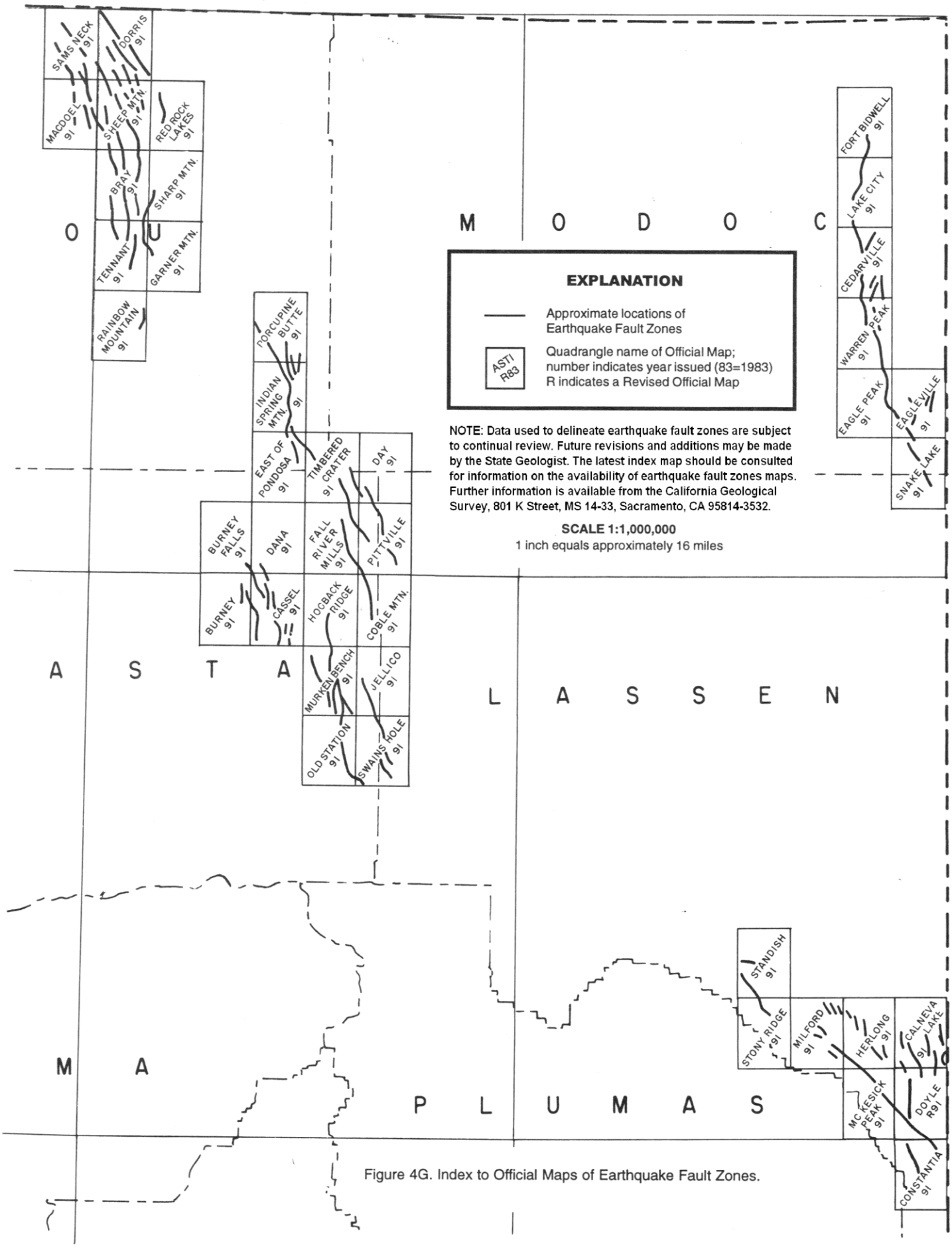

Figure 4G. Index to Official Maps of Earthquake Fault Zones.

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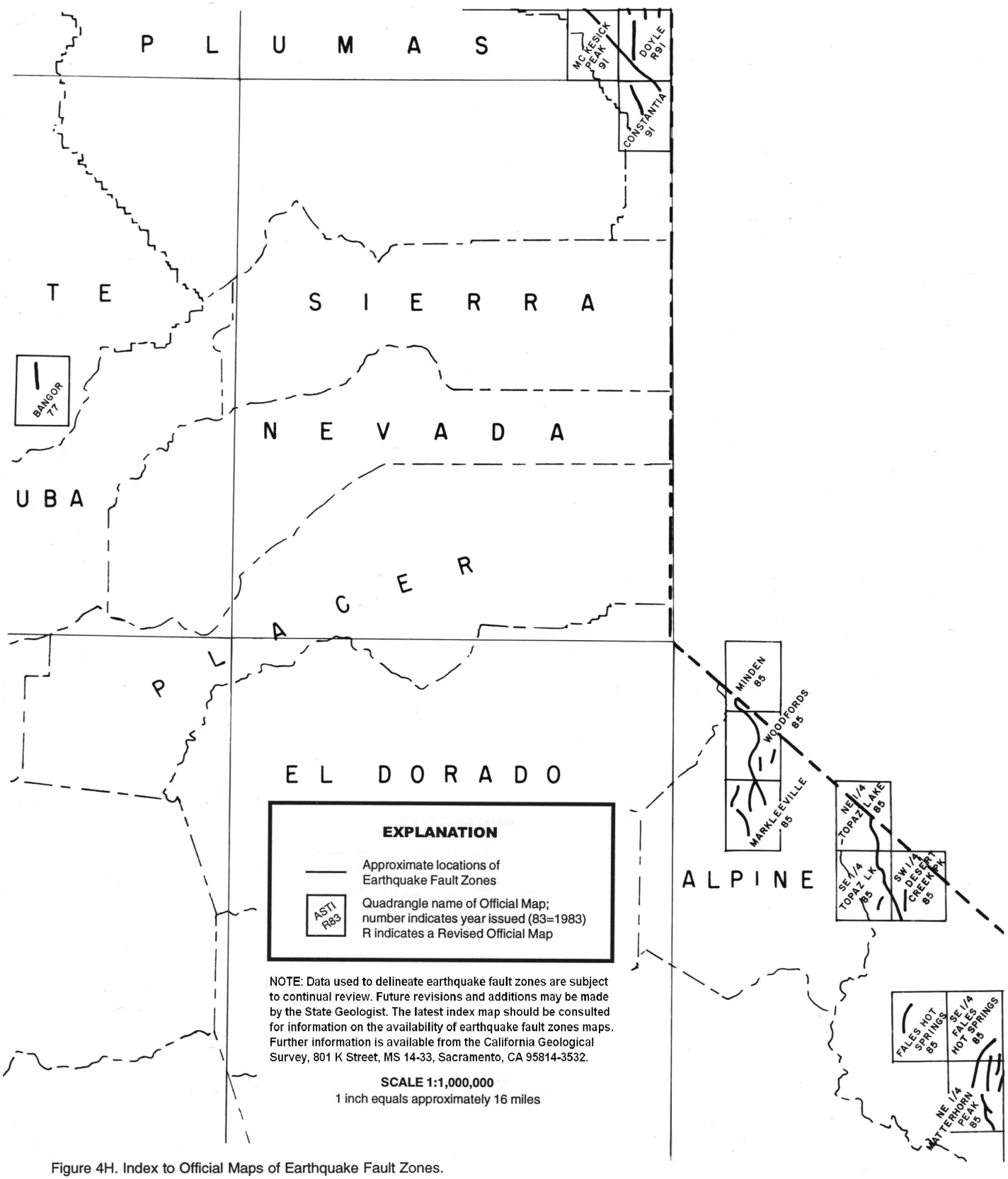

Figure 4H. Index to Official Maps of Earthquake Fault Zones.

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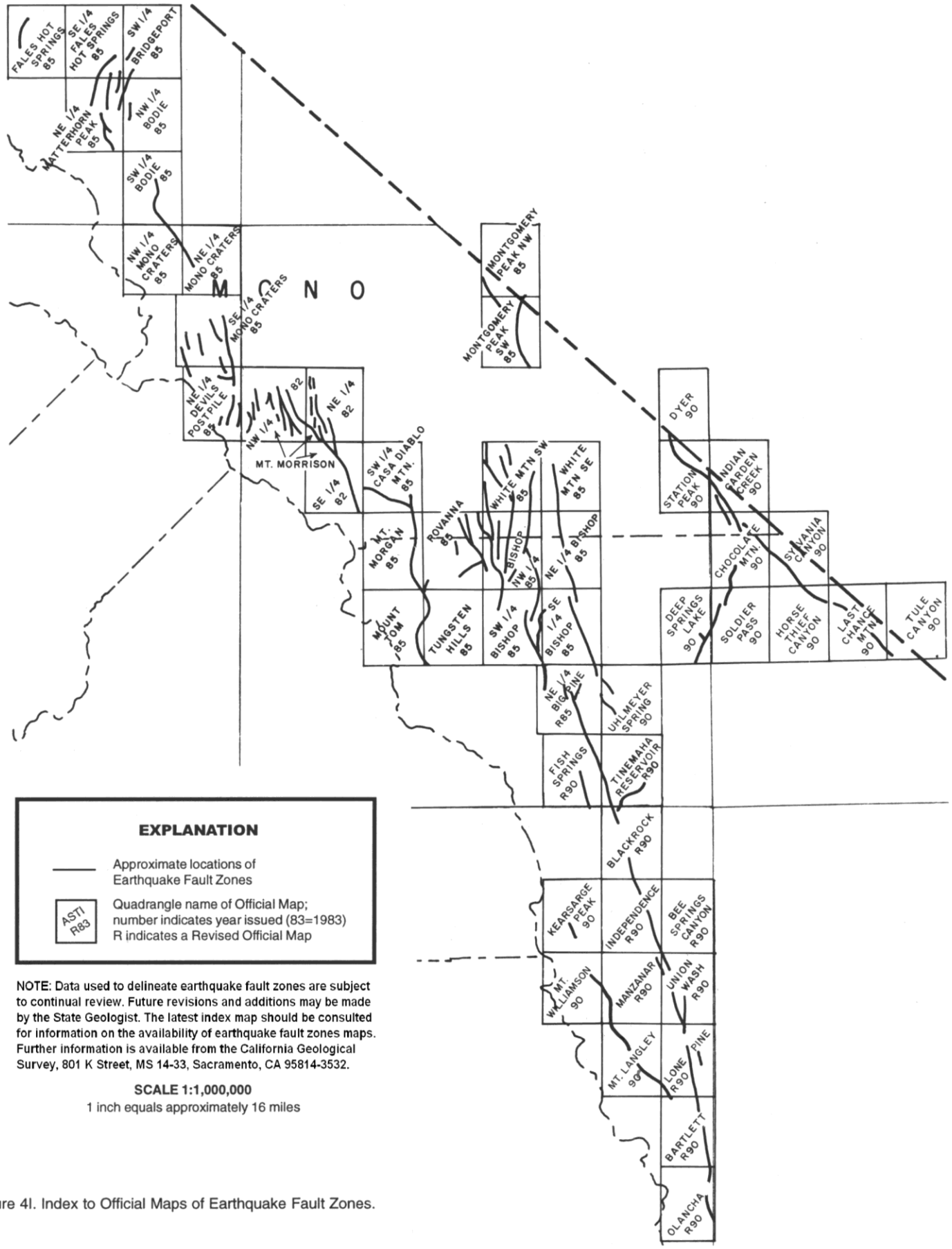

Figure 4I. Index to Official Maps of Earthquake Fault Zones.

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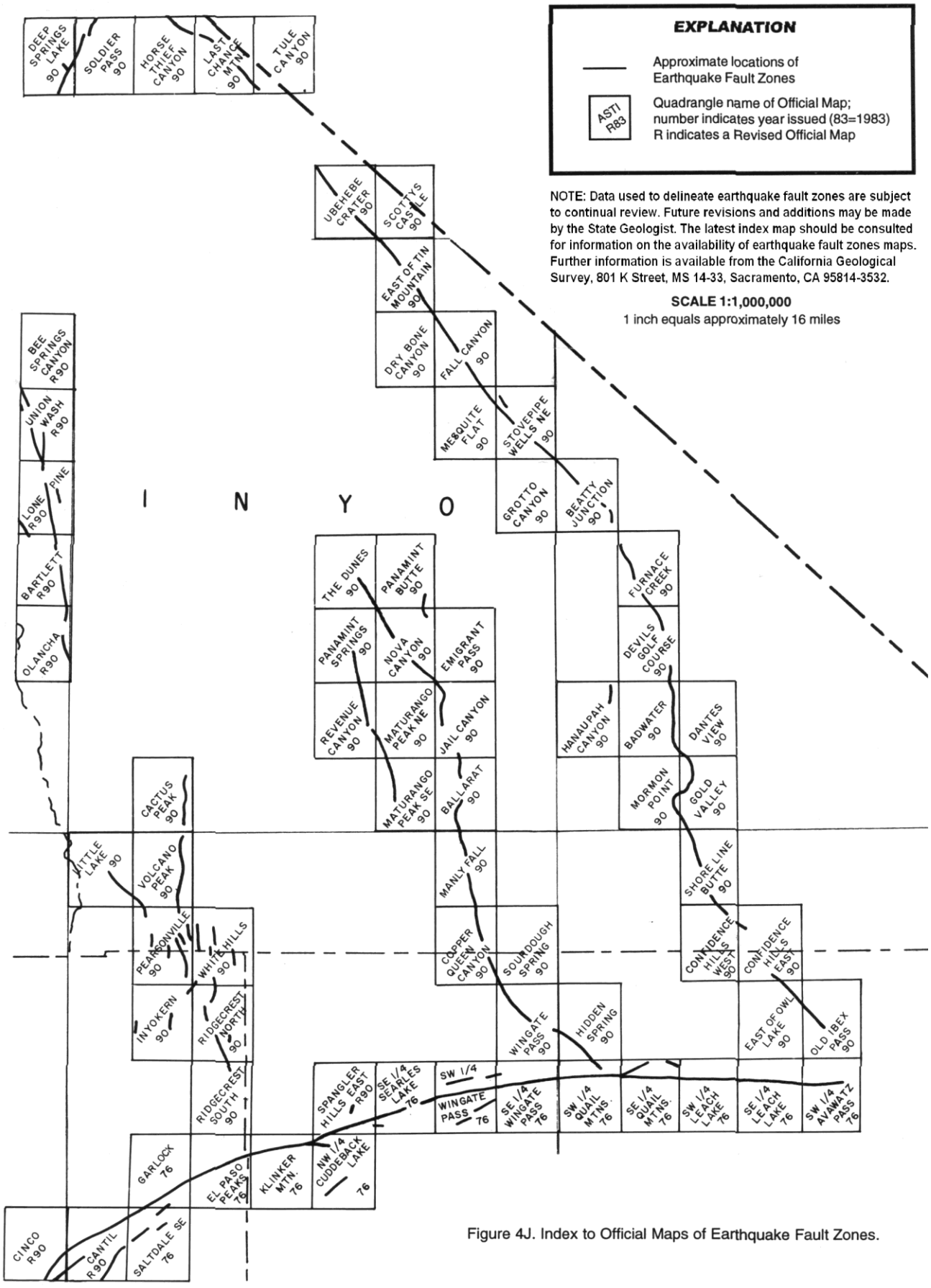

Figure 4J. Index to Official Maps of Earthquake Fault Zones.

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APPENDICES

Data are presented herein to provide city and county officials, property owners, developers, geologists, and others with specific information they may need to effectuate the Act.

Because the Act must be implemented at the local government level, it is imperative that the local entities understand its various aspects.

Appendix A
ALQUIST-PRIOLO EARTHQUAKE FAULT ZONING ACT[1]
Excerpts from California Public Resources Code

DIVISION 2. Geology, Mines and Mining
CHAPTER 7.5 Earthquake Fault Zones[2]

2621. This chapter shall be known and may be cited as the Alquist-Priolo Earthquake Fault Zoning Act[1].

2621.5. (a) It is the purpose of this chapter to provide for the adoption and administration of zoning laws, ordinances, rules, and regulations by cities and counties in implementation of the general plan that is in effect in any city or county. The Legislature declares that this chapter is intended to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prohibit the location of developments and structures for human occupancy across the trace of active faults. Further, it is the intent of this chapter to provide the citizens of the state with increased safety and to minimize the loss of life during and immediately following earthquakes by facilitating seismic retrofitting to strengthen buildings, including historical buildings, against ground shaking.

(b) This chapter is applicable to any project, as defined in Section 2621.6, which is located within a delineated earthquake fault zone, upon issuance of the official earthquake fault zones maps to affected local jurisdictions, except as provided in Section 2621.7.

(c) The implementation of this chapter shall be pursuant to policies and criteria established and adopted by the Board[3]

2621.6. (a) As used in this chapter, "project" means either of the following:

(1) Any subdivision of land which is subject to the Subdivision Map Act, (Division 2 (commencing with Section 66410) of Title 7 of the Government Code), and which contemplates the eventual construction of structures for human occupancy.

(2) Structures for human occupancy, with the exception of either of the following:

(A) Single-family wood-frame or steel-frame dwellings to be built on parcels of land for which geologic reports have been approved pursuant to paragraph (1).

(B) A single-family wood-frame or steel-frame dwelling not exceeding two stories when that dwelling is not part of a development of four or more dwellings.

(b) For the purposes of this chapter, a mobilehome whose body width exceeds eight feet shall be considered to be a single-family wood-frame dwelling not exceeding two stories.

2621.7. This chapter, except Section 2621.9, shall not apply to any of the following:

(a) The conversion of an existing apartment complex into a condominium.

(b) Any development or structure in existence prior to May 4, 1975, except for an alteration or addition to a structure that exceeds the value limit specified in subdivision (c).

(c) An alteration or addition to any structure if the value of the alteration or addition does not exceed 50 percent of the value of the structure.

(d) (1) Any structure located within the jurisdiction of the City of Berkeley or the City of Oakland which was

1 Known as the Alquist-Priolo Special Studies Zones Act prior to January 1, 1994.

2 Know as Special Studies Zones prior to January 1, 1994.

3 State Mining and Geology Board.

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damaged by fire between October 20, 1991, and October 23, 1991, if granted an exemption pursuant to this subdivision.

(2) The city may apply to the State Geologist for an exemption and the State Geologist shall grant the exemption only if the structure located within the earthquake fault zone is not situated upon a trace of an active fault line, as delineated in an official earthquake fault zone map or in more recent geologic data, as determined by the State Geologist.

(3) When requesting an exemption, the city shall submit to the State Geologist all of the following information:

(A) Maps noting the parcel numbers of proposed building sites that are at least 50 feet from an identified fault and a statement that there is not any more recent information to indicate a geologic hazard.

(B) Identification of any sites within 50 feet of an identified fault.

(C) Proof that the property owner has been notified that the granting of an exemption is not any guarantee that a geologic hazard does not exist.

(4) The granting of an exemption does not relieve a seller of real property or an agent for the seller of the obligation to disclose to a prospective purchaser that the property is located within a delineated earthquake fault zone, as required by Section 2621.9.

(e) (1) Alterations which include seismic retrofitting, as defined in Section 8894.2 of the Government Code, to any of the following listed types of buildings in existence prior to May 4, 1975:

(A) Unreinforced masonry buildings, as described in subdivision (a) of Section 8875 of the Government Code.

(B) Concrete tilt-up buildings, as described in Section 8893 of the Government Code.

(C) Reinforced concrete moment resisting frame buildings as described in Applied Technology Council Report 21 (FEMA Report 154).

(2) The exemption granted by paragraph (1) shall not apply unless a city or county acts in accordance with all of the following:

(A) The building permit issued by the city or county for the alterations authorizes no greater human occupancy load, regardless of proposed use, than that authorized for the existing use permitted at the time the city or county grants the exemption. This may be accomplished by the city or county making a human occupancy load determination that is based on, and no greater than, the existing authorized use, and including that determination on the building permit application as well as a statement substantially as follows: "Under subparagraph (A) of paragraph (2) of subdivision (e) of Section 2621.7 of the Public Resources Code, the occupancy load is limited to the occupancy load for the last lawful use authorized or existing prior to the issuance of this building permit, as determined by the city or county."

(B) The city or county requires seismic retrofitting, as defined in Section 8894.2 of the Government Code, which is necessary to strengthen the entire structure and provide increased resistance to ground shaking from earthquakes.

(C) Exemptions granted pursuant to paragraph (1) are reported in writing to the State Geologist within 30 days of the building permit issuance date.

(3) Any structure with human occupancy restrictions under subparagraph (A) of paragraph (2) shall not be granted a new building permit that allows an increase in human occupancy unless a geologic report, prepared pursuant to subdivision (d) of Section 3603 of Title 14 of the California Code of Regulations in effect on January 1, 1994, demonstrates that the structure is not on the trace of an active fault, or the requirement of a geologic report has been waived pursuant to Section 2623.

(4) A qualified historical building within an earthquake fault zone that is exempt pursuant to this subdivision may be repaired or seismically retrofitted using the State Historical Building Code, except that, notwithstanding any provision of that building code and its implementing regulations, paragraph (2) shall apply.

2621.8. Notwithstanding Section 818.2 of the Government Code, a city or county which knowingly issues a permit that grants an exemption pursuant to subdivision (e) of Section 2621.7 that does not adhere to the requirements of paragraph (2) of subdivision (e) of Section 2621.7, may be liable for earthquake-related injuries or deaths caused by failure to so adhere.

2621.9. (a) A person who is acting as an agent for a transferor of real property that is located within a delineated earthquake fault zone, or the transferor, if he or she is acting without an agent, shall disclose to any prospective transferee the fact that the property is located within a delineated earthquake fault zone.

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(b) Disclosure is required pursuant to this section only when one of the following conditions is met:

(1) The transferor, or the transferor's agent, has actual knowledge that the property is within a delineated earthquake fault zone.

(2) A map that includes the property has been provided to the city or county pursuant to Section 2622, and a notice has been posted at the offices of the county recorder, county assessor, and county planning agency that identifies the location of the map and any information regarding changes to the map received by the county.

(c) In all transactions that are subject to Section 1103 of the Civil Code, the disclosure required by subdivision (a) of this section shall be provided by either of the following means:

(1) The Local Option Real Estate Transfer Disclosure Statement as provided in Section 1102.6a of the Civil Code.

(2) The Natural Hazard Disclosure Statement as provided in Section 1103.2 of the Civil Code.

(d) If the map or accompanying information is not of sufficient accuracy or scale that a reasonable person can determine if the subject real property is included in a delineated earthquake fault hazard zone, the agent shall mark "Yes" on the Natural Hazard Disclosure Statement. The agent may mark "No" on the Natural Hazard Disclosure Statement if he or she attaches a report prepared pursuant to subdivision (c) of Section 1103.4 of the Civil Code that verifies the property is not in the hazard zone. Nothing in this subdivision is intended to limit or abridge any existing duty of the transferor or the transferor's agents to exercise reasonable care in making a determination under this subdivision.

(e) For purposes of the disclosures required by this section, the following persons shall not be deemed agents of the transferor:

(1) Persons specified in Section 1103.11 of the Civil Code.

(2) Persons acting under a power of sale regulated by Section 2924 of the Civil Code.

(f) For purposes of this section, Section 1103.13 of the Civil Code shall apply.

(g) The specification of items for disclosure in this section does not limit or abridge any obligation for disclosure created by any other provision of law or that may exist in order to avoid fraud, misrepresentation, or deceit in the transfer transaction.

2622. (a) In order to assist cities and counties in their planning, zoning, and building-regulation functions, the State Geologist shall delineate, by December 31, 1973, appropriately wide earthquake fault zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults, and such other faults, or segments thereof, as the State Geologist determines to be sufficiently active and well-defined as to constitute a potential hazard to structures from surface faulting or fault creep. The earthquake fault zones shall ordinarily be one-quarter mile or less in width, except in circumstances which may require the State Geologist to designate a wider zone.

(b) Pursuant to this section, the State Geologist shall compile maps delineating the earthquake fault zones and shall submit the maps to all affected cities, counties, and state agencies, not later than December 31, 1973, for review and comment. Concerned jurisdictions and agencies shall submit all comments to the State Mining and Geology Board for review and consideration within 90 days. Within 90 days of such review, the State Geologist shall provide copies of the official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within any such zone.

(c) The State Geologist shall continually review new geologic and seismic data and shall revise the earthquake fault zones or delineate additional earthquake fault zones when warranted by new information. The State Geologist shall submit all revised maps and additional maps to all affected cities, counties, and state agencies for their review and comment. Concerned jurisdictions and agencies shall submit all comments to the State Mining and Geology Board for review and consideration within 90 days. Within 90 days of that review, the State Geologist shall provide copies of the revised and additional official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within the earthquake fault zone.

(d) In order to ensure that sellers of real property and their agents are adequately informed, any county that receives an official map pursuant to this section shall post a notice within five days of receipt of the map at the offices of the county recorder, county assessor, and county planning commission, identifying the location of the map and the effective date of the notice.

2623. (a) The approval of a project by a city or county shall be in accordance with policies and criteria established by the State Mining and Geology Board and the findings of the State Geologist. In the development of such policies and criteria, the State Mining and Geology Board shall seek the comment and advice of affected cities, counties,

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and state agencies. Cities and counties shall require, prior to the approval of a project, a geologic report defining and delineating any hazard of surface fault rupture. If the city or county finds that no undue hazard of that kind exists, the geologic report on the hazard may be waived, with the approval of the State Geologist.

(b) After a report has been approved or a waiver granted, subsequent geologic reports shall not be required, provided that new geologic data warranting further investigations is not recorded.

(c) The preparation of geologic reports that are required pursuant to this section for multiple projects may be undertaken by a geologic hazard abatement district.

2624. Notwithstanding any provision of this chapter, cities and counties may do any of the following:

(1) Establish policies and criteria which are stricter than those established by this chapter.

(2) Impose and collect fees in addition to those required under this chapter.

(3) Determine not to grant exemptions authorized under this chapter.

2625. (a) Each applicant for approval of a project may be charged a reasonable fee by the city or county having jurisdiction over the project.

(b) Such fees shall be set in an amount sufficient to meet, but not to exceed, the costs to the city or county of administering and complying with the provisions of this chapter.

(c) The geologic report required by Section 2623 shall be in sufficient detail to meet the criteria and policies established by the State Mining and Geology Board for individual parcels of land.

2630. In carrying out the provisions of this chapter, the State Geologist and the board shall be advised by the Seismic Safety Commission.

SIGNED INTO LAW DECEMBER 22, 1972; AMENDED SEPTEMBER 16, 1974, MAY 4, 1975, SEPTEMBER 28, 1975, SEPTEMBER 22, 1976, SEPTEMBER 27, 1979, SEPTEMBER 21, 1990, JULY 29, 1991, AUGUST 16, 1992, JULY 25, 1993, OCTOBER 7, 1993, AND OCTOBER 7, 1997

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Appendix B

POLICIES AND CRITERIA OF THE STATE MINING AND GEOLOGY BOARD

With Reference to the Alquist-Priolo Earthquake Fault Zoning Act

(Excerpts from the California Code of Regulations, Title 14, Division 2)

3600. Purpose.

It is the purpose of this subchapter to set forth the policies and criteria of the State Mining and Geology Board, hereinafter referred to as the "Board," governing the exercise of city, county, and state agency responsibilities to prohibit the location of developments and structures for human occupancy across the trace of active faults in accordance with the provisions of Public Resources Code Section 2621 et seq. (Alquist-Priolo Earthquake Fault Zoning Act). The policies and criteria set forth herein shall be limited to potential hazards resulting from surface faulting or fault creep within earthquake fault zones delineated on maps officially issued by the State Geologist.

NOTE: Authority cited: Section 2621.5, Public Resources Code. Reference: Sections 2621-2630, Public Resources Code.

3601. Definitions.

The following definitions as used within the Act and herein shall apply:

(a) An "active fault" is a fault that has had surface displacement within Holocene time (about the last 11,000 years), hence constituting a potential hazard to structures that might be located across it.

(b) A "fault trace" is that line formed by the intersection of a fault and the earth's surface, and is the representation of a fault as depicted on a map, including maps of earthquake fault zones.

(c) A "lead agency" is the city or county with the authority to approve projects.

(d) "Earthquake fault zones" are areas delineated by the State Geologist, pursuant to the Alquist-Priolo Earthquake Fault Zoning Act (Public Resources Code Section 2621 et seq.) and this subchapter, which encompass the traces of active faults.

(e) A "structure for human occupancy" is any structure used or intended for supporting or sheltering any use or occupancy, which is expected to have a human occupancy rate of more than 2,000 person-hours per year.

(f) "Story" is that portion of a building included between the upper surface of any floor and the upper surface of the floor next above, except that the topmost story shall be that portion of a building included between the upper surface of the topmost floor and the ceiling or roof above. For the purpose of the Act and this subchapter, the number of stories in a building is equal to the number of distinct floor levels, provided that any levels that differ from each other by less than two feet shall be considered as one distinct level.

NOTE: Authority cited: Section 2621.5, Public Resources Code. Reference: Sections 2621-2630, Public Resources Code.

3602. Review of Preliminary Maps.

(a) Within 45 days from the issuance of proposed new or revised preliminary earthquake fault zone map(s), cities and counties shall give notice of the Board's announcement of a ninety (90) day public comment period to property owners within the area of the proposed zone. The notice shall be by publication, or other means reasonably calculated to reach as many of the affected property owners as feasible. Cities and counties may also give notice to consultants who may conduct geologic studies in fault zones. The notice shall state that its purpose is to provide an opportunity for public comment including providing to the Board geologic information that may have a bearing on the proposed map(s).

(b) The Board shall also give notice by mail to those California Registered Geologists and California Registered Geophysicists on a list provided by the State Board of Registration for Geologists and Geophysicists. The notice shall indicate the affected jurisdictions and state that its purpose is to provide an opportunity to present written technical comments that may have a bearing on the proposed zone map(s) to the Board during a 90-day public comment period.

(c) The Board shall receive public comments during the 90-day public comment period. The Board shall

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conduct at least one public hearing on the proposed zone map(s) during the 90-day public comment period.

(d) Following the end of the 90-day public comment period, the Board shall forward its comments and recommendations with supporting data received to the State Geologist for consideration prior to the release of official earthquake fault zone map(s).

NOTE: Authority cited: Section 2621.5, Public Resources Code. Reference: Section 2622, Public Resources Code.

3603. Specific Criteria.

The following specific criteria shall apply within earthquake fault zones and shall be used by affected lead agencies in complying with the provisions of the Act:

(a) No structure for human occupancy, identified as a project under Section 2621.6 of the Act, shall be permitted to be placed across the trace of an active fault. Furthermore, as the area within fifty (50) feet of such active faults shall be presumed to be underlain by active branches of that fault unless proven otherwise by an appropriate geologic investigation and report prepared as specified in Section 3603(d) of this subchapter, no such structures shall be permitted in this area.

(b) Affected lead agencies, upon receipt of official earthquake fault zones maps, shall provide for disclosure of delineated earthquake fault zones to the public. Such disclosure may be by reference in general plans, specific plans, property maps, or other appropriate local maps.

(c) No change in use or character of occupancy, which results in the conversion of a building or structure from one not used for human occupancy to one that is so used, shall be permitted unless the building or structure complies with the provisions of the Act.

(d) Application for a development permit for any project within a delineated earthquake fault zone shall be accompanied by a geologic report prepared by a geologist registered in the State of California, which is directed to the problem of potential surface fault displacement through the project site, unless such report is waived pursuant to Section 2623 of the Act. The required report shall be based on a geologic investigation designed to identify the location, recency, and nature of faulting that may have affected the project site in the past and may affect the project site in the future. The report may be combined with other geological or geotechnical reports.

(e) A geologist registered in the State of California, within or retained by each lead agency, shall evaluate the geologic reports required herein and advise the lead agency.

(f) One (1) copy of all such geologic reports shall be filed with the State Geologist by the lead agency within thirty (30) days following the report's acceptance. The State Geologist shall place such reports on open file.

NOTE: Authority cited: Section 2621.5, Public Resources Code. Reference: Sections 2621.5, 2622, 2623, and 2625(c), Public Resources Code.

ADOPTED NOVEMBER 23, 1973; REVISED JULY 1, 1974, AND JUNE 26, 1975.
CODIFIED IN CALIFORNIA CODE OF REGULATIONS JANUARY 31, 1979;
REVISED OCTOBER 18, 1984, JANUARY 5, 1996, AND APRIL 1, 1997.

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Appendix C

GUIDELINES FOR EVALUATING THE HAZARD OF SURFACE RUPTURE

(These guidelines, also published as DMG Note 49 (1997), are not part of the Policies and Criteria of the State Mining and Geology Board. Similar guidelines were adopted by the Board for advisory purposes in 1996.)

These guidelines are to assist geologists who investigate faults relative to the hazard of surface fault rupture. Subsequent to the passage of the Alquist-Priolo Earthquake Fault Zoning Act (1972), it became apparent that many fault investigations conducted in California were incomplete or otherwise inadequate for the purpose of evaluating the potential of surface fault rupture. It was further apparent that statewide standards for investigating faults would be beneficial. These guidelines were initially prepared in 1975 as DMG Note 49 and have been revised several times since then.

The investigation of sites for the possible hazard of surface fault rupture is a deceptively difficult geologic task. Many active faults are complex, consisting of multiple breaks. Yet the evidence for identifying active fault traces is generally subtle or obscure and the distinction between recently active and long-inactive faults may be difficult to make. It is impractical from an economic, engineering, and architectural point of view to design a structure to withstand serious damage under the stress of surface fault rupture. Once a structure is sited astride an active fault, the resulting fault-rupture hazard cannot be mitigated unless the structure is relocated, whereas when a structure is placed on a landslide, the potential hazard from landsliding often can be mitigated. Most surface faulting is confined to a relatively narrow zone a few feet to a few tens of feet wide, making avoidance (i.e., building setbacks) the most appropriate mitigation method. However, in some cases primary fault rupture or rupture along branch faults can be distributed across zones hundreds of feet wide or manifested as broad warps, suggesting that engineering strengthening or design may be of additional mitigative value (e.g., Lazarte and others, 1994).

No single investigative method will be the best, or even useful, at all sites, because of the complexity of evaluating surface and near surface faults and because of the infinite variety of site conditions. Nonetheless, certain investigative methods are more helpful than others in locating faults and evaluating the recency of activity.

The evaluation of a given site with regard to the potential hazard of surface fault rupture is based extensively on the concepts of *recency* and *recurrence* of faulting along existing faults. In a general way, the more recent the faulting the greater the probability for future faulting (Allen, 1975). Stated another way, faults of known historic activity during the last 200 years, as a class, have a greater probability for future activity than faults classified as Holocene age (last 11,000 years) and a much greater probability of future activity than faults classified as Quaternary age (last 1.6 million years). However, it should be kept in mind that certain faults have recurrent activity measured in tens or hundreds of years whereas other faults may be inactive for thousands of years before being reactivated. Other faults may be characterized by creep-type rupture that is more or less on-going. The magnitude, sense, and nature of fault rupture also vary for different faults or even along different strands of the same fault. Even so, future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970, p. 68). The development of a new fault or reactivation of a long-inactive fault is relatively uncommon and generally need not be a concern in site development.

As a practical matter, fault investigations should be directed at the problem of locating existing faults and then attempting to evaluate the recency of their activity. Data should be obtained both from the site and outside the site area. The most useful and direct method of evaluating recency is to observe (in a trench or road cut) the youngest geologic unit faulted and the oldest unit that is not faulted. Even so, active faults may be subtle or discontinuous and consequently overlooked in trench exposures (Bonilla and Lienkaemper, 1991). Therefore, careful logging is essential and trenching needs to be conducted in conjunction with other methods. For example, recently active faults may also be identified by direct observation of young, fault-related geomorphic (i.e., topographic) features in the field or on aerial photographs. Other indirect and more interpretive methods are identified in the outline below. Some of these methods are discussed in Bonilla (1982), Carver and McCalpin (1996), Hatheway and Leighton (1979), McCalpin

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(1996a, b, c), National Research Council (1986), Sherard and others (1974), Slemmons (1977), Slemmons and dePolo (1986), Taylor and Cluff (1973), the Utah Section of the Association of Engineering Geologists (1987), Wallace (1977), Weldon and others (1996), and Yeats and others (1997). McCalpin (1996b) contains a particularly useful discussion of various field techniques. Many other useful references are listed in the bibliographies of the references cited here.

The purpose, scope, and methods of investigation for fault investigations will vary depending on conditions at specific sites and the nature of the projects. Contents and scope of the investigation also may vary based on guidelines and review criteria of agencies or political organizations having regulatory responsibility. However, there are topics that should be considered in all comprehensive fault investigations and geologic reports on faults. For a given site some topics may be addressed in more detail than at other sites because of the difference in the geologic and/or tectonic setting and/or site conditions. These investigative considerations should apply to any comprehensive fault investigation and may be applied to any project site, large or small. Suggested topics, considerations, and guidelines for fault investigations and reports on faults are provided in the following annotated outline. Fault investigations may be conducted in conjunction with other geologic and geotechnical investigations (see DMG Notes 42 and 44; also California Department of Conservation, Division of Mines and Geology, 1997). Although not all investigative techniques need to be or can be employed in evaluating a given site, the outline provides a checklist for preparing complete and well-documented reports. Most reports on fault investigations are reviewed by local or state government agencies. Therefore it is necessary that the reports be documented adequately and written carefully to facilitate that review. The importance of the review process is emphasized here, because it is the reviewer who must evaluate the adequacy of reports, interpret or set standards where they are unclear, and advise the governing agency as to their acceptability (Hart and Williams, 1978; DMG Note 41).

The scope of the investigation is dependent not only on the complexity and economics of a project, but also on the level of risk acceptable for the proposed structure or development. A more detailed investigation should be made for hospitals, high-rise buildings, and other critical or sensitive structures than for low-occupancy structures such as wood-frame dwellings that are comparatively safe. The conclusions drawn from any given set of data, however, must be consistent and unbiased. Recommendations must be clearly separated from conclusions, because recommendations are not totally dependent on geologic factors. The final decision as to whether, or how, a given project should be developed lies in the hands of the owner and the governing body that must review and approve the project.

CONTENTS OF GEOLOGIC REPORTS ON FAULTS

Suggested topics, considerations, and guidelines for investigations and reports

The following topics should be considered and addressed in detail where essential to support opinions, conclusions, and recommendations, in any geologic report on faults. It is not expected that all of the topics or investigative methods would be necessary in a single investigation. In specific cases it may be necessary to extend some of the investigative methods well beyond the site or property being investigated. Particularly helpful references are cited parenthetically below.

I. Text.

A. Purpose and scope of investigation; description of proposed development.

B. Geologic and tectonic setting. Include seismicity and earthquake history.

C. Site description and conditions, including dates of site visits and observations. Include information on geologic units, graded and filled areas, vegetation, existing structures, and other factors that may affect the choice of investigative methods and the interpretation of data.

D. Methods of investigation.

1. Review of published and unpublished literature, maps, and records concerning geologic units, faults, ground-water barriers, and other factors.

2. Stereoscopic interpretation of aerial photographs and other remotely sensed images to detect fault-related topography (geomorphic features), vegetation and soil contrasts, and other lineaments of possible fault origin. The area interpreted usually should extend beyond the site boundaries.

3. Surface observations, including mapping of geologic and soil units, geologic structures, geomorphic features and surfaces, springs, deformation of engineered structures due to fault creep, both on and beyond the site.

4. Subsurface investigations.

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a. Trenching and other excavations to permit detailed and direct observation of continuously exposed geologic units, soils, and structures; must be of adequate depth and be carefully logged (see Taylor and Cluff, 1973; Hatheway and Leighton, 1979; McCalpin, 1996b).

b. Borings and test pits to permit collection of data on geologic units and ground water at specific locations. Data points must be sufficient in number and spaced adequately to permit valid correlations and interpretations.

c. Cone penetrometer testing (CPT) (Grant and others, 1997; Edelman and others, 1996). CPT must be done in conjunction with continuously logged borings to correlate CPT results with on-site materials. The number of borings and spacing of CPT soundings should be sufficient to adequately image site stratigraphy. The existence and location of a fault based on CPT data are interpretative.

5. Geophysical investigations. These are indirect methods that require a knowledge of specific geologic conditions for reliable interpretations. They should seldom, if ever, be employed alone without knowledge of the geology (Chase and Chapman, 1976). Geophysical methods alone never prove the absence of a fault nor do they identify the recency of activity. The types of equipment and techniques used should be described and supporting data presented (California Board of Registration for Geologists and Geophysicists, 1993).

   a. High resolution seismic reflection (Stephenson and others, 1995; McCalpin, 1996b).

   b. Ground penetrating radar (Cai and others, 1996).

   c. Other methods include: seismic refraction, magnetic profiling, electrical resistivity, and gravity (McCalpin, 1996b).

6. Age-dating techniques are essential for determining the ages of geologic units, soils, and surfaces that bracket the time(s) of faulting (Pierce, 1986; Birkeland and others, 1991; Rutter and Catto, 1995; McCalpin, 1996a).

   a. Radiometric dating (especially ^{14}C).

   b. Soil-profile development.

   c. Rock and mineral weathering.

   d. Landform development.

   e. Stratigraphic correlation of rocks/minerals/fossils.

   f. Other methods -- artifacts, historical records, tephrochronology, fault scarp modeling, thermoluminescence, lichenometery, paleomagnetism, dendrochronology, etc.

7. Other methods should be included when special conditions permit or requirements for critical structures demand a more intensive investigation.

   a. Aerial reconnaissance overflights.

   b. Geodetic and strain measurements.

   c. Microseismicity monitoring.

E. Conclusions.

1. Location and existence (or absence) of hazardous faults on or adjacent to the site; ages of past rupture events.

2. Type of faults and nature of anticipated offset, including sense and magnitude of displacement, if possible.

3. Distribution of primary and secondary faulting (fault zone width) and fault-related deformation.

4. Probability of or relative potential for future surface displacement. The likelihood of future ground rupture seldom can be stated mathematically, but may be stated in semiquantitative terms such as low, moderate, or high, or in terms of slip rates determined for specific fault segments.

5. Degree of confidence in and limitations of data and conclusions.

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F. Recommendations.

1. Setback distances of proposed structures from hazardous faults. The setback distance generally will depend on the quality of data and type and complexity of fault(s) encountered at the site. In order to establish an appropriate setback distance from a fault located by indirect or interpretative methods (e.g. borings or cone penetrometer testing), the area between data points also should be considered underlain by a fault unless additional data are used to more precisely locate the fault. State and local regulations may dictate minimum distances (e.g., Sec. 3603 of California Code of Regulations, Appendix B).

2. Additional measures (e.g., strengthened foundations, engineering design, flexible utility connections) to accommodate warping and distributive deformation associated with faulting (Lazarte and others, 1994).

3. Risk evaluation relative to the proposed development.

4. Limitations of the investigation; need for additional studies.

II. References.

A. Literature and records cited or reviewed; citations should be complete.

B. Aerial photographs or images interpreted -- list type, date, scale, source, and index numbers.

C. Other sources of information, including well records, personal communications, and other data sources.

III. Illustrations -- these are essential to the understanding of the report and to reduce the length of text.

A. Location map -- identify site locality, significant faults, geographic features, regional geology, seismic epicenters, and other pertinent data; 1:24,000 scale is recommended. If the site investigation is done in compliance with the Alquist-Priolo Act, show site location on the appropriate Official Map of Earthquake Fault Zones.

B. Site development map -- show site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, borings, geophysical traverses, locations of faults, and other data; recommended scale is 1:2,400 (1 inch equals 200 feet), or larger.

C. Geologic map -- show distribution of geologic units (if more than one), faults and other structures, geomorphic features, aerial photographic lineaments, and springs; on topographic map 1:24,000 scale or larger; can be combined with III(A) or III(B).

D. Geologic cross-sections, if needed, to provide 3-dimensional picture.

E. Logs of exploratory trenches and borings -- show details of observed features and conditions; should not be generalized or diagrammatic. Trench logs should show topographic profile and geologic structure at a 1:1 horizontal to vertical scale; scale should be 1:60 (1 inch = 5 feet) or larger.

F. Geophysical data and geologic interpretations.

IV. Appendix: Supporting data not included above (e.g., water well data, photographs, aerial photographs).

V. Authentication: Investigating geologist's signature and registration number with expiration date.

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Appendix D

GENERAL GUIDELINES FOR REVIEWING GEOLOGIC REPORTS

(These general guidelines are published as DMG Note 41 (1997). Similar guidelines were adopted by the State Mining and Geology Board for advisory purposes in 1996).

The purpose of this article is to provide general guidance for those geologists who review geologic reports of consultants on behalf of agencies having approval authority over specific developments. These general guidelines are modified from an article titled, "Geologic Review Process" by Hart and Williams (1978).

The geologic review is a critical part of the evaluation process of a proposed development. It is the responsibility of the reviewer to assure that each geologic investigation, and the resulting report, adequately addresses the geologic conditions that exist at a given site. In addition to geologic reports for tentative tracts and site development, a reviewer evaluates Environmental Impact Reports, Seismic Safety and Public Safety Elements of General Plans, Reclamation Plans, as-graded geologic reports, and final, as-built geologic maps and reports. In a sense, the geologic reviewer enforces existing laws, agency policies, and regulations to assure that significant geologic factors (hazards, mineral and water resources, geologic processes) are properly considered, and potential problems are mitigated prior to project development. Generally, the reviewer acts at the discretion or request of, and on behalf of a governing agency -- city, county, regional, state, federal -- not only to protect the government's interest but also to protect the interest of the community at large. Examples of the review process in a state agency are described by Stewart and others (1976). Review at the local level has been discussed by Leighton (1975), Berkland (1992), Larson (1992), and others. Grading codes, inspections, and the review process are discussed in detail by Scullin (1983). Nelson and Christenson (1992) specifically discuss review guidelines for reports on surface faulting.

THE REVIEWER

Qualifications

In order to make appropriate evaluations of geologic reports, the reviewer should be an experienced geologist familiar with the investigative methods employed and the techniques available to the profession. Even so, the reviewer must know his or her limitations, and at times ask for the opinions of others more qualified in specialty fields (e.g., geophysics, mineral exploitation and economics, ground water, foundation and seismic engineering, seismology). In California, the reviewer must be licensed by the State Board of Registration for Geologists and Geophysicists in order to practice (Wolfe, 1975). The Board also certifies engineering geologists and hydrogeologists, and licenses geophysicists. Local and regional agencies may have additional requirements.

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The reviewer must have the courage of his or her convictions and should not approve reports if an inadequate investigation has been conducted. Like any review process, there is a certain "give-and-take" involved between the reviewer and investigator. If there is clear evidence of incompetence or misrepresentation in a report, this fact should be reported to the reviewing agency or licensing board. California Civil Code Section 47 provides an immunity for statements made "in the initiation or course of any other proceedings authorized by law." Courts have interpreted this section as providing immunity to letters of complaint written to provide a public agency or board, including licensing boards, with information that the public board or agency may want to investigate (see *King v. Borges*, 28 Cal. App. 3d 27 [1972]; and *Brody v. Montalbano*, 87 Cal. App. 3d 725 [1978]). Clearly, the reviewer needs to have the support of his or her agency in order to carry out these duties.

The reviewer should bear in mind that some geologic investigators are not accomplished writers, and almost all are working with restricted budgets. Also, the reviewer may by limited by their agency's policies, procedures, and fee structures. Thus, while a reviewer should demand that certain standards be met, he or she should avoid running rough-shod over the investigator. The mark of a good reviewer is the ability to sort out the important from the insignificant and to make constructive comments and recommendations.

A reviewer may be employed full time by the reviewing agency or part-time as a consultant. Also, one reviewing agency (such as a city) may contract with another agency (such as a county) to perform geologic reviews. The best reviews generally are performed by experienced reviewers. Thus, the use of multiple, part-time reviewers by a given agency tends to prevent development of consistently high-quality and efficient reviews. One of the reasons for this is that different reviewers have different standards, which results in inconsistent treatment of development projects. The primary purpose of the review procedure should always be kept in mind -- namely, to assure the adequacy of geologic investigations.

Other Review Functions

Aside from his or her duties as a reviewer, the reviewing geologist also must interpret the geologic data reported to other agency personnel who regulate development (e.g., planners, engineers, inspectors). Also, the reviewing geologist sometimes is called upon to make investigations for his or her own agency. This is common where a city or county employs only one geologist. In fact, some reviewers routinely divide their activities between reviewing the reports of others and performing one or several other tasks for the employing agency (such as advising other agency staff and boards on geologic matters; making public presentations) (see Leighton, 1975).

Conflict of Interest

In cases where a reviewing geologist also must perform geologic investigations, he or she should never be placed in the position of reviewing his or her own report, for that is no review at all. A different type of conflict commonly exists in a jurisdiction where the geologic review is performed by a consulting geologist who also is practicing commercially (performing geologic investigations) within the same jurisdictional area. Such situations should be avoided, if at all possible.

GEOLOGIC REVIEW

The Report

The critical item in evaluating specific site investigations for adequacy is the resulting geologic report. A report that is incomplete or poorly written cannot be evaluated and should not be approved. As an expediency, some reviewers do accept inadequate or incomplete reports because of their personal knowledge of the site. However, unless good reasons can be provided in writing, it is recommended that a report not be accepted until it presents the pertinent facts correctly and completely.

The conclusions presented in the report regarding the geologic hazards or problems must be separate from and supported by the investigative data. An indication regarding the level of confidence in the conclusions should be provided. Recommendations based on the conclusions should be made to mitigate those geology-related problems which would have an impact on the proposed development. Recommendations also should be made concerning the need for additional geologic investigations.

Report Guidelines and Standards

An investigating geologist may save a great deal of time (and the client's money), and avoid misunderstandings, if he or she contacts the reviewing geologist at the initiation of the investigation. The reviewer should not only be familiar with the local geology and sources of information, he or she also should be able to provide specific guidelines for investigative reports and procedures to be followed. Guidelines and check-lists for geologic or geotechnical reports have been prepared by a number of reviewing agencies and are available to assist the reviewer in his or her evaluation of reports (e.g., DMG Notes 42, 44, 46, 48, and 49; California Department of Conservation, Division of

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Mines and Geology, 1997). A reviewer also may wish to prepare his or her own guidelines or check-lists for specific types of reviews.

If a reviewer has questions about an investigation, these questions must be communicated in writing to the investigator for response. After the reviewer is satisfied that the investigation and resulting conclusions are adequate, this should be clearly indicated in writing to the reviewing agency so that the proposed development application may be processed promptly. The last and one of the more important responsibilities of the reviewer should be implementation of requirements assuring report recommendations are incorporated and appropriate consultant inspections are made.

The biggest problem the reviewer faces is the identification of standards. These questions must be asked: "Are the methods of investigation appropriate for a given site?" and "Was the investigation conducted according to existing standards of practice?" Answers to these questions lie in the report being reviewed. For example, a reported landslide should be portrayed on a geologic map of the site. The conclusion that a hazard is absent, where previously reported or suspected, should be documented by stating which investigative steps were taken and precisely what was seen. The reviewer must evaluate each investigative step according to existing standards. It should be recognized that existing standards of practice generally set minimum requirements (Keaton, 1993). Often the reviewer is forced to clarify the standards, or even introduce new ones, for a specific purpose.

Depth (Intensity) of Review

The depth of the review is determined primarily by the need to assure that an investigation and resulting conclusions are adequate, but too often the depth of review is controlled by the time and funds available. A report on a subdivision (e.g., for an EIR or preliminary report) may be simply evaluated against a check-list to make certain it is complete and well-documented. Additionally, the reviewer may wish to check cited references or other sources of data, such as aerial photographs and unpublished records.

Reviewers also may inspect the development site and examine excavations and borehole samples. Ideally, a field visit may not be necessary if the report is complete and well-documented. However, field inspections are of value, and generally are necessary to determine if field data are reported accurately and completely. Also, if the reviewer is not familiar with the general site conditions, a brief field visit provides perspective and a visual check on the reported conditions. Whether or not on-site reviews are made, it is important to note that the geologic review process is not intended to replace routine grading inspections that may be required by the reviewing agency to assure performance according to an approved development plan.

Review Records

For each report and development project reviewed, a clear, concise, and logical written record should be developed. This review record may be as detailed as is necessary, depending upon the complexity of the project, the geology, and the quality and completeness of the reports submitted. At a minimum, the record should:

1. Identify the project, permits, applicant, consultants, reports, and plans reviewed;

2. Include a clear statement of the requirements to be met by the parties involved, data required, and the plan, phase, project, or report being considered or denied;

3. Contain summaries of the reviewer's field observations, associated literature and aerial photographic review, and oral communications with the applicant and the consultant;

4. Contain copies of any pertinent written correspondence; and

5. The reviewer's name and license number(s), with expiration dates.

The report, plans, and review record should be kept in perpetuity to document that compliance with local requirements was achieved and for reference during future development, remodeling, or rebuilding. Such records also can be a valuable resource for land-use planning and real-estate disclosure.

Appeals

In cases where the reviewer is not able to approve a geologic report, or can accept it only on a conditional basis, the developer may wish to appeal the review decision or recommendations. However, every effort should be made to resolve problems informally prior to making a formal appeal. An appeal should be handled through existing local procedures (such as a hearing by a County Board of Supervisors or a City Council) or by a specially appointed Technical Appeals and Review Panel comprised of geoscientists, engineers, and other appropriate professionals. Adequate notice should be given to allow time for both sides to prepare their cases. After an

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appropriate hearing, the appeals decision should be in writing as part of the permanent record.

Another way to remedy conflicts between the investigator and the reviewer is by means of a third party review. Such a review can take different paths ranging from the review of existing reports to in-depth field investigations. Third party reviews are usually done by consultants not normally associated with the reviewing/permitting agency.

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DMG NOTE 46 - Guidelines for geologic/seismic considerations in environmental impact reports, 1986.

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Appendix E

PRODUCTS OF THE FAULT EVALUATION AND ZONING PROGRAM

Since the passage of the AP Act, staff of the Fault Evaluation and Zoning Program have published numerous reports on the Act and the surface fault rupture hazard. These, as well as unpublished files of geologic information, are listed below. A notation next to each entry is the publication number: CD – California Geological Survey compact disc, CG -- California Geology, N – DMG/CGS Note, SP -- Special Publication, SR -- Special Report, o.p. -- report is out of print, * -- an outside publication not available from CGS. Numbers alone (e.g., 89-16) are Open-File Report numbers. The publications are listed chronologically by groups below.

AVAILABILITY

Reports listed here are available for reference at offices of the California Geological Survey in Sacramento, Menlo Park, and Los Angeles. Some reports are also available for reference at county and university libraries. Copies of available CGS reports may be purchased by mail order or over-the-counter from any office (see exceptions below):

OFFICES OF THE CALIFORNIA GEOLOGICAL SURVEY

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IMPLEMENTATION OF THE ALQUIST-PRIOLO ACT

Official Maps of Earthquake Fault Zones, by California Geological Survey, 1974-2007. As of August 2007, 547 new and revised Official APEFZ maps have been issued. Special Publication 42 provides an index to these maps and describes how they can be purchased.

SP 42 **Fault-rupture hazard zones in California,** by W.A. Bryant and E.W. Hart, 2007, 42 p. (pdf version only). Includes an index map which identifies all 7.5-minute topographic maps in which AP Earthquake Fault Zones are located. (Revised periodically).

CG **Zoning for surface fault hazards in California -- The New Special Studies Zones maps,** by E.W. Hart, 1974: v. 27, n. 10, p. 227-230.

SP 47 o.p. **Active fault mapping and evaluation program – 10-year program to implement Alquist-Priolo Special Studies Zones Act, 1976.**

CG **The review process and the adequacy of geologic reports,** by R.M. Stewart, E.W. Hart, and P.Y. Amimoto, 1976: Bulletin of the International Association of Engineering Geology, n. 14, p. 83-88. (Reprinted in California Geology, v. 30, n. 10, p. 224-229).

CG **Geologic review process,** by E.W. Hart and J.W. Williams, 1978: v. 31, n. 10, p. 235-236.

***** **Zoning for the hazard of surface fault rupture in California,** by E.W. Hart, 1978, *in* Proceedings of the Second International Conference on Microzonation, San Francisco, November 26-December 1, 1978: NSF Special Publication, p. 635-645.

CG **Fault Evaluation and Zoning Program,** by E.W. Hart, 1980: v. 33, n. 7, p. 147-152.

***** **Zoning for surface-faulting in California,** by E.W. Hart, 1986, *in* Proceedings of Conference XXXII -- Workshop on future directions in evaluating earthquake hazards in southern California, November 12-13, 1985: U.S. Geological Survey Open-File Report 86-401, p. 74-83.

90-18 **A study of the effectiveness of the Alquist-Priolo Program,** by R. Reitherman and D.J. Leeds, 1990.

N 41 **General guidelines for reviewing geologic reports,** by E.W. Hart and W.A. Bryant, 1997. (Also Appendix D in SP 42).

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N 49 **Guidelines for evaluating the hazard of surface fault rupture,** by E.W. Hart and W.A. Bryant 1997. (Also Appendix C in SP 42).

CD 2000-03 - Digital images of official maps of Alquist-Priolo Earthquake Fault Zones of California, Southern Region, by DMG staff, 2000.

CD 2000-04 - Digital images of official maps of Alquist-Priolo Earthquake Fault Zones of California, Central Coastal Region, by DMG staff, 2000.

CD 2000-05 - Digital images of official maps of Alquist-Priolo Earthquake Fault Zones of California, Northern and Eastern Region, by DMG staff, 2000.

CD 2001-04 - GIS files of official Alquist-Priolo Earthquake Fault Zones, Central Coastal Region, developed by W.A. Bryant, R. Martin, P.Wong, D. Maldonado, J. Wampole, and D. Dixon, 2001.

CD 2001-05 - GIS files of official Alquist-Priolo Earthquake Fault Zones, Southern Region, developed by W.A. Bryant, R. Martin, P.Wong, D. Maldonado, J. Wampole, and D. Dixon, 2001.

CD 2001-06 - GIS files of official Alquist-Priolo Earthquake Fault Zones, Northern and Eastern Region, developed by W.A. Bryant, R. Martin, P.Wong, D. Maldonado, J. Wampole, and D. Dixon, 2001.

POST-EARTHQUAKE INVESTIGATIONS

CG **Ground rupture associated with faulting -- Oroville earthquake, August 1975,** by E.W. Hart, 1975: v. 28, p. 274-276.

SR 124 **Ground rupture along the Cleveland Hill fault,** by E.W. Hart and J.S. Rapp, 1975, *in* Sherburne, R.W. and Hauge, C.J., editors, Oroville, California, Earthquake 1 August 1975, p. 61-72.

***** **Geologic setting, historical seismicity and surface effects of the Imperial Valley earthquake, October 15, 1979, Imperial County, California,** by E. Leivas, E.W. Hart, R.D. McJunkin, and C.R. Real, 1980, *in* Imperial County, California, Earthquake October 15, 1979: EERI Reconnaissance Report, February 1980, p. 5-19.

81-5 **Preliminary map of October 1979 fault rupture, Imperial and Brawley faults, Imperial County, California,** by E.W. Hart, 1981.

80-12 o.p. **Preliminary map of surface rupture associated with the Mammoth Lakes earthquakes, May 25 and 27, 1980,** by W.A. Bryant, G.C. Taylor, E.W. Hart, and J.E. Kahle, 1980.

SR 150 **Surface rupture associated with the Mammoth Lakes earthquakes of 25 and 27 May, 1980,** by G.C. Taylor and W.A. Bryant, 1980, *in* Sherburne, R.W., editor, Mammoth Lakes, California earthquakes of May 1980, p. 49-67.

SR 150 **Rockfalls generated by the Mammoth Lakes earthquakes of May 25 and 27, 1980,** by W.A. Bryant, 1980, *in* Sherburne, R.W., editor, Mammoth Lakes, California earthquakes of May 1980, p. 69-73.

SR 150 **Planned zoning of active faults associated with the Mammoth Lakes earthquakes of May 1980,** by E.W. Hart, 1980, *in* Sherburne, R.W., editor, Mammoth Lakes, California earthquakes of May 1980, p. 137-141.

CG **Ground rupture, Coalinga earthquake of 10 June 1983,** by R.D. McJunkin and E.W. Hart, 1983: v. 36, n. 8, p. 182-184.

SP 66 **Surface faulting northwest of Coalinga, California, June and July 1983,** by E.W. Hart and R.D. McJunkin, 1983, *in* Bennett, J.H. and Sherburne, R.W., editors, The 1983 Coalinga, California earthquakes, p. 201-219.

SP 68 **Evidence for surface faulting associated with the Morgan Hill earthquake of April 24, 1984,** by E.W. Hart, 1984, *in* Bennett, J.H. and Sherburne, R.W., editors, The 1984 Morgan Hill, California earthquake, p. 161-173.

CG **Fault rupture associated with the July 21, 1986 Chalfant Valley Earthquake, Mono and Inyo counties, California,** by J.E. Kahle, W.A. Bryant, and E.W. Hart, 1986: v. 39, n. 11, p. 243-245.

CG **Magnitude 5.9 North Palm Springs earthquake, July 8, 1986, Riverside County, California: Lifeline damage,** by G. Borchardt and M.W. Manson, 1986: v. 39, n. 11, p. 248-252.

CG **Preliminary report: Surface rupture, Superstition Hills earthquakes of November 23 and 24, 1987,** by J.E. Kahle, C.J. Wills, E.W. Hart, J.A. Treiman, R.B. Greenwood, and R.S. Kaumeyer, 1988: v. 41, n. 4, p. 75-84.

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CG **Liquefaction at Soda Lake: Effects of the Chittenden earthquake swarm of April 18, 1990, Santa Cruz County, California,** by C.J. Wills and M.W. Manson, 1990: v. 43, n. 10, p. 225-232.

***** **Surface fissures and the mapping of CDMG Special Studies Zones,** by E.W. Hart, 1990, *in* Reid, G., editor, What we have learned from the October 17, 1989 7.1M Loma Prieta earthquake: 16th Annual Saber Society Symposium Proceedings Volume, p. 87-99.

SP 104 **The search for fault rupture and the significance of ridge-top fissures, Santa Cruz Mountains, California,** by E.W. Hart, W.A. Bryant, C.J. Wills, and J.A. Treiman, 1990, *in* McNutt, S.R. and Sydnor, R.H., editors, The Loma Prieta Earthquake of October 17, 1989, p. 83-94.

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FERs **Fault Evaluation Reports,** by Fault Evaluation and Zoning Project Staff, 1976-2007, copies of the FERs are available for reference in the Bay Area and Southern California regional offices of CGS. An index to FERs and copies of FERs through 1989 on microfiche are available as Open-File Reports 90-9 to 90-14 (see below). FERs completed through 2000 have been digitally archived and are available for purchase (see below).

81-6 **Evidence of Holocene movement of the San Andreas fault zone, northern San Mateo County, California,** by T.C. Smith, 1981.

81-7 **Sargent, San Andreas, and Calaveras fault zones: Evidence for recency in the Watsonville East, Chittenden and San Felipe quadrangles, California,** by W.A. Bryant, D.P. Smith, and E.W. Hart, 1981.

81-8 **Recently active strands of the Greenville fault, Alameda, Contra Costa and Santa Clara counties, California,** by E.W. Hart, 1981.

81-9 **Evidence for recent faulting, Calaveras and Pleasanton faults, Diablo and Dublin quadrangles, California,** by E.W. Hart, 1981.

SP 62 **Southern Hayward fault zone, Alameda and Santa Clara counties, California,** by W.A. Bryant, 1982, *in* Proceedings -- Conference on earthquake hazards of the eastern San Francisco Bay area, p. 35-44.

***** **Self-guided field trip No. 4 -- Fault creep along the Hayward fault** in the Richmond-San Pablo area, by T.C. Smith, 1982, *in* Conference on earthquake hazards of the [eastern] San Francisco Bay area, Field Trip Guidebook: California State University, Hayward.

84-54 **Evidence of recent faulting along the Owens Valley, Round Valley, and White Mountains fault zones, Inyo and Mono counties, California,** by W.A. Bryant, 1984.

84-55 **Evidence of recent faulting along the Mono Lake fault zone, Mono County, California,** by W.A. Bryant, 1984.

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84-56 **Evidence of recent faulting along the Antelope Valley fault zone, Mono County, California,** by W.A. Bryant, 1984.

88-14 **Recently active traces of the Newport-Inglewood fault zone, Los Angeles and Orange counties, California,** by W.A. Bryant, 1988.

CG **A neotectonic tour of the Death Valley fault zone,** by C.J. Wills, 1989: v. 42, n. 9, p. 195-200.

CG **Deep Springs fault, Inyo County, California, An example of the use of relative-dating techniques,** by W.A. Bryant, 1989: v. 42, n. 11, p. 243-255.

***** **The Rose Canyon fault zone; a historical review,** by J.A. Treiman, 1989, *in* Seismic risk in the San Diego region, a workshop on the Rose Canyon fault system: Proceedings volume of a workshop sponsored by the Southern California Earthquake Preparedness Project, June 29-30, 1989.

90-9 **Index to fault evaluation reports prepared 1976-1989 under the Alquist-Priolo Special Studies Zones Act,** by C.J. Wills, P. Wong, and E.W. Hart, 1990.

90-10 **Microfiche copies of Fault Evaluation Reports for northern California,** by Division of Mines and Geology staff.

90-11 **Microfiche copies of Fault Evaluation Reports for the southern Coast Ranges,** by Division of Mines and Geology staff.

90-12 **Microfiche copies of Fault Evaluation Reports for the Transverse Ranges,** by Division of Mines and Geology staff.

90-13 **Microfiche copies of Fault Evaluation Reports for the Peninsular Ranges,** by Division of Mines and Geology staff.

90-14 **Microfiche copies of Fault Evaluation Reports for eastern California,** by Division of Mines and Geology staff.

CG **Active faults north of Lassen Volcanic National Park,** by C.J. Wills, 1991, v. 44, p. 51-58.

***** **The Green Valley Fault,** by W.A. Bryant, *in* Field trip guide to the geology of western Solano County: Northern California Geological Society, 1991, p. 1-10.

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79-10 **Summary report -- Fault evaluation program, 1978 area (Peninsular Ranges-Salton Trough region),** by E.W. Hart, D.P. Smith, and R.B. Saul, 1979.

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81-3 **Summary report -- Fault evaluation program, 1979-1980 area (southern San Francisco Bay region),** by E.W. Hart, W.A. Bryant, and T.C. Smith, 1981.

SP 62 **California's fault evaluation program -- southern San Francisco Bay region,** by E.W. Hart, T.C. Smith, and W.A. Bryant, 1982, *in* Proceedings -- Conference on earthquake hazards in the eastern San Francisco Bay area, p. 395-404.

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88-1 **Summary report -- Fault evaluation program, 1986-1987, Mojave Desert region and other areas,** by E.W. Hart, W.A. Bryant, J.E. Kahle, M.W. Manson, and E.J. Bortugno, 1987.

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C File, reports by consulting geologists that predate the Earthquake Fault Zones or are outside the Zones at the time of the study. Over 600 reports on file. Reports are available for reference at the Bay Area and Southern California regional offices of CGS, and the Geologic Information and Publications Office in Sacramento.

77-6 o.p. **Index to geologic reports for sites within Special Studies Zones,** by W.Y.C. Lo and J.G. Moreno, 1977 (superseded by OFR 84-31).

84-31 **Index to geologic reports for sites within Special Studies Zones,** by P. Wong, 1984. (Index map to the AP File reports).

89-5 **Index to geologic reports for development sites within Special Studies Zones in California, July 1, 1984 to December 31, 1988,** by P. Wong, 1989. (Update for OFR 84-31).

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Appendix F

WAIVER PROCEDURE FOR THE ALQUIST-PRIOLO ACT

Section 2623 of the Act states, "If the city or county [having jurisdiction over the lands] finds that no undue [fault] hazard...exists, the geologic report on such hazard may be waived, with approval of the State Geologist." The location of the proposed development or structure may be approved following such waiver.

The State Geologist will review waiver requests only after receiving the Waiver Form completed by the city or county geologist and the property owner, and accompanied by supporting statements and data in writing that would justify approval of the waiver request.

WAIVER FORM FOR THE ALQUIST-PRIOLO ACT

(Pursuant to Chapter 7.5, Div. 2, California Public Resources Code)

1. City or County Geologist, State Registered

I, _____ , Registered Geologist,
(*Print Name*)

representing _____ , recommend that the
(*City/County*)

property: _____
(*Description, size, proposed development*)

_____
(*Location of Site - also show location on "Earthquake Fault Zones" maps*)

_____ , be granted a waiver from geologic studies
(*Permit Number*)

relating to active faults*. Supporting statements that no undue hazard relative to faults exists at the site are attached to this form in writing on City or County letterhead with the City or County Geologist's signature and registration number, and that the Geologist representing the City or County is in agreement with the data:

Attached Data Includes:	YES	NO		YES	NO
1. Geologic Fault Map(s)	_____	_____	4. Aerial Photo(s)	_____	_____
2. Geologic Report(s)	_____	_____	5. Reference to Report(s)	_____	_____
3. Subsurface Geologic Data	_____	_____	6. Other information	_____	_____

_____
(*City or County Registered Geologist's Signature*) (*R.G. No.*) (*Date*)

2. Owner of the Property

I, _____ , acknowledge that the property
is within an Earthquake Fault Zone associated with the _____ fault.

_____
(*Owner's Signature*) (*Date*)

3. State Geologist

Date Received by CGS _____
(*Date*)

Reviewer _____
(*Registered Geologist's Signature*) (*R.G. No.*) (Date)

Recommendation of Waiver:
Approved: ☐ Not Approved: ☐ (Explanation attached)

State Approval of Review: _____
(*State Geologist*) (*Date*)

*Defined in Policies and Criteria of the State Mining and Geology Board (See Appendix B)

Mail form to: **State Geologist**
California Geological Survey
801 K Street, MS 12-30
Sacramento, California 95814-3531

CGS Form/Alquist-Priolo

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Figure 1.—Map showing regional subdivisions of the conterminous United States used in discussion of distribution of swelling clays.

COLOR-CODE EXPLANATION FOR SWELLING-CLAY MAP

- Unit contains abundant clay having high swelling potential
- Part of unit, generally less than 50 percent, consists of clay having high swelling potential
- Unit contains abundant clay having slight to moderate swelling potential
- Part of unit, generally less than 50 percent, consists of clay having slight to moderate swelling potential
- Unit contains little or no swelling clay
- Data insufficient to indicate clay content of unit and (or) swelling potential of clay. Shown in westernmost States only

INTRODUCTION

This map identifies geologic units that contain swelling clays and, within broad limits, categorizes them according to the swelling-potential hazard they pose. This information is useful in identifying areas in which detailed investigation might be desirable to determine more precisely the distribution and swelling potential of clay, both for the purposes of land–use planning and for general assessment of environmental problems on a national scale.

Swelling clays occur in all 48 States of the conterminous United States. Where they are at or near the surface and within the zone of weathering, they constitute a potential source of damage to buildings, roads, and other structures. Soil and regolith are lightweight types of construction such as concrete slabs for highways, canal linings, spillways, and houses commonly crack and buckle and fail if not adequately supported by these foundations. Slope materials containing swelling clays are especially susceptible to landsliding. Annual loss due to damage resulting from swelling clays within the United States is estimated to be at least 2.3 billion dollars, and during this century, these losses have been twice as great as those from floods, earthquakes, hurricanes, and tornadoes (Jones and Holtz, 1973).

A swelling clay, according to the American Geological Institute Glossary of Geology (Bates and Jackson, 1980, p. 631), is a "clay that is capable of absorbing large quantities of water, causing it to increase in volume."

Dry clays that are capable of absorbing water, if unconfined, will increase in volume in an amount proportional to the amount of water absorbed. However, the amount of water absorbed and the degree of swelling vary for particular types of clay are dependent on many variable and interrelated factors that have not been, and probably cannot be, formulated in such terms as to be applicable to all clays in combinations that exist in nature.

For purposes of this map, the term swelling clays is applied to those clays that, due to swelling caused by absorption of moisture, are known to cause damage to foundations and structures. It also includes those clays that, on the basis of their mineralogic composition and physical properties, are believed to have the potential to do so. These same clays also may be a source of engineering problems due to shrinkage resulting from a loss of moisture.

MINERALOGY AND PROPERTIES OF SWELLING CLAYS

The term "clay" is used for a natural, earthy, fine-grained material that develops plasticity when mixed with a limited amount of water. The term also applies to definite group of hydrous aluminum silicate minerals and to grains or particles that are either <2μm or <4μm in diameter, depending upon which definition or classification is used (see Truesdell and Varnes, 1950, for comparison of grain-size definitions of sedimentary materials). The term also applies to those rocks classified fine fly grouse: smectite (montmorillonite, beidellite, nontronite, and others); illite (illite and glauconite); kaolinite (kaolinite, halloysite, and dickite); chlorite (chlorite and others); and sepolite (sepolite and palygorskite). Many of these clay minerals do occur as the dominant mineral in some areas and almost all of them occur as minor constituents of other clays. Most clay deposits, however, are mixtures of two or more different clay minerals, which are referred to as mixed-layer clays. The composition of the term also applies to clay mineral montmorillonite or beidellite, interlayered with chlorite or with a mica.

The inherent swelling potential of aggregates of clay minerals is closely related to the total external and internal surface areas of clay-mineral particles. Clay minerals are capable of adsorbing water on their outer surfaces, and water so adsorbed will cause a small amount of swelling; water also enlarges the spacing of the layers in layer clay minerals, however, such as montmorillonite and beidellite of the smectite group, are capable of adsorbing large amounts of water between the individual silicate layers of the structural lattice, which results in a high swelling potential. Vermiculite, allophane, montmorillonite, and degraded mica (illite) and chlorite, though less common, are also capable of adsorbing appreciable amounts of water. These expandable clay minerals consist of atoms arranged in lattice form in sheets with sheets or layers of the lattice are bound together by atomic physicochemical forces. The strengths of these forces vary with the types of clay minerals and with the water content and the chemical composition of the adjacent interlayer solutions.

The swelling potential of clay is dependent upon the amount and kind of clay minerals present, their exchangeable ions, the electrolyte content of the aqueous solution, particle-size distribution, shape and fabric of the mineral content, superimposed load, and probably other factors.

Clay units composed almost entirely of Na-, Ca-, and Mg-montmorillonite are commonly referred to as bentonites. They have a number of commercial uses, many of which are related to their absorptive and swelling properties.

Volume changes of 1400 to 2000 percent are reported from laboratory tests in which samples of dry Na-montmorillonite were immersed in water, and changes of 45 to 145 percent have been reported for Ca-montmorillonite (Mielenz and Schieltz, 1960, p. 232). The inherent swelling capacities of vermiculite, attapulgite, illite, and degraded chlorite have not been fully investigated. Available evidence suggests that they have low to moderate swelling capacities.

The amount of volume change generated by a swelling clay under laboratory conditions is usually considerably greater than that generated by the same clay in the field under natural conditions. This is possibly due to changes in diagenetic and environmental factors as a consequence of collecting and preparing specimens for testing (Ladd, 1960; Parcher and Liu, 1965; Woodward, Clyde and Associates, 1967, p. 75).

The results of specific field measurements of volume changes in swelling clays generally are lacking, because of difficulties in obtaining and recording relevant data. The most obvious volume changes are those that affect the land surface; in many cases these changes are manifest as a result of damage to structures. Uplift of land surface due to increase in volume of swelling clay generally amounts to no more than a few inches; however, uplift of more than a foot has been reported (Mielenz and Okeson, 1946, p. 271). Horizontal displacement also results from swelling; however, information on the amounts of displacement is meager. Laboratory tests conducted on undisturbed specimens of swelling clay indicated a vertical to horizontal displacement ratio varying between 0.3 and 0.7 (Parcher and Liu, 1965).

Dry swelling clays absorb much larger quantities of water before becoming plastic than do dry, non-swelling clays. They also remain plastic over a wider range of moisture content. This range of moisture content is referred to by engineers as the plasticity index (PI) and is expressed as the numerical difference between the plastic limit (the percent moisture content at which a clay passes from the solid to the plastic state) and the liquid limit (the percent moisture content at which clay passes from the plastic to the liquid state). The PI bears a direct relation to the amount and type of clay minerals present and to the orientation and size of clay particles. Other factors remaining constant, the PI increases with (1) increase in amount of expandable clay minerals, (2) decrease in degree of parallel orientation of the plate clay minerals, and (3) decrease in size of particles. Swelling clays commonly have a PI of an artificially saturated Na-kaolinite.

Plasticity index ranges from near zero to as much as 1 for artificially saturated sodium kaolinites to more than 600 for some Na-montmorillonites (Grim, 1962, p. 213). The PI of most expandable clay minerals is usually greater than 50, whereas for nonexpandable types it is generally less than 50. Mixtures of expandable and nonexpandable clay minerals generally indicate small particle size and lack of common orientation of platy clay-mineral particles.

The PI is generally a good indicator of swelling potential. Seed and others (1962, p. 87), who found the PI to be the most reliable indicator of swelling potential, also noted ". . . that this parameter alone can provide an assessment of swelling that is probably accurate to within 50 percent." Seed, Woodward and Kennedy (1967, p. 11) found the PI to be "the most reliable working tool" in identifying potentially troublesome clays in the laboratory. The loss of the tests provide indications of the general magnitude of problems to be anticipated in the field: however, where dry densities and high moisture conditions that influence swell, the test indications may be drastically misleading (Hamilton, 1965).

Information is meager on swelling pressures generated under actual field conditions because of the complexity involved. The manner the clay may be tied confined and other factors that affect swelling are uncontrolled. Lateral and vertical pressures of as much as 0.84 and 2.3 tons/ft² (81 and 220 kg/cm²) are reported from field measurements for a bentonitic clay in central Texas, and a pressure of 5 tons/ft² (3.5 kg/cm²) is reported for a bentonitic clay in Oregon (Mielenz and King, 1955).

The general physical appearance of swelling clays in outcrop varies widely, and no fixed group of criteria can be established for identification that is universally applicable. Clays that contain abundant montmorillonite, such as bentonites of the Cretaceous Mowry and Belle Fourche Shales of Wyoming, and the Pierre Shale of the Great Plains, commonly contain gypsum as fibers and veins. Paleocene Midway Group of Mississippi and the Eocene Jackson and Claiborne Groups of Texas, are hard and brittle when dry, dense and waxy when moist, and highly plastic and sticky when wet. Dry bentonites disintegrate in water slake rapidly and increase in volume. Dry surfaces of outcrops usually exhibit intricate patterns of shrinkage cracks that may be coated with white alkali stemming. From a distance, the surface of such an outcrop resembles popcorn in appearance, and is aptly referred to as a "popcorn surface," or, in Mississippi, as "gumbo" (Grim and Cuthbert, 1945). Popcorn weathering occurs on outcrops of clays and bentonitic shales containing both Na- and Ca-montmorillonite.

ORIGIN AND OCCURRENCE OF SMECTITIC CLAYS

Because most swelling clays that cause engineering problems are composed largely, or in part, of montmorillonite, special attention is given to the origin and occurrence of montmorillonite.

Clays, including smectites, are formed mostly by alteration of other minerals and rocks, but the physical and chemical environmental requirements for alteration to form clay are not completely known. Evidence from laboratory investigations and the formation of smectite has been obtained by studying the geologic settings of their occurrence and by their synthesis in the laboratory. Smectites are formed by alteration of silica-bearing rocks; the altering solutions are alkaline (pH above 7), magnesium rich, and stagnant. (Keller, 1956, p. 957; Grim, 1953, 316–323). Silica-bearing rocks as varied as granite, basalt, serpentine, and graywacke sandstone may alter to smectite under the appropriate conditions. The smectite species formed depends on the composition of the parent rock and on the present rock and altering solutions. Glassy rhyolitic volcanic ash is especially susceptible to alteration and is known to be the parent material of many smectite deposits.

Smectite in sedimentary clays may have formed in place, or it may have been derived from the weathered rocks of older deposited clays. Grim and Johns (1954, p. 69) ". . . the accumulation of nearly all the highly montmorillonitic, thick, and widespread shale units that are of recognized engineering significance, . . ." has resulted from deposition of volcanic ash in ocean basins. Marine smectitic clays are more abundant and extensive than those of other origin. Some of the widespread geologic history ocean basins have been the largest repositories of detrital sediments and probably have been the largest areas in which the environment was favorable for the formation of smectite. Smectitic sedimentary beds also have formed in saline alkaline lakes and playas in the deserts of the western United States (Droste, 1961; Deike and Jones, 1960). Those deposits generally are not as widespread as marine bentonite beds, but the smectite in them may be highly expansive.

The occurrence of smectite in the stratigraphic column is distinctly related to moisture conditions and cause large volume changes in near-surface swelling clays. Construction of concrete slabs and buildings that protect underlying sediments from the weather in regions of humid climate may result in a decrease in moisture levels and cause underlying clays to shrink, whereas, in arid regions or in regions where ponded groundwaters are common moisture contents beneath covered areas may increase and underlying clays may swell as a result of moisture migration in response to the gain thereof in the tension, humidity of the atmosphere (Mielenz and King, 1955, p. 233). Moisture increases and swelling may also be caused by watering of lawns and shrubbery, breakage of water and sewer lines, and modifications of the surface that produce ponding. Shrinkage of clays may result from loss of moisture by evaporation from beneath heating units such as fireplaces, boilers, and furnaces.

The stability of slopes at the site of an engineered structure may be affected by chemical or organic waste that comes in contact with the clay. The exchangeable ion chemistry of swelling clay minerals may be changed, which, in turn, may alter the water-retention capacity of the clay and adversely affect its volume and strength. This also may occur where concrete construction contact a clay foundation, because of an increase in the calcium ion concentration. Research is needed on the possible effects of deleterious ground water and chemical wastes on high-quality bentonite and rock used in fills or foundation-quality clays.

Moisture levels in clays may be considerably reduced and swelling potentials increased because of removal of moisture by root systems. The amount of moisture removed from the ground can be large; a single tree can transpire the equivalent of 100 gallons of water per day (Forsyth and Lewis, 1965). The root system of some plants extend to depths of as much as 30 ft.

Time is important in determining the amount of swelling that may take place in response to local changes in the environment and moisture conditions of a clay body. Swelling clays have low permeabilities and, where wetted, they create materials and further reduce permeabilities. Because of the slow migration of water through swelling clays, it may take several years for moisture levels to reach a state of near equilibrium in clay-bearing deposits (Woodward, Clyde and Associates, 1967). The required will depend in part on climate, moisture content at time of construction, and the type of soil-moisture control used, which are mentioned (White and Richter, 1959, p. 2). The presence of silt, sand, and other noncl ay materials will reduce the swelling potential in proportion to their amount. The noncl ay materials are dilutants that in effect reduce the swelling potential per unit volume of clay. Seed and others (1962, p. 87) and Woodward-Clyde and Associates (1967, p. 75–107), who noted: "No one test is universally suited for all conditions. . . ." also state, the tests provide indications of the general magnitude of problems to be anticipated in the field: however, where dry densities and high moisture conditions that influence swell, the test indications may be drastically misleading (Hamilton, 1965).

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ROCKY MOUNTAIN REGION

In the Rocky Mountain region (fig. 1), extensive areas are underlain by geologic units that contain clays with high swelling potential. Beds or zones of high swelling clay occur in Cretaceous and Jurassic age marine and nonmarine deposits, shallow marine and continental Tertiary rocks, Tertiary basin-fill deposits, and Quaternary alluvial, glacial, and lake deposits.

Geologic materials containing clays with slight to moderate swelling potential are widespread and range in age from Upper Paleozoic to Quaternary. This category includes extensive Tertiary basin-fill deposits, Quaternary lake bed sediments, and Jurassic and Triassic continental red beds and marine deposits.

Rocks with little or no swelling clay are mostly Precambrian and Paleozoic igneous, sedimentary, and metamorphic rocks, and unaltered Tertiary volcanics and intrusives that form the major mountain masses of the region.

Cretaceous shale, claystone, and siltstone, with abundant high swelling clays, are exposed or near the surface in wide areas of the Rocky Mountain region (Tourtelot, 1974). In general, Cretaceous sediments in the northern part of the region contain more smectitic mixed-layer clays and bentonite because parts of Idaho, Montana, and British Columbia were the scene of episodic volcanism throughout the Cretaceous Period. The farther the sedimentary deposit is from its volcanic source terrane, however, the greater the proportion of smectitic mixed-layer clays, because mixed-layer clays are of smaller particle size than other clays in the clay mineral suite (Gautier, 1983). In the Cretaceous units, smectites with high swelling potential may occur as the major constituent in discrete beds of "bentonite" (beds of altered volcanic ash), or more commonly as scattered or disseminated particles or debris (Schultz and others, 1980). The Pierre Shale in parts of Montana, Wyoming, Colorado, and New Mexico and the Bearpaw Shale in Montana are examples of widespread upper Cretaceous formations with highly swelling clays, capable of causing costly damage to homes, highways, and other man-made structures (Scott, 1969; Hogan, 1973; Seals, 1973; Hart, 1974). Similarly, the Cretaceous Mancos Shale, extensive in parts of western Colorado, eastern Utah, and northwestern New Mexico, is known to cause construction and highway maintenance problems (Hepworth, 1965; Marchino, 1971; Brakey, 1973; Price, 1973). The Tertiary and Cretaceous Denver Formation and upper Cretaceous Arapahoe and Dawson Formations in north-central Colorado are particularly well known for their swelling clay problems because of their occurrence in a metropolitan area where damage to homes and other light structures has been severe (Holtz, 1959; Sealy, 1973; Hart, 1974). Many Cretaceous units in Wyoming and Montana contain bentonites with high swelling potential. The Mowry, Belle Fourche, Carlile, Claggett, Niobrara, and Thermopolis Shales are noted for numerous bentonite beds ranging in thickness from a few inches to as much as several feet (Knechtel and Patterson, 1956, 1958).

Tertiary continental deposits with potentially high swelling clays include the intermontane basin deposits throughout southwestern Montana (Berg, 1969), the Fort Union Formation in eastern Montana (Smith and Redlinger, 1953; Berg, 1969; Hogan, 1973), and rocks of the White River Group in southeastern Wyoming and northeastern Colorado (Denson and Bergendahl, 1961; Scott, 1978). Deposits of bentonite or bentonitic material have also been reported in the Tertiary Uinta and Browns Park Formations of northeastern Utah and northwestern Colorado (Untermann and Untermann, 1964), and in lacustrine deposits of the upper Tertiary and Quaternary Santa Fe Group in central New Mexico (Patterson and Holmes, 1962).

Large quantities of potentially expansive clay also occur in deposits of Jurassic age. A study of clay minerals in the Morrison Formation in the Colorado Plateau areas of Utah, Colorado, and New Mexico by Keller (1962) revealed an "enormous" amount of smectite.

Clays with high swelling potential, largely derived from the alteration of volcanic debris, are abundant in parts of the Triassic Chinle Formation of southeastern Utah and northwestern New Mexico (Schultz, 1963; Molenaar, 1983). According to Patrick and Smethen (1976): "The shales of the Chinle represent some of the most expansive materials in the United States." Morris (1973) described severe highway maintenance problems in the Chinle Formation in an adjacent area of northeastern Arizona.

Quaternary deposits in the region, in general, have low swelling potential. In some cases, however, they may contain clays with high swelling potential, especially where derived from highly expansive parent materials. Pleistocene glacial till deposits in northern Montana (Colton and others, 1961) are an engineering concern where they are derived from expansive Cretaceous shales (Hogan, 1973). Varved glacial-lake clays in west-central Montana are recognized as a potential cause of construction problems because of their high plasticity and shrink-swell capacity (Smith and Schuster, 1971; Lemke and Maughan, 1977). Other Quaternary deposits with local areas of potentially swelling clays include Pleistocene alluvial and loess deposits in north-central Colorado (Sealy, 1973; Hart, 1974) and alluvial and lacustrine deposits in east-central New Mexico where the Pliocene Ogallala Formation and eroded Permian rocks appear to be a major source of swelling clays (Glass and others, 1973). Some playa deposits in arid and semi-arid regions of western Utah and southeastern New Mexico reportedly contain prominent amounts of smectite (Gwynn and Kerr, 1962), and uplift has been observed near fissures of desiccation polygons on playas surfaces, suggesting a swelling clay effect (Neal and others, 1968).

MID-CONTINENT REGION

In the Mid-continent region (fig. 1), clays with high swelling potential (those that contain large amounts of smectite) occur in geologic units of Cretaceous, Tertiary, and Quaternary age. Units of rock and sediment that are expected in areas bordering the Gulf Coast, and in Oklahoma, Nebraska, South and North Dakota, and western Kansas. In other parts of the region, swelling clays have slight to moderate swelling potentials: most are Paleozoic in age and contain large amounts of illite, varying amounts of mixed-layer clays, and usually less than 10 percent montmorillonite.

In the Mid-continent region, swelling clays that have caused the greatest amount of damage are contained in stratigraphic sequences ranging in age from Cretaceous to Quaternary. Damage has been reported in an area extending along the Gulf Coast from east-central Texas to Alabama. In this area, clay deposits with high swelling potential are thick, numerous, and commonly contain bentonite and montmorillonite in large volume percentages. Particularly troublesome are clays contained in the Washita, Woodbine, Eagle Ford, Taylor, and Navarro Groups of Cretaceous age in Texas (McDonald, 1956; Parker, Bishop and Hampton, 1972) and the Selma Chalk and Beaumont clay of Cretaceous age (Holtz, 1959; Vijayvergiya and Sullivan, 1974). Cretaceous clays have caused damage to many buildings and other structures constructed on the South Bosque Formation shales in Waco and the Houston black clay deposits in Houston (Parker, Bishop and Hampton, 1972). Paleocene and equivalent rocks, clays with high swelling potential in formations of Late Cretaceous, Paleocene, and Eocene age have destroyed houses in Fairfax County due to large vertical movements of foundations. Other swelling-related problems include collapse of basement walls where these clays have been used as backfill. Damage to roads in the area occurs in the form of distorted pavements and curbs and weakened subgrades. To reduce the shrink-swell hazard to house foundations, Fairfax County has enacted ordinances requiring that foundations on highly plastic clays be at least 4 ft (1.2 m) beneath grade, that foundations be drained, and that trees be kept away from the foundations (Dallaire, 1976).

Patrick and Snethen (1976) have noted clays with low swelling potential in shales of the Potomac Group in the District of Columbia. They also reported that the Quaternary coastal deposits of the Atlantic Coastal Plain locally may show low swelling potential. Knechtel and others (1964) noted that the clay fractions of the Calvert, Choptank, and St. Marys Formations, in the Miocene Chesapeake Group of southern Maryland, contain large percentages of montmorillonite. Barbee (1956) reported on volume-change problems of the marine Tuxedo clay deposits on the coastal plain near the District of Columbia, where buildings were damaged by the swelling of the clay and other structures were cracked by shrinking of the same clays.

Thin potassium bentonite or metabentonite strata, which may cause local foundation problems, have been noted in Paleozoic units in Virginia, West Virginia, Pennsylvania, New York, and adjacent States to the west and southwest by various researchers (Rosenkrans, 1934; Flowers, 1952; Weaver, 1956; Nelson, 1959; Collins, 1979). In general, these strata are too limited in extent to be shown on the accompanying map.

The New England States are nearly devoid of swelling clays in amounts that can cause damage to structures. However, Patrick and Snethen (1976) have noted that local areas of clay in Pleistocene marine deposits may have low swelling potential.

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Swelling cl

WATER SUPPLY AGREEMENT

The parties to this agreement, entered into this 27th day of October 1992, are IMPERIAL IRRIGATION DISTRICT, an irrigation district (hereinafter referred to as "IID"); and SECOND IMPERIAL GEOTHERMAL COMPANY a California general partnership (hereinafter referred to as "SIGC").

1. RECITALS:

This agreement (hereinafter referred to as the "Agreement") is made with reference to the following facts:

1.1 WHEREAS, SIGC is currently undertaking geothermal development activities precedent to the construction and operation of the SIGC Geothermal Power Project (hereinafter referred to as the "Project") located within the service area of the IID, Imperial County, California. Exhibit A attached hereto identifies the expected site of the proposed Project.

1.2 WHEREAS, SIGC requires a continuous supply of water in connection with construction and operation of the Plant.

1.3 WHEREAS the Board of Directors of the IID has determined that it is in its best interest to make available up to 5,000 acre-feet annually of water from its canal system for beneficial consumptive use by SIGC in accordance with the terms and conditions hereinafter recited.

2. AGREEMENT:

2.1 In consideration of the mutual covenants contained herein, SIGC and IID agree as follows.

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3. DELIVERY:

3.1 Upon receipt of the payment described in paragraph 7.1(a), IID shall permit SIGC to take from an IID operated canal at the location depicted on Exhibit B (or where otherwise agreed by the parties) such water as may be required by SIGC for use in and incidental to the operation of its Project, and for no other purpose in a total quantity not to exceed 5000 acre-feet during any consecutive 12-month period; provided, however, nothing in this agreement shall be construed to require IID to modify or enlarge its existing canal system to make water available to SIGC, and SIGC shall not be entitled to take water at a rate which will unreasonably deplete the supply available in the canal for other uses.

3.2 SIGC shall be responsible, at its sole cost and expense, for the construction, installation, and maintenance of any structures, facilities or improvements necessary in connection with its retrieval of water from said IID canal. The IID shall assist SIGC in obtaining any necessary easements, permits or other rights to transport said water from the canal to the Project and SIGC may terminate this agreement if it cannot reasonably obtain such permits.

4. DRAINAGE RIGHTS:

4.1 IID shall permit SIGC to discharge drain water into the IID drainage system.

5. TERM:

5.1 The term of this Agreement shall commence upon execution of this Agreement by both parties (the "Effective Date") and shall remain in effect until terminated pursuant to this Section 5. The obligation of IID to furnish water to SIGC under this Agreement

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shall commence on the date SIGC initiates start-up and check-out operations of the Project which will utilize such water and shall terminate the earlier of:

(a) 30 years following the date the Project achieves Firm Operation as such term is defined in Section 2.17 of the Power Purchase Contract dated April 16, 1985, between SIGC and Southern California Edison Company

(b) At the option of the IID, thirty-six (36) months from the date the Project has ceased to operate.

(c) December 31, 2024.

The termination date for delivery of water from IID's canal system may be extended by mutual agreement of the parties. Any such extension must be in writing.

6. REQUIREMENTS NOTICE:

6.1 SIGC shall project the total quantity of water to be purchased by SIGC on an annual basis, to reflect the anticipated water requirements for the Project. SIGC shall on or before each November 1st, provide IID with written notice of the approximate quantity of water to be purchased during each month of the following calendar year ("Quantity Notice Letter"). Such amount shall constitute a good faith estimate on the part of SIGC, but shall not constitute a minimum or maximum quantity of water to be purchased during the specified period.

7. PAYMENT/BILLING:

7.1 For the right to take and use the water identified herein:

(a) SIGC agrees to pay IID a one-time fee for the cost of water conservation

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projects in the amount of $500,000, payable March 31, 1993, provided however that the foregoing payment shall not be owed by SIGC until a financial closing occurs which enables SIGC to proceed with construction of the Project, provided further, however, that the foregoing payment shall be made no later than September 30, 1993.

(b) SIGC shall pay a per acre-foot charge for water used by the Project at IID's industrial water rate (currently $57.50 per acre-foot) as amended, from time to time, payable monthly.

(c) SIGC shall install a meter at the inlet to its Project to measure water usage at such Project.

7.2 For the right to discharge into IID's drainage system, SIGC shall pay:

(a) an amount equal to double the industrial rate per acre-foot for drainage water in excess of 15% of the IID water used by the Project.

The above shall be calculated and payable monthly based on meter readings provided by SIGC to the Regional Water Quality Control Board with copies provided to IID.

8. RULES AND REGULATIONS:

8.1 SIGC shall be obligated to comply with the "Rules and Regulations Governing the Distribution and Use of Water and Construction, Operation and Maintenance of the Canal and Drainage System of Imperial Irrigation District," in its present form or as it may be reasonably amended hereafter. Notwithstanding SIGC's obligation to comply with said Rules and Regulations, any conflict between this agreement and said Rules and Regulations pertaining to SIGC's payment obligation set forth in paragraph 7 of this

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agreement, shall be resolved in favor of the provisions of this Agreement.

9. GOVERNING LAW:

9.1 This agreement shall be interpreted, governed by and construed under the laws of the State of California or the laws of the United States, as applicable, as if executed within and to be performed wholly within the State of California.

10. BINDING OBLIGATIONS; ASSIGNMENT:

10.1 This agreement shall be binding upon and inure to the benefit of the parties and their successors and assigns. No party may assign or transfer its rights or obligations under this agreement without the prior written consent of the other party hereto. Such consent shall not be unreasonably withheld. However, without prior consent, IID may assign its rights under this agreement as security for any water conservation financing IID might obtain in carrying out this agreement. SIGC may, without prior consent, assign its rights to a lender, lessor, and/or trustee acting on behalf of a lender or lessor, or any other financing entity which acquires an interest in the Project (collectively "Financing Entities") in connection with any financing involving the Project. Notwithstanding the foregoing, IID agrees that no successor or assignee, including any such Financing Entity shall, by reason of any assignment, be subject to any liability or obligation hereunder, unless such party shall have elected to assume the role of SIGC under this Agreement, in which case such Financing Entities (or any transferee of the Project) shall become liable to perform such duties and obligations. In the event of an assignment of SIGC's rights hereunder to any Financing Entities, IID shall take such further actions and execute such documents as are reasonably requested by such Financing Entities to effectuate such assignment.

Solely with respect to any Financing Entity which acquires an

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interest in this agreement, IID agrees to give written notice to such Financing Entities of any default and will afford such Financing Entities a reasonable period of time to commence appropriate action to cure such default, should they choose to do so and, in the event that this Agreement is terminated by reason of bankruptcy of any party, IID will, at the option of any Financing Entity, enter into a new contract with such Financing Entities or their successors or assigns, having terms similar to this Agreement.

11. NO THIRD PARTY RIGHTS:

11.1 Except as provided in paragraph 10.1, the parties do not intend to create rights and/or to grant remedies to any third party or others as a beneficiary of this Agreement or of any duty, covenant, obligation or undertaking established hereunder.

12. NO DEDICATION OF FACILITIES:

12.1 Any undertaking by one party to another party under any provision of this Agreement shall not constitute the dedication of the system or any portion thereof of the party to the public or to the other party, and it is understood and agreed that any such undertaking under any provision of this Agreement by a party shall cease upon the termination of its obligations hereunder.

13. NON-WAIVER:

13.1 None of the provisions of this agreement shall be considered waived by any party except when such waiver is given in writing. The failure of any party to insist in any one or more instances upon strict performance of any of the provisions of this agreement or to take advantage of any of its rights hereunder shall not be construed as a waiver of any such provisions or their relinquishment of any such rights for the future, but the same

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shall continue and remain in full force and effect.

14. UNCONTROLLABLE FORCES:

14.1 No party shall be considered to be in default in the performance of any of its obligations under this agreement when a failure of performance shall be due to an uncontrollable force. The term "Uncontrollable Force" shall mean any cause beyond the control of the party affected including, but not restricted to, flood, drought, earthquake, tornado, storm, fire, pestilence, lightning and any other natural catastrophe, epidemic, war, riot, civil disturbance or disobedience, strike, labor dispute, labor or material shortage, sabotage, acts, including restraint or enjoinder by proper authority, of civil or military authority (whether valid or invalid), inaction or non-action by or inability to obtain or keep the necessary authorizations or approvals from any governmental agency or authority, which by exercise of due diligence such party could not reasonably have been expected to avoid and which by exercise of due diligence it has been unable to overcome. Nothing contained herein shall be construed as to require a party to settle any strike or labor dispute in which it may be involved. Any party rendered unable to fulfill any of its obligations under this agreement by reason of an uncontrollable force shall give prompt written notice of such fact to the other parties and shall exercise due diligence, and cooperate with any efforts of such other parties, to remove such inability with all reasonable dispatch.

15. WATER RIGHTS:

15.1 Nothing contained in this Agreement is intended or shall be construed to affect, alter, or in any way limit or restrict the rights held by IID by contract or law to divert or use Colorado River water. The right of the Project to use water hereunder is

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not cumulative, and it has no right in subsequent 12-month periods to water that is not used in a current 12-month period. Any water that is not required to be made available for use by the Project in any 12-month period may be used by IID as it, in its sole discretion, shall determine.

16. LATE PAYMENT PENALTY:

16.1 If SIGC (solely with respect to the payments under 7.1(a) and 7.1(b) and 7.2(a)) fails to pay any amount when due, an interest charge on the unpaid amount due based on the late payment charge percentage calculated by the Department of the Treasury and published quarterly in the Federal Register (but not less than 0.5% per month) shall be added on the first day following the due date and monthly thereafter until the payment, any penalty and interest are paid in full. Additionally, if any payment is not made within three (3) business days after written notice received by the defaulting party, that such payment is overdue, a penalty of two percent (2%) of the amount due shall be added thereto.

17. TERMINATION:

17.1 If SIGC breaches this Agreement, including failure to make payment when due, IID shall have the following rights and remedies:

(a) If usage charges for water used by the Project is not paid within sixty (60) days after written notice is received by SIGC and any Financing Entities, IID may suspend this Agreement with respect to such Project, and such Project shall have no further rights to use water hereunder until and unless such default (plus penalty and interest) is fully cured within an additional six months, after which time

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IID may terminate this Agreement with respect to such Project if such default is still outstanding.

(b) If SIGC fails to make any payment for discharge into IID's drainage system under paragraph 7.2 within sixty (60) days after receipt of notice by SIGC and any Financing Entities of such failure, IID may terminate all discharge rights hereunder until such default is cured but such suspension shall not affect any usage rights hereunder which shall continue in full force and effect.

(c) IID may charge penalties and interest only in accordance with paragraph 16 above.

(d) IID may institute any available and appropriate legal or equitable action to enforce the terms of this Agreement.

(e) IID may cease delivering water to SIGC upon the expiration of the period referenced in Section 17.1(a).

IID may use any or all of these rights and remedies in case of SIGC's breach and if it selects one, shall not waive its rights to select or use any other. IID acknowledges (and will accept) that any Financing Entities or other parties which acquire an interest in the Project may cure any breach of this Agreement and such cure shall be considered as full performance hereunder.

18. NOTICES:

18.1 All notices, requests, demands and other communications required or permitted under this agreement shall be in writing and

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shall be deemed to have been received when delivered or on the fifth business day following the mailing, by registered or certified mail, postage prepaid, return receipt requested, thereof address as set forth below:

If to IID:

IMPERIAL IRRIGATION DISTRICT
Attention: General Manager
P.O. Box 937
333 E. Barioni Blvd.
Imperial, CA 92251

If to SIGC:

SECOND IMPERIAL GEOTHERMAL COMPANY
Attention: Ros Pont, Executive Director
343 Second Street
Los Altos, CA 94022

with copies to: OESI Power Corporation
Attn: General Counsel
Bldg. One, Suite 255
4000 Kruse Way Place
Lake Oswego, OR 97035

Any party may change the addressee or address to which communications or copies are to be sent by giving notice of such change of addressee or address in conformity with the provisions of this paragraph for the giving of notice.

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19. CONDITIONS AND MISCELLANEOUS PROVISIONS

19.1 SIGC is a general partnership duly organized and validly existing in good standing under the California Uniform Partnership Act, and has all requisite power and authority to enter into and perform its obligations hereunder. The execution, delivery and performance by SIGC of this Agreement has been duly authorized by all necessary action on the part of SIGC and does not require any approval or consent of any holder (or any trustee for any holder) of any indebtedness or other obligation of SIGC. This agreement has been duly executed and delivered on behalf of SIGC by the appropriate officers of a general partner and constitutes the legal, valid and binding obligation of SIGC, enforceable against SIGC in accordance with its terms. However, SIGC understands that there are some third parties which claim that IID does not have the legal right to deliver conserved water for use in geothermal operations. If IID is enjoined, restrained, or otherwise precluded by proper authority from delivering conserved water to SIGC, IID shall use diligent best efforts so as to enable IID to perform its obligations under this Agreement.

19.2 IID is an irrigation district duly organized and validly existing in good standing under the laws of the State of California, and has all requisite power and authority to enter into and perform its obligations hereunder. The execution, delivery and performance by IID of this Agreement has been duly authorized by all necessary action on the part of IID and does not require any approval or consent of any holder (or any trustee for any holder) of any indebtedness or other obligation of IID. This Agreement has been duly executed and delivered on behalf of IID by the appropriate officers of IID and constitutes the legal, valid and binding obligation of IID, enforceable against IID in accordance with its terms.

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19.3 This agreement sets forth the entire agreement between SIGC and IID with respect to the matters to herein, superseding all previous agreements, oral or written.

19.4 Any owner trustee (the "Owner Trustee") which acquires an interest in the Project shall only be liable hereunder from the income and proceeds of the trust estate created in connection with the financing pursuant to which the Owner Trustee acquires an interest in the Project (the "Trust Estate") and only to the extent that the Owner Trustee shall have received sufficient assets, income and/or proceeds from the Trust Estate to make such payments. Each of IID and SIGC agrees for itself and for its successors and assigns that, as against the Owner Trustee, it will look solely to the assets, income and/or proceeds of the Trust Estate for the payment of any amounts payable by the Owner Trustee hereunder and agrees and confirms that the Owner Trustee is in no way personally liable for any such amounts or on account of any such representation, warranty, covenant or agreement, but nothing hereunder shall limit the liability of the Owner Trustee, in its individual capacity or as Owner Trustee, for its own gross negligence or willful misconduct.

IN WITNESS WHEREOF, SIGC and IID have caused this agreement to be executed on the day and year first above written.

IMPERIAL IRRIGATION DISTRICT



By _____
President

ATTEST: _____
Secretary

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SECOND IMPERIAL GEOTHERMAL COMPANY

By Amor 14 Corporation,
a general partner

By _____
Name:
Title:

ATTEST: _____

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BOARD AGENDA FACT SHEET

CLERK USE ONLY
BOS ACTION
#_____

Air Pollution Control District
Department /Agency

October 23, 2018
Requested Board Date

1. Request:

Board Approval	X	**Information Only/Presentation**	
Other (specify) _____		**Schedule Hearing Time:** _____	

2. Requested Action: *Type requested action below*

The Imperial County Air Pollution Control District is requesting the Air Pollution Control District Board of Directors to hold a public hearing, October 23, 2018 at 10:45 am to consider 1) The approval and adoption of the 2018 PM10 Redesignation Request and Maintenance Plan (2018 PM10 Plan) with associated staff report, and 2) Certification and adoption of the Notice of Exemption for the 2018 PM10 Plan

3. **Cost $** 0.00 **Source:** N/A

4. **If approval of Contract, reviewed/approved by County Counsel on:** N/A

By: _____ **Action Request #** _____
Assigned by County Counsel's Office

5. **If approval of position allocation change, approved by Human Resources on:** N/A

By: _____

6. **Electronic copy submittal date:** October 9, 2018 **By:** Reyes Romero

_____
Department Head/Agency Representative

INSTRUCTIONS: ***Back-up must be submitted 11 BUSINESS days prior to requested date. Back-up submitted must contain an Original and 6 copies. Copies must be submitted double sided and three (3) hole punched. Back-up must be submitted in a PDF format to cobstaff@co.imperial.ca.us.***

CEO/CLERK USE ONLY:

DATE STAMP

BOARD DATE: _____

Action _____ **Filing** _____

Consent _____ **Presentation** _____

Hearing _____ **CEO Approval** _____

Other (specify) _____

_____ _____
CEO ***Date***

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150 SOUTH NINTH STREET
EL CENTRO, CA 92243-2850

TELEPHONE: (442) 265-1800
FAX: (442) 265-1799

AIR POLLUTION CONTROL DISTRICT

October 23, 2018

TO: Honorable Board of Directors

CC: Tony Rouhotas, County Executive Officer

FROM: Matt Dessert, Air Pollution Control Officer

SUBJECT: The Imperial County Air Pollution Control District is requesting the Air Pollution Control District Board of Directors to hold a public hearing, October 23, 2018 at 10:45 am to consider 1) The approval and adoption of the 2018 PM_{10} Redesignation Request and Maintenance Plan (2018 PM_{10} Plan) with associated staff report, and 2) Certification and adoption of the Notice of Exemption for the 2018 PM_{10} Plan

The Imperial County Air Pollution Control District (Air District) respectfully requests approval and adoption of the 2018 PM_{10} Request for Redesignation and Maintenance Plan (2018 PM_{10} Plan), the associated staff report, findings and certification and adoption of the Categorical Exemption for the 2018 PM_{10} Plan.

The Air District is asking for the Board's consideration in adopting the following:

1. 2018 PM_{10} Plan – is a Request for Redesignation of the Imperial Valley Planning Area from a "Serious" non-attainment to an attainment area of the PM_{10} National Ambient Air Quality Standard (NAAQS) and a Maintenance Plan. The Request provides the data review requirements associated with the quality-assured PM_{10} monitoring data from 2014 through 2016, which illustrates that, when excluding exceptional events, the Imperial Valley Planning Area did not violate the NAAQS. The Request further discusses and provides those elements necessary for the US EPA Administrator to make five findings prior to granting the Request for Redesignation. One of those elements is a fully approved maintenance plan, which contains a contingency plan for the Imperial Valley Planning Area.

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2. 2018 PM_{10} SIP Staff Report - gives background on the PM_{10} "Serious" non-attainment status, Request for Redesignation and the elements of the maintenance plan. It also summarizes the PM_{10} problem in Imperial County, the development of the 2018 PM_{10} Plan, the CEQA environmental review process, recommendations made by the advisory board and APCD staff, and a declaration of findings.

3. Categorical Exemption- Staff is recommending the filing of a Notice of Exemption under the provisions of the California Code of Regulations §15307. Class 8 exemptions include actions taken by regulatory agencies to assure the maintenance, restoration, enhancement, or protection of the environment. The 2018 PM_{10} Plan does not require any foreseeable construction activities nor any relaxation of the standards allowing for the degradation of the environment.

Recommendations

The Air District staff recommends the adoption of the proposed 2018 PM_{10} Plan, staff report and findings. Concurrently, the Air District recommends the certification and adoption of the filing of a Notice of Exemption for the 2018 PM_{10} Plan.

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STAFF REPORT

IMPERIAL COUNTY 2018 REDESIGNATION REQUEST AND MAINTENANCE PLAN FOR PARTICULATE MATTER LESS THAN 10 MICRONS IN DIAMETER (2018 PM_{10} PLAN)

October 23, 2018

I. BACKGROUND

In 1987, the United States Environmental Protection Agency (USEPA) adopted the 24-hour PM_{10} National Ambient Air Quality Standard (NAAQS) of 150 micrograms per cubic meter ($\mu g/m^3$). The Imperial Valley Planning Area is currently designated as a Serious nonattainment area for the 24-hour PM_{10} NAAQS. Under the Clean Air Act (CAA), an area can be redesignated as attainment if, among other requirements, the USEPA determines that the NAAQS has been attained. The 24-hour PM_{10} NAAQS allows for one exceedance of the 24-hour average PM_{10} standard (150 $\mu g/m^3$) per year averaged over a three consecutive calendar year period, excluding exceptional events, measured at each monitoring site within an area based on quality-assured air quality monitoring data.

The Imperial County Air Pollution Control District (ICAPCD) adopted a PM_{10} State Implementation Plan for Imperial County in 2009 (2009 PM_{10} Plan). The 2009 PM_{10} Plan demonstrated that the Imperial Valley Planning Area would have been in attainment of the 24-hour PM_{10} NAAQS "but-for" international emissions emanating from Mexico, based on air quality monitoring data for 2006 through 2008. The 2009 PM_{10} Plan established a dust-focused control strategy for attaining the 24-hour PM_{10} NAAQS. In 2012, USEPA and ICAPCD negotiated additional revisions to the Regulation VIII fugitive dust rules related to paved and unpaved roads, agricultural activities, construction and demolition activities, and open area wind erosion; ICAPCD adopted those revisions in October 2012. In February 2013, USEPA finalized approval of the revised Regulation VIII fugitive dust rules as Best Available Control Measures (BACM) and confirmed that they constituted "reasonable control" of the sources covered by them, "for the purpose of evaluating whether the exceedance of the PM_{10} NAAQS is an 'exceptional event' including reasonable and appropriate control measures on significant contributing anthropogenic sources."

Now, the ICAPCD has developed this 2018 PM_{10} Plan and is requesting redesignation of Imperial County Planning Area as attainment. A review of the quality-assured PM_{10} monitoring data from 2014 through 2016 shows that, when excluding exceptional events submitted by ICAPCD and the California Air Resources Board (CARB), the Imperial Valley Planning Area did not violate the federal 24-hour PM_{10} NAAQS. During this period, elevated PM_{10} events associated with high wind driven dust storms were flagged and

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documented in accordance with the USEPA's Exceptional Events regulation (40 CFR § 50.14). Upon concurrence from the USEPA, these events will be excluded from NAAQS determination and a clean data finding will be sought. A clean data finding does not constitute a redesignation to attainment under the CAA. Accordingly, the purpose of the 2018 PM_{10} Plan is to request redesignation of the Imperial Valley Planning Area as a PM_{10} attainment area and to submit the requisite maintenance plan and other required actions to qualify for such redesignation by the USEPA.

II. THE NATURE OF THE PM_{10} PROBLEM WITHIN IMPERIAL COUNTY

Particulate matter (PM) is a general term used to describe a complex group of airborne solid, liquid, or semi-volatile materials of various size and composition. Primary PM is emitted directly into the atmosphere from both human activities (including agricultural operations, industrial processes, construction and demolition activities, and entrainment of road dust into the air) and non-anthropogenic activities (such as windblown dust and ash resulting from forest fires). Secondary PM is formed in the atmosphere from predominantly gaseous combustion by-product precursors, such as sulfur and nitrogen oxides (SO_X and NO_X) and volatile organic compounds (VOCs). The relative proportion of primary and secondary PM in a given geographic area can vary widely depending upon such factors as the mix of sources in the area, the mix of PM precursors, and local meteorology.

The overwhelming majority of airborne PM in the Imperial Valley Planning Area is primary PM. The major source of Imperial's primary PM is fugitive windblown dust, with other contributions resulting from entrained road dust, farming, and construction activities. During the 2014 through 2016 monitoring period, all elevated PM_{10} events were directly related to high wind driven dust storms in which precursor emissions played an insignificant role. In addition, on days favouring the build-up of local PM_{10} precursor emissions (i.e., low wind days) ambient PM_{10} concentrations remained below the NAAQS. CARB evaluated the role that precursor emissions play in the overall ambient PM levels in Imperial County and concluded that the contribution of each precursor can be considered insignificant for the purposes of this redesignation request and maintenance plan.

PM air pollution has undesirable and detrimental environmental effects. PM affects vegetation, both directly (e.g., deposition of nitrates and sulfates may cause direct foliar damage) and indirectly (e.g., coating of plants upon gravitational settling reduces light absorption). PM_{10} is respirable, with fine and ultrafine particles reaching the alveoli deep in the lungs, and larger particles depositing principally in the nose and throat area. PM_{10} deposition in the lungs results in irritation that triggers a range of inflammation responses, such as mucus secretion and bronchoconstriction, and exacerbates pulmonary dysfunctions, such as asthma, emphysema, and chronic bronchitis.

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Imperial County continues making steady progress towards improving air quality and expeditious attainment of the PM_{10} NAAQS. The overwhelming majority of 24-hour ambient PM_{10} concentration measurements by the Imperial County PM_{10} beta attenuation monitoring (BAM) monitors show PM_{10} concentrations are well below the 150 $\mu g/m^3$ NAAQS. Only three to nine percent of measurements at those stations were above 100 $\mu g/m^3$ during 2014-2016, and only 21 to 48 percent were above 50 $\mu g/m^3$. An analysis of the PM_{10} concentrations shows a decrease of the average annual PM_{10} concentration that is the result of the permanent and enforceable reductions that have been achieved due to implementation of the Regulation VIII rules. Since 2000, the average annual PM_{10} concentration in Imperial County, when exceptional events are excluded, has fallen from 96 $\mu g/m^3$ to 46 $\mu g/m^3$ in 2016. This represents an approximate 52 percent decrease in the general PM_{10} levels in Imperial County over that period. This type of reduction is also seen in the trend of the annual average of individual 24-hour average PM_{10} levels, when exceptional events are excluded, at all long-term (1-in-6 day sampling) monitors across Imperial County. The table below shows these declining trends, with a trend annual average of 24-hour PM_{10} levels in 2016 at less than 26% of the 24-hour average PM_{10} NAAQS.

Station	24-hour Average PM_{10} Trend per Year from 2000-2016/7 (ug/m^3/year)	24-hour Average PM_{10} Trend Average in 2016 (ug/m^3)
Calexico	-1.9	40
El Centro	-0.7	33
Brawley	-0.4	39
Westmorland	-0.9	33
Niland	-0.1	37

III. 2018 PM_{10} PLAN AND MAINTENANCE PLAN

The ICAPCD is requesting redesignation of the Imperial Valley Planning Area from Serious nonattainment to attainment of the PM_{10} NAAQS under CAA Section 107(d)(3)(E) protocol.

Section 107(d)(3)(E) of the CAA requires the USEPA administrator to make five findings prior to granting a request for redesignation:

1. The USEPA has determined that the NAAQS has been attained;
2. The applicable implementation plan has been fully approved by the USEPA under Section 110(k);
3. The USEPA has determined that the improvement in air quality is due to permanent and enforceable reductions in emissions;
4. The State has met all applicable requirements for the area under Section 110 and Part D; and

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5. The USEPA has fully approved a maintenance plan, including a contingency plan, for the area under Section 175A.

Since the first Imperial County PM_{10} Attainment Plan was adopted in 2009, the ICAPCD has adopted stringent Best Available Control Measures (BACM) to control fugitive dust. These measures have provided for continuous attainment of the 24-hour PM_{10} standard (excluding exceptional or natural events) in the region, despite regional growth.

Based on analyses of long-term meteorological variables, including rainfall and wind speeds, the ICAPCD found that meteorological conditions during the 2014-2016 period were conducive to higher PM_{10} concentrations. Yet, excluding exceptional events, the Imperial County did not violate the 24-hour PM_{10} standard during this three-year period. In the 2014-2016 period, Imperial County experienced 58 days with PM_{10} concentrations in excess of the 24-hour NAAQS. All of these exceedances were due to exceptional events. These events were primarily caused by gusty westerly winds brought on by low pressure systems. A smaller fraction of the events were the result of monsoonal fronts passing through the region. These events were documented, publicly noticed, and are being submitted to the USEPA in separate submittals.

As described above, the Imperial Valley Planning Area, did not violate the NAAQS from 2014 through 2016 (when excluding exceptional events), and this is attributable to a successful emissions control strategy. The PM_{10} Control Strategy, including adopted Regulation VIII fugitive dust rules, has led to permanent and enforceable emissions reductions in the area. In 2013, the USEPA approved the Regulation VIII rules as BACM for significant sources. Another important component of the ICAPCD's strategy to maintain attainment of the PM_{10} NAAQS is mitigation of the exposed playa at the Salton Sea. The Salton Sea will continue to shrink, especially as drainage flows from local agricultural use continue to reduce. Stabilizing the parts of the playa expected to become emissive as they are exposed will minimize dust emissions. The State's Salton Sea Management Program (SSMP) and Phase I Plan and Imperial Irrigation District's (IID) Salton Sea Air Quality Management Program (SS AQM Program) are designed to proactively provide reasonable controls as the playa is exposed.

The CAA specifies that for an area to be redesignated as attainment, the USEPA must approve a maintenance plan. The purpose of the maintenance plan is to provide for the maintenance of the 24-hour PM_{10} NAAQS for at least ten years after the redesignation. The Imperial County PM_{10} Maintenance Plan includes the following components:

1. Attainment emission inventories for directly emitted PM_{10};
2. Demonstration that PM_{10} attainment concentrations at federal reference monitoring stations will be maintained for ten years after redesignation;
3. Commitment to ongoing monitoring network operation for continued verification of attainment; and
4. Contingency provisions to address any future violations.

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In addition, eight years after the area is redesignated as attainment, the ICAPCD will submit a revised Imperial County PM_{10} Maintenance Plan providing for continued attainment for an additional ten years.

IV. 2018 PM_{10} PLAN AND MAINTENANCE PLAN DEVELOPMENT

After several months of cooperative and coordinated efforts between the ICAPCD, CARB and USEPA, the ICAPCD prepared and released a draft version of the 2018 PM_{10} Plan and Maintenance Plan for review by the respective agencies on September 6, 2018. The Draft 2018 PM_{10} Plan and Maintenance Plan address and include all comments by the agencies.

A public notice for two public workshops inviting the community to review and comment on the Draft 2018 PM_{10} Plan and Maintenance Plan was published in the Imperial County local newspaper of greatest circulation, the Imperial Valley Press, on September 21, 2018 (English). In addition, a second public notice was published in Adelante Valle, on September 21, 2018 (Spanish), with a simultaneous publication on the ICAPCD's website.

ICAPCD staff conducted two public workshops to present, discuss, and take comments on the Draft 2018 PM_{10} Plan and Maintenance Plan. The first workshop was held in the morning in El Centro while the second workshop was held late afternoon in Brawley on September 25, 2018. The ICAPCD considered written comments received from the public and affected sources during the public workshops and incorporated comments into the proposed Draft 2018 PM_{10} Plan as appropriate.

A public notice for a Public Hearing on the adoption of the Draft 2018 PM_{10} Plan and Maintenance Plan was published in the Imperial County local newspaper of greatest circulation, the Imperial Valley Press, on September 20, 2018 (English), in Adelante Valle, on September 21, 2018 (Spanish), and simultaneously on the ICAPCD's website.

Adoption by our Governing Board is scheduled for October 23, 2018, after which the Draft 2018 PM_{10} Plan and Maintenance Plan will be forwarded to CARB for adoption by the CARB Board.

V. CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

The Draft 2018 PM_{10} Plan and Maintenance Plan is a "project" as defined by the California Environmental Quality Act (CEQA). Under CEQA, a lead agency has the principal responsibility for carrying out or approving a project that may have a significant effect upon the environment. Since the Draft 2018 PM_{10} Plan and Maintenance Plan imposes the greatest discretionary authority of approval upon the ICAPCD, it is therefore the lead agency for the project.

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As part of the review process, the ICAPCD examined the Draft 2018 PM_{10} Plan and Maintenance Plan for applicability to CEQA. As directed by §21084 of the Public Resources Code, the Secretary for Resources identified a list of projects determined not to have a significant effect on the environment and which by their very nature are therefore exempt from the provisions of CEQA. Because the Draft 2018 PM_{10} Plan and Maintenance Plan does not propose or impose any new regulation and in fact demonstrates attainment of the NAAQS but for exceptional events, a Class 8 categorical exemption (§15307 of the guidelines) applies. A Class 8 exemption describes those actions taken by regulatory agencies, as authorized by state or local ordinance to assure the maintenance, restoration, enhancement, or protection of the environment where the regulatory process involves procedures for protection of the environment. No reasonably foreseeable construction activities may occur nor any relaxation of the standards allowing for the degradation of the environment are proposed. Therefore, under CEQA, the Draft 2018 PM_{10} Plan and Maintenance Plan is exempt.

Staff is recommending the filing of a Notice of Exemption under the provisions of California Code of Regulations §15307.

VI. RECOMMENDATIONS

ADVISORY BOARD:

On September 25, 2018, the ICAPCD presented the Draft 2018 PM_{10} Plan and Maintenance Plan to the Advisory Board for consideration. After discussion of the influence, impact, determinations, and findings, the Advisory Board gave its full approval and recommended forwarding the plan and associated findings on to the ICAPCD Board of Directors for adoption and approval.

STAFF:

ICAPCD staff recommends adoption of the attached Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter. After addressing the technical and non-technical issues raised by CARB and the USEPA during its development, the Draft 2018 PM_{10} Plan and Maintenance Plan effectively demonstrates that with concurrence of USEPA on the submitted exceptional events, Imperial County is in attainment of the PM_{10} NAAQS. In addition, the filing of a Notice of Exemption for the 2018 PM_{10} Plan.

VII. DECLARATION OF FINDINGS:

The ICAPCD Board hereby finds as follows:

The ICAPCD is a regulatory agency and the public agency with the principle responsibility

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for carrying out the project and is exempt from CEQA.

Clean air is a valuable and essential natural resource.

Imperial Valley was reclassified as a "Serious" nonattainment area August 11, 2004 and on December 11, 2007 the USEPA finalized its ruling that the Imperial Valley failed to attain the PM_{10} NAAQS by December 21, 2001.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter meets the requirements of the federal CAA for areas classified as "Serious" nonattainment of the NAAQS for PM_{10}. Failure to adopt the 2018 PM_{10} Plan for the Particulate Matter Less Than 10 Microns in Diameter and Maintenance Plan would guarantee that the Imperial County would not meet federal PM_{10} standards as required by the CAA.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter demonstrates attainment as required by the CAA with a long-term effect resulting in a reduction in emissions from stationary and mobile sources.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter incorporates updated emissions inventories and ambient measurements.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter satisfies the planning requirements set forth in the federal CAA including establishing a transportation conformity budget based on the latest planning assumptions.

The emissions reductions achieved by the continued implementation of the 2018 PM_{10} Plan for the Particulate Matter Less Than 10 Microns in Diameter and Maintenance Plan control measures would provide for continued attainment of the PM_{10} NAAQS.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter demonstrates that air quality monitoring data for 2014 through 2016 shows that the Imperial Valley Planning Area is in attainment of the 24-hour PM_{10} NAAQS, excluding exceptional events.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter is technically sound and capable of being understood by those persons directly affected by it.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for

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Particulate Matter Less Than 10 Microns in Diameter does not conflict with or contradicts any existing statute, court decision, state, or federal regulation.

The Draft Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less Than 10 Microns in Diameter is not duplicative of any existing state or federal regulation or plan.

The ICAPCD has a population of less than 500,000 people.

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AIR POLLUTION CONTROL DISTRICT

DRAFT

IMPERIAL COUNTY 2018 REDESIGNATION REQUEST AND MAINTENANCE PLAN FOR PARTICULATE MATTER LESS THAN 10 MICRONS IN DIAMETER

Adopted _____ __, 2018

Air Pollution Control Officer

Matt Dessert

Assistant Air Pollution Control Officer

Reyes Romero

Co-Authors

California Air Resources Board
Air Quality Planning & Science Division

Imperial County Air Pollution Control District

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2018 IMPERIAL COUNTY REDESIGNATION REQUEST AND MAINTENANCE PLAN FOR PARTICULATE MATTER LESS THAN 10 MICRONS IN DIAMETER

DRAFT

Prepared for

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OCTOBER 2018

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Abbreviations and Acronyms

AVTD	Average Vehicle Trips per Day
BACM	Best Available Control Measure
BACT	Best Available Control Technology
CAA	Federal Clean Air Act
CARB	California Air Resources Board
CEPAM	California Emissions Projection Analysis Model
CMP	Conservation Management Practice (agriculture)
DM	*de minimis*
ICAPCD	Imperial County Air Pollution Control District
ICPWD	Imperial County Public Works Department
IID	Imperial Irrigation District
NAA	nonattainment area
NAAQS	National Ambient Air Quality Standards
NEAP	Natural Events Action Plan
PM	particulate matter
PM_{10}	particulate matter less than 10 microns in aerodynamic diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in aerodynamic diameter
RACM	Reasonably Available Control Measure
RFP	Reasonable Future Progress
RTP	Regional Transportation Plan
SCAG	Southern California Association of Governments
SCS	Sustainable Communities Strategy
SIP	State Implementation Plan
SSI	Size Selective Inlet
TPA	Regional Transportation Planning Agency
tpd	tons per day
USEPA	United States Environmental Protection Agency
VDT	Vehicle Daily Trips
VDE	Visible Dust Emissions
WESTAR	Western States Air Resources Council
WRAP	Western Regional Air Partnership
$\mu g/m^3$	microgram per cubic meter
µm	micron or micrometer

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1 Introduction

On behalf of the Imperial County Air Pollution Control District (ICAPCD or "District"), this document brings together the data and discussion necessary to revise the previous State Implementation Plan submittal ("Plan" or "SIP submittal") for particulate matter less than 10 microns in aerodynamic diameter (PM_{10}) and requests redesignation of the Imperial Valley Planning Area as attainment. Particulate matter less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$), which is a size subset of PM_{10}, has its own federal standards and separate SIPs will address $PM_{2.5}$ Clean Air Act (CAA) requirements. This Plan includes all required elements in CAA Section 107(d)(3)(E) for a redesignation request and maintenance plan needed by the United States Environmental Protection Agency (USEPA) to approve a redesignation. This chapter provides an overview of particulate matter as an air pollutant, a brief description of the Imperial County area, and a discussion of the purpose and regulatory background associated with this document.

1.1 Purpose

The Imperial Valley Planning Area is currently designated as a Serious nonattainment area for the 24-hour PM_{10} National Ambient Air Quality Standard (NAAQS). Under the CAA, an area can be redesignated as attainment if, among other requirements, the USEPA determines that the NAAQS has been attained. The 24-hour PM_{10} NAAQS allows for one exceedance of the 24-hour average PM_{10} standard (150[1] micrograms per cubic meter [$\mu g/m^3$]) per year averaged over a three consecutive calendar year period, excluding exceptional events, measured at each monitoring site within an area based on quality-assured air quality monitoring data.

A review of the quality-assured PM_{10} monitoring data from 2014 through 2016 shows that, when excluding exceptional events, the Imperial Valley Planning Area did not violate the federal 24-hour PM_{10} standard. During this period, elevated PM_{10} events associated with high wind driven dust storms were flagged and documented in accordance with the USEPA's Exceptional Events regulation (40 CFR § 50.14).[2] Upon concurrence from the USEPA, these events will be excluded from NAAQS determination and a clean data finding will be sought. A clean data finding does not constitute a redesignation to attainment under the CAA. Accordingly, the purpose of this document is to request redesignation of the Imperial Valley Planning Area as attainment for PM_{10} and to submit the requisite maintenance plan and other required actions to qualify for such redesignation by the USEPA.

1.2 Particulate Matter Air Pollution

Particulate matter (PM) is a general term used to describe a complex group of airborne solid, liquid, or semi-volatile materials of various size and composition. Primary PM is emitted directly into the atmosphere from both human activities (including agricultural operations, industrial processes, construction and demolition activities, and entrainment of road dust into the air) and non-anthropogenic activities (such as windblown dust and ash resulting from forest fires). Secondary PM is formed in the atmosphere from predominantly gaseous combustion by-product

[1] Per USEPA data handling procedures, an exceedance is a measurement over 154.9 $\mu g/m^3$, since a reading of 154.9 $\mu g/m^3$ would round down to 150 $\mu g/m^3$.

[2] Treatment of air quality monitoring data influenced by exceptional events, 40 CFR § 50.14

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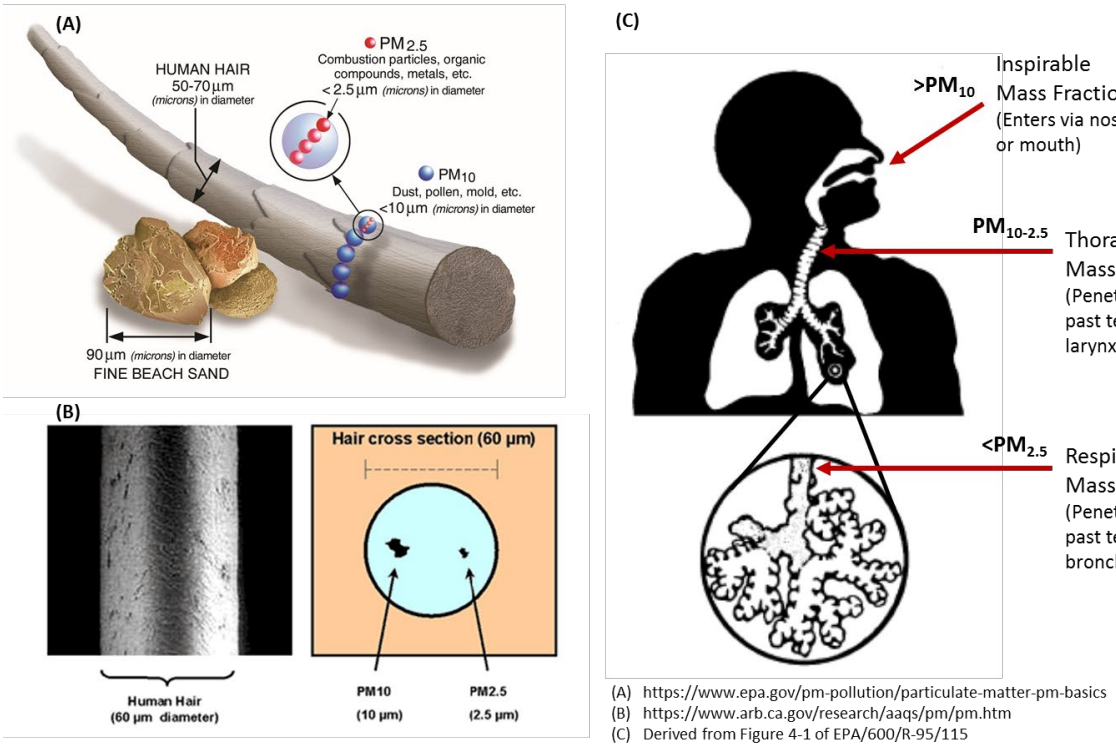
precursors, such as sulfur and nitrogen oxides (SO_X and NO_X), and volatile organic compounds (VOCs). The relative proportion of primary and secondary PM in a given geographic area can vary widely depending upon such factors as the mix of sources in the area, the mix of PM precursors, and meteorology. In addition, PM and its precursors can be transported hundreds or thousands of miles while suspended in the atmosphere.[3] Consequently, ambient PM in an area may be the combination of primary and secondary particles that result from the emissions of local and remote sources.

Federal and state regulators have established both PM_{10} and $PM_{2.5}$ as separate criteria pollutants based, in part, on how the human body reacts to the different sized particulate and the composition of the different size fractions. Figure 1-1 shows the relative sizes of PM_{10} and $PM_{2.5}$, as well as how far they travel into the human body.



(A) https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
(B) https://www.arb.ca.gov/research/aaqs/pm/pm.htm
(C) Derived from Figure 4-1 of EPA/600/R-95/115

Figure 1-1. $PM_{2.5}$ and PM_{10} Relative Sizes and Health Impact Pathways

PM_{10} and $PM_{2.5}$ are based on the size of the particulates; however, they also have different components. Although PM_{10} includes all "fine" $PM_{2.5}$-sized particulates, it also includes "coarse" primary particulates such as dust generated from activities (e.g., construction, mining, etc.) and entrained from soil surfaces by the wind. Figure 1-2 is a general schematic of the components in

[3] National Research Council. 2010. *Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States*. Washington, DC: The National Academies Press. Available at: https://doi.org/10.17226/12743. Accessed: June 2018.

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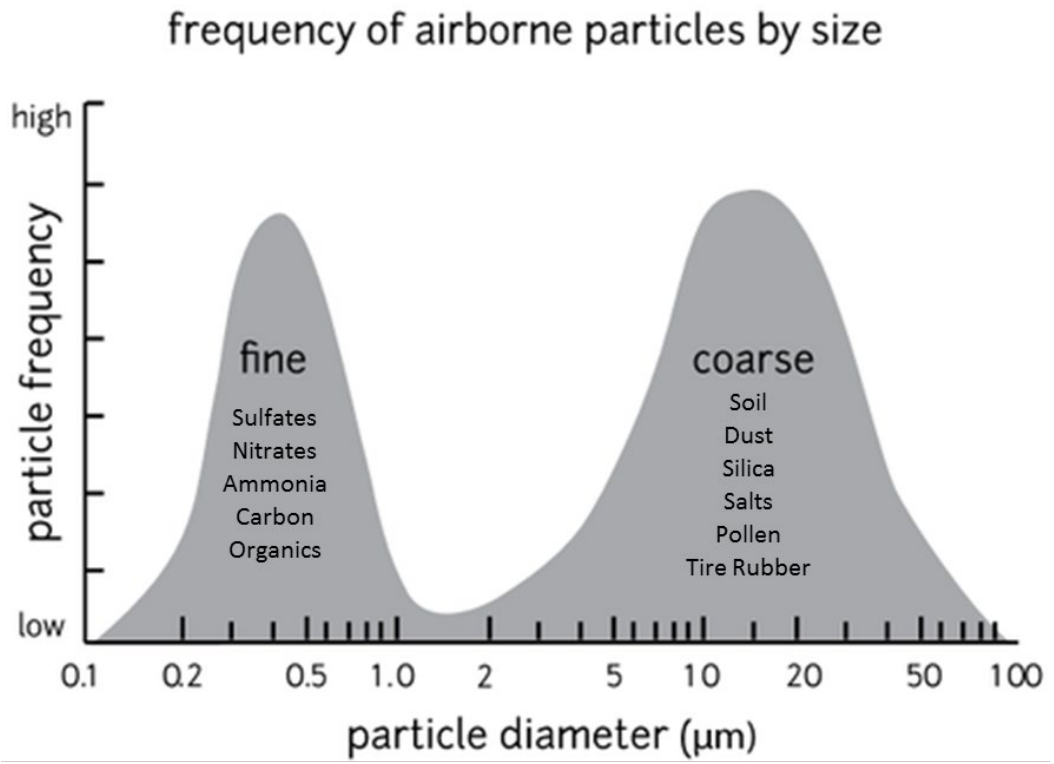
fine and coarse PM; the relative contribution depends on how the different sources are represented in a given area.



Derived from https://publiclab.org/wiki/revisions/pm/25078

Figure 1-2. Properties and Sources of $PM_{2.5}$ and PM_{10}

Ammonium nitrate and ammonium sulfate are formed by NO_X and SO_X (generally from combustion) and ammonia (from fertilizers, manures, wastewater treatment, etc.). Combustion also produces primary (or elemental) carbon and many organic aerosols. Note that the relative contribution of fine and coarse material is dependent on the location, sources, and meteorology.

For PM_{10}, the overwhelming majority of airborne PM in the Imperial Valley Planning Area is primary PM. The major source of primary PM is fugitive windblown dust, with other contributions from entrained road dust, farming, and construction activities. During the 2014 through 2016 monitoring period, all elevated PM_{10} events were directly tied to high wind driven dust storms in which precursor emissions played an insignificant role. In addition, on days favoring the build-up of local PM_{10} precursor emissions (i.e. low wind days) ambient PM_{10} concentrations remained below the NAAQS. CARB evaluated the role that precursor emissions play in the overall ambient PM levels in Imperial County in a study that involved comparing PM_{10} and $PM_{2.5}$ concentration and speciation data from 2007 through 2016. Specifically, five dates with complete concentration and matching speciation data were selected and the data analyzed. CARB's goal was to estimate on each day what percentage of the measured PM_{10}'s mass was contributed by SO_X, NO_X, NH_3, and VOCs. CARB determined that each of these precursors contributed to about 2% or less of the total PM_{10} as an average across the five selected days.

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Comparing these percentages to a precursor significance threshold level developed for the $PM_{2.5}$ 24-hr standard, CARB concluded that the contribution of each precursor can be considered insignificant for the purposes of this redesignation request and maintenance plan. A more detailed summary of the precursor analysis conducted by CARB is provided in Appendix A.

As discussed previously, particle size is a critical characteristic of PM that primarily determines the location of PM deposition along the respiratory system (and associated health effects) as well as the degradation of visibility through light scattering. In the United States, federal and state agencies have established two types of PM air quality standards, reported in Table 1-1 below. PM_{10} corresponds to the fraction of PM no greater than 10 microns or micrometers (µm) in aerodynamic diameter, while $PM_{2.5}$ refers to the subset of PM_{10} of aerodynamic diameter smaller than 2.5 µm, which is commonly called fine particulate matter. The California state standards are presented for comparative purposes, but are otherwise outside the scope of this document.

Table 1-1. National and State Ambient Air Quality Standards for Particulate Matter

Pollutant	Averaging Time	California Standards	National Standards
Respirable Particulate Matter (PM_{10})	Annual	20 µg/m^3	--
	24-hour	50 µg/m^3	150 µg/m^3
Fine Particulate Matter ($PM_{2.5}$)	Annual	12 µg/m^3	12 µg/m^3
	24-hour	--	35 µg/m^3

PM air pollution has undesirable and detrimental environmental effects. PM affects vegetation, both directly (e.g., deposition of nitrates and sulfates may cause direct foliar damage) and indirectly (e.g., coating of plants upon gravitational settling reduces light absorption). PM also accumulates to form regional haze, which reduces visibility due to scattering of light. Agencies concerned with haze include the National Park Service, the U.S. Forest Service, the Western Regional Air Partnership (WRAP), and the Western States Air Resources Council (WESTAR).

PM_{10} is respirable, with fine and ultrafine particles reaching the alveoli deep in the lungs, and larger particles depositing principally in the nose and throat area. PM_{10} deposition in the lungs results in irritation that triggers a range of inflammation responses, such as mucus secretion and bronchoconstriction, and exacerbates pulmonary dysfunctions, such as asthma, emphysema, and chronic bronchitis. Sufficiently small particles may penetrate into the bloodstream and impact functions such as blood coagulation, cardiac autonomic control, and mobilization of inflammatory cells from the bone marrow. Individuals susceptible to higher health risks from exposure to PM_{10} airborne pollution include children, the elderly, smokers, and people of all ages with low pulmonary/cardiovascular function. For these individuals in particular, adverse health effects of PM_{10} pollution include coughing, wheezing, shortness of breath, phlegm,

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bronchitis, and aggravation of lung or heart disease, leading to increased risks of hospitalization and mortality from asthma attacks and heart attacks.[4]

1.3 Imperial County

1.3.1 Geography, Population, and Land Use

Imperial County extends over 4,284 square miles[5] in the southeastern corner of California. It is bordered on the south by Mexico, on the east by Arizona, on the west by the Coyote and Fish Creek Mountains (which are in San Diego County), and on the north by Riverside County. The Salton Trough runs approximately northwest to southeast through the center of the County and extends into Mexico. The elevation in Imperial County ranges from about 230 feet below sea level at the Salton Sea in the north to more than 2,800 feet on the mountain summits to the west.

Imperial County's population is about 190,600[6] and its principal industries are farming and retail trade. Most of the population, farming, and retail trade exist in a band of land that, on average, comprises less than one-fourth the width of the County, stretching from the south shore of the Salton Sea to the Mexican border. The road network is densest within this strip, as shown in Figure 1-3. The rest of Imperial County is the Salton Sea and mostly dry, barren desert areas with little or no human population.

Imperial County's agricultural industry was valued at $2.06 billion in 2016. Vegetable and melon crops led the County tally, grossing more than $1 billion, followed by livestock which grossed $468 million. More than 100 types of crops and commodities are grown in Imperial County, and in 2016, it ranked among the top ten out of all 58 counties in California for gross value of agricultural production.[7] Approximately half a million acres of land were harvested in Imperial County in 2014 and this amount has remained fairly constant over the past decade. During the high season, approximately 25 percent of Imperial County's labor force work in the agricultural sector. Additionally, Imperial County has more acreage and production of alfalfa than any other county in the United States. It is also a major producer of lettuce, feedlot beef, melons, carrots, Sudan grass hay, onions, and numerous other commodities.

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[4] Additional details regarding the adverse health effects of PM can be found in the San Joaquin Valley 2006 PM_{10} Plan (Chapter 1, Section 1.5). Available at: http://www.valleyair.org/Air_Quality_Plans/06PM10.htm. Accessed: June 2018.

[5] Official website of Imperial County. Available at: http://www.co.imperial.ca.us/. Accessed: June 2018.

[6] State of California Department of Finance. Population Estimates. Available at: http://www.dof.ca.gov/Forecasting/Demographics/Estimates/. Accessed: June 2018.

[7] Agricultural Impact Associates. Economic Contributions of Imperial County Agriculture. Crop Report PLUS Series. December 2017. Available at: http://www.co.imperial.ca.us/ag/docs/spc/2016_Imperial_County_Crop_Report_Plus.pdf Accessed: June 2018.

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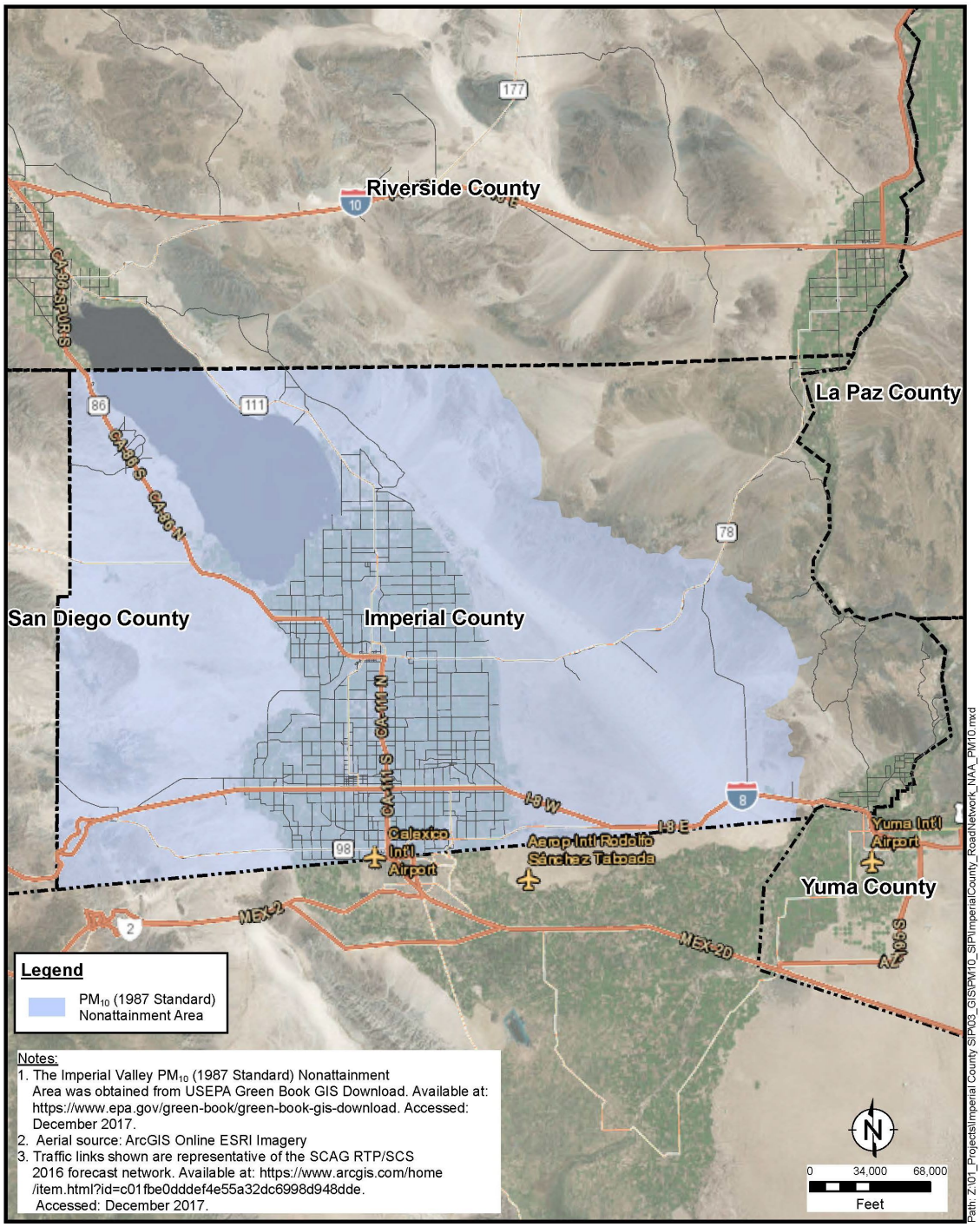

Figure 1-3. Road map of Imperial County

1.3.2 Climate and Meteorology

Climatic conditions in Imperial County are governed by the large-scale sinking and warming of air in the semi-permanent tropical high pressure center of the Pacific Ocean. The high pressure ridge blocks out most mid-latitude storms except in winter when it is weakest and farthest south. The coastal mountains prevent the intrusion of any cool, damp air found in California coastal

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environs. Because of the barrier and weakened storms, Imperial County experiences clear skies, extremely hot summers, mild winters, and little rainfall. The sun shines, on the average, more in Imperial County than anywhere else in the United States.

Winters are mild and dry with daily average temperatures ranging between 65 and 75ºF (18-24ºC). During winter months it is not uncommon to record maximum temperatures of up to 80ºF. Summers are extremely hot with daily average temperatures ranging between 104 and 115ºF (40-46ºC). It is not uncommon to record maximum temperatures of 120ºF during summer months.

The flat terrain of the valley and the strong temperature differentials created by intense solar heating, produce moderate winds and deep thermal convection. The combination of subsiding air, protective mountains, and distance from the ocean all combine to severely limit precipitation. Rainfall is highly variable with precipitation from a single heavy storm able to exceed the entire annual total during a later drought condition. The average annual rainfall is just over three inches (7.5 centimeters) with most of it occurring in late summer or mid-winter.

Humidity is low throughout the year, ranging from an average of 28 percent in summer to 52 percent in winter. The large daily oscillation of temperature produces a corresponding large variation in the relative humidity. Nocturnal humidity rises to 50 to 60 percent, but drops to about 10 percent during the day.

The wind in Imperial County follows two general patterns. Wind statistics indicate prevailing winds are from the west-northwest through southwest; a secondary flow maximum from the southeast is also evident. The prevailing winds from the west and northwest occur seasonally from fall through spring and are known to be from the Los Angeles area. Occasionally, Imperial County experiences periods of extremely high wind speeds. Wind speeds can exceed 31 miles per hour (mph) and this occurs most frequently during the months of April and May. However, speeds of less than 6.8 mph account for more than one-half of the observed wind measurements.

1.3.3 Atmospheric Stability and Dispersion

Air pollutant concentrations are primarily determined by the amount of pollutant emissions in an area and the degree to which these pollutants are dispersed in the atmosphere. The stability of the atmosphere is one of the key factors affecting pollutant dispersion. Atmospheric stability regulates the amount of vertical and horizontal air exchange, or mixing, that can occur within a given air basin. Restricted mixing and low wind speeds are generally associated with a high degree of stability in the atmosphere. These conditions are characteristic of temperature inversions.

In the atmosphere, air temperatures normally decrease as altitude increases. At varying distances above the Earth's surface, however, a reversal of this gradient can occur. This condition, termed an “inversion”, is simply a warm layer of air above a layer of cooler air, and it has the effect of limiting the vertical dispersion of pollutants. The height of the inversion determines the size of the mixing volume trapped below. Inversion strength or intensity is measured by the thickness of the layer and the difference in temperature between the base and

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the top of the inversion. The strength of the inversion determines how easily it can be broken by winds or solar heating.

Imperial County experiences surface inversions almost every day of the year. Due to strong surface heating, these inversions are usually broken allowing pollutants to be more easily dispersed. Weak surface inversions are caused by radiative cooling of air in contact with the cold surface of the Earth at night. In valleys and low lying areas, this condition is intensified by the addition of cold air flowing down slope from the hills and pooling on the valley floor.

However, in some circumstances the presence of the Pacific high pressure cell can cause the air to warm to a temperature higher than the air below. This highly stable atmospheric condition, termed a subsidence inversion can act as a nearly impenetrable lid to the vertical mixing of pollutants. The strength of these inversions makes them difficult to disrupt. Consequently, they can persist for one or more days, causing air stagnation and the build-up of pollutants—a condition that frequently occurs across the southern border of Imperial County in the densely populated city of Mexicali, Mexico. In the past these elevated pollution levels have been observed to impact ambient air quality in the nearby city of Calexico, Imperial County.

1.4 Regulation VIII and Imperial County 2009 PM_{10} SIP

1.4.1 Background

In response to the opinion of the U.S. Court of Appeals for the Ninth Circuit in *Sierra Club* v. *United States Environmental Protection Agency, et al.*, in August 2004 the USEPA found that the Imperial Valley Planning Area had failed to attain the NAAQS by the Moderate area PM_{10} attainment date of December 31, 1994, and as a result reclassified the area from a Moderate to a Serious PM_{10} nonattainment area.[8] Also in August 2004, the USEPA proposed a rule to find that the Imperial Valley Planning Area had failed to attain the annual and 24-hour PM_{10} standards by the Serious area deadline of December 31, 2001.[9] The USEPA finalized the rule on December 11, 2007,[10] citing as the basis for the rule that six Imperial County monitoring stations were in violation of the 24-hour standard during 1999 to 2001. The USEPA's final rule action required the state to submit to the USEPA by December 11, 2008 (within one year of the rule's publication in the Federal Register) an air quality plan that demonstrates that the County will attain the PM_{10} standard as expeditiously as practicable.

In response to this rule action, ICAPCD developed the *2009 Imperial County State Implementation Plan for Particulate Matter Less than 10 Microns in Aerodynamic Diameter*[11]

[8] United States Environmental Protection Agency. 2004. *Finding of Failure to Attain and Reclassification to Serious Nonattainment; Imperial Valley Planning Area; California; Particulate Matter of 10 Microns or Less; Final Rule.* Federal Register. Vol. 69. No. 154. August 11, 2004. p. 48792.

[9] United States Environmental Protection Agency. 2004. *Finding of Failure to Attain; Imperial Valley Planning Area; California; Particulate Matter of 10 Microns or Less; Proposed Rule*. Federal Register. Vol. 69. No. 154. August 11, 2004. p. 48835.

[10] United States Environmental Protection Agency. 2007. *Finding of Failure to Attain; California – Imperial Valley Nonattainment Area; PM-10. Final Rule.* Federal Register. Vol. 72. No. 237. December 11, 2007. p. 70222.

[11] Imperial County Air Pollution Control District. 2009. 2009 Imperial County State Implementation Plan for Particulate Matter Less Than 10 Microns in Aerodynamic Diameter. August 11. Available at: http://www.co.imperial.ca.us/airpollution/attainment%20plans/final%20ic%202009%20pm10%20sip%20document.pdf. Accessed: June 2018.

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("2009 PM_{10} SIP") which included the required sections of an air quality assessment, emission inventory, District control strategy (including Best Available Control Measures [BACM] and Best Available Control Technology [BACT]), and transportation conformity budgets. For the first main required section, the air quality assessment, an evaluation of the air quality data from 2006 to 2008 was performed in order to determine the peak concentrations around which the control strategy was to be designed. It was found that during this period, there were five days with ambient air PM_{10} concentration measurements that exceeded the 24-hour NAAQS.[12] After extensive technical analysis, the District concluded that each of these exceedances was caused by either transport of pollutants from Mexico or natural high wind events. In the case of exceedances caused by international transport, the CAA contains a specific provision to address them. It establishes that although these exceedances are still considered violations of the standard, the state is not required to develop an attainment strategy addressing the pollution that causes them. For exceedances caused by wind events, there is an applicable provision in the Exceptional Events Rule adopted by the USEPA in 2007 and revised in 2016.[13] This rule recognizes that there are certain naturally occurring, uncontrollable events that can result in exceedances of federal air quality standards, and that appropriately documented events can be excluded from consideration of a region's attainment status.

Given these circumstances, the Imperial Valley Planning Area was considered to have met the federal PM_{10} standard "but-for" international emissions and hence, no attainment demonstration was required. Additionally, the requirements for reasonable further progress (RFP), a five percent yearly reduction in emissions, and contingency measures were not applicable since their sole purpose is to bring an area into attainment of the standard. Nevertheless, the District did address contingency measures in the 2009 PM_{10} SIP in order to provide additional assurance that PM_{10} levels would remain below the standard into the future.

The next major requirement for the 2009 SIP was the emission inventory. This section provided an estimate of the amounts of PM_{10} emissions coming from specific sources. To perform this analysis, the District chose 2005 as the baseline year, from which future emission estimates were calculated based on factors such as growth trends and reductions from rules and regulations. The results of the analysis showed that the greatest sources of PM_{10} emissions in the Imperial Valley Planning Area from 2006 to 2010 were from fugitive dust. More specifically, area-wide dust sources and windblown dust were responsible for the vast majority of the emissions, together comprising approximately 97 percent of PM_{10} emissions for all of Imperial County in 2006. Estimates for 2007 to 2010 were similar.

The conclusions reached based on the emission inventory provided the basis for the next major requirement: the District control strategy. Since the CAA requires Serious nonattainment areas to implement BACM for all area sources considered to be significant contributors to violations of the federal standard, a strategy was created to address them. It was found that there were only two significant area source categories in the emission inventory: agricultural tilling and unpaved

[12] Imperial County was only implementing one-in-six day monitoring at this time; therefore, five measured exceedances would have been interpreted as 30 "expected" exceedances under Appendix K to 40 CFR Part 50.

[13] United States Environmental Protection Agency. 2016. *Treatment of Data Influenced by Exceptional Events; Final rule; notification to states with areas subject to mitigation requirements; final guidance.* Federal Register. Vol. 81. No. 191. October 3, 2016. p. 68216.

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road dust. Although these were the only two source categories requiring BACM, in 2005 the District developed a set of fugitive dust rules to address multiple different sources. Collectively, these rules are known as Regulation VIII. In total, the six source categories covered by Regulation VIII are construction and earthmoving activities, bulk materials, carry-out and track-out, open areas, paved and unpaved roads, and agricultural conservation management practices, with the last two specifically addressing the significant area sources identified in the emission inventory. By 2006, the rules were submitted to the USEPA, but no action was taken until February 2010, at which time the USEPA proposed only a partial approval of the rules.[14] The USEPA also identified several rule components which they believed required additional analysis in order to demonstrate BACM-level equivalence.

In response to the partial approval/disapproval of the rules and SIP submission, the District and the California Department of Parks and Recreation challenged the USEPA's decision and related actions on proposed exceptional events.[15] These challenges were overseen by the U.S. Court of Appeals for the Ninth Circuit, which ultimately suggested that the parties engage in a discussion to determine if the dispute could be resolved through a settlement agreement.

1.4.2 Settlement Agreement

On February 17, 2012, the U.S. Court of Appeals issued an Order that directed the parties in litigation to undergo mediation. Eventually a Settlement Agreement was reached, the details of which were published in the Federal Register on August 21, 2012.[16] Several specific stipulations were put forth by the agreement (provided as Appendix B), which ICAPCD and the USEPA were required to adhere to for a speedy approval and subsequent promulgation of the revised rules. First, the proposed agreement required that the District revise Regulation VIII and submit it to the District Governing Board within ninety days of the execution of the settlement. Additionally, the revisions were to be substantially the same as those laid out within the Settlement Agreement, and meet all local, state, and federal administrative requirements before they could be incorporated into the revised SIP. Second, the Settlement Agreement required that once the District Governing Board adopted the rules, the District had fourteen days to submit them to the California Air Resources Board (CARB) for expedited submittal to the USEPA to be incorporated into the California SIP. Third, it was required that the USEPA sign for publication in the Federal Register a proposal to take action on the submission within sixty days of the submittal by CARB. As long as the revised Regulation VIII was substantially the same as set forth in the Settlement Agreement, the USEPA had to propose full approval of the submission.

Fourth, once the USEPA approved the submission, they also had to make a statement that their preliminary determination was that the revised Regulation VIII constituted "reasonable control" of the sources covered by it, "for the purpose of evaluating whether the exceedance of the PM_{10}

[14] United States Environmental Protection Agency. 2010. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Final rule.* Federal Register. Vol. 75. No. 130. July 8, 2010. p. 39366.

[15] See *Imperial County Air Pollution Control District v. EPA,* No. 10-72709 (9th Cir.) and *California Department of Parks and Recreation v. EPA*, No. 10-72729 (9th Cir.).

[16] United States Environmental Protection Agency. 2012. *Proposed Settlement Agreement, Clean Air Act Citizen Suit; Notice of Proposed Settlement Agreement; Request for Public Comment.* Federal Register. Vol. 77. No. 162. August 21, 2012. p. 50506.

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NAAQS is an 'exceptional event' including reasonable and appropriate control measures on significant contributing anthropogenic sources." It is important to note that this statement only applied to the exceedance of the PM_{10} NAAQS and no other pollutant standards. In addition, events that differ significantly from those discussed during mediation in terms of meteorology, sources, or conditions were excluded. Fifth, the USEPA was to make a determination to defer imposition of any previously assigned sanctions pursuant to the Administrative Procedure Act, 5 U.S.C. 553(d)(1), pending public comments on the proposed action. Sixth, the USEPA was to take final action on the Regulation VIII submission within sixty days of the public comments. Then, the USEPA was required to deliver the notice of final rulemaking promptly to the Office of Federal Register for final review and publication.

Along with these six major requirements, the Settlement Agreement also included a set of provisions to detail the consequences if either the District or the USEPA failed to adhere to the terms of the agreement. However, both parties executed their ends of the agreement in a timely manner, and the provisions did not need to be enforced. On October 16, 2012, the rule revisions in the Settlement Agreement were adopted by ICAPCD and submitted to the USEPA soon after on November 7, 2012. Finally, on January 7, 2013,[17] the USEPA proposed to approve the revisions to Regulation VIII and opened it for public comment. After thirty days, the USEPA finalized both the approval of the revisions and a temporary termination of previously imposed highway funding sanctions.

1.5 Document Organization

The District is requesting redesignation of the Imperial Valley Planning Area from Serious nonattainment to attainment of the PM_{10} NAAQS under CAA Section 107(d)(3)(E) protocol.

Section 107(d)(3)(E) of the CAA requires the USEPA administrator to make five findings prior to granting a request for redesignation:

1. The USEPA has determined that the NAAQS has been attained.
2. The applicable implementation plan has been fully approved by the USEPA under Section 110(k).
3. The USEPA has determined that the improvement in air quality is due to permanent and enforceable reductions in emissions.
4. The State has met all applicable requirements for the area under Section 110 and Part D.
5. The USEPA has fully approved a maintenance plan, including a contingency plan, for the area under Section 175A.

As will be described in the following Chapter, PM_{10} air quality in the Imperial Valley Planning Area, excluding exceptional events, did not violate the NAAQS from 2014 through 2016. Therefore, Chapter 2 provides information on the required monitoring network and confirmation that the 2014-2016 24-hour PM_{10} concentration data shows attainment of the NAAQS. Chapter 3 describes the PM_{10} Control Strategy, including adopted Regulation VIII fugitive dust

[17] United States Environmental Protection Agency. 2013. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Proposed rule.* Federal Register. Vol. 78. No. 4. January 7, 2013. p. 922.

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rules, that has led to permanent and enforceable emissions reduction in the area and that USEPA approved as BACM for significant sources in 2013 (see Section 1.4 for a summary of the previous 2009 PM_{10} SIP submittal, subsequent Settlement Agreement with the USEPA, and USEPA's approval of Imperial County's fugitive dust rules as BACM for significant sources). Chapter 4 addresses the applicable requirements for a maintenance plan and CAA Section 110 and Part D, including emission inventories, continuous monitoring requirements, and contingency provisions. Chapter 5 discusses issues related to the contraction of the Salton Sea and federal, state, and local programs to stabilize the playa as it becomes exposed. Chapter 6 is the formal redesignation request. Together these chapters directly address and satisfy the requirements of CAA Section 107. Chapter 6 also includes a checklist of all these satisfied requirements.

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2 PM_{10} Air Quality

2.1 Overview

As briefly described in the previous section of this document, PM_{10} air quality in the Imperial Valley Planning Area, excluding exceptional events, did not violate the NAAQS from 2014 through 2016. This Chapter describes a monitoring network that is consistent with CAA Section 110 and Part D requirements and demonstrates that the 2014-2016 24-hour PM_{10} concentration data shows attainment of the NAAQS. According to USEPA guidance, a demonstration of attainment of the PM_{10} standard must rely on three complete, consecutive calendar years of quality-assured air quality monitoring data collected in accordance with 40 CFR Part 50, Appendix J. The NAAQS allows for one exceedance of the 24-hour PM_{10} standard per year averaged over a three consecutive calendar year period.

2.2 Imperial County Air Monitoring Network

During the 2014-2016 time period, ICAPCD operated filter-based, size-selective inlet (SSI) PM_{10} monitors at five stations located in the populated areas of the County (see Figure 2-1): Calexico-Ethel, El Centro, Brawley, Westmorland, and Niland.[18,19] These stations form a monitoring network oriented south to north from the United States-Mexico border. These SSI monitors meet federal performance criteria and historically had been the sole source of official data for long-term air quality planning and attainment demonstrations. Beginning in 2013, data collected by collocated Beta Attenuation Mass (BAM) monitors at the Brawley and Niland stations were deemed suitable for submission to the USEPA Air Quality System (AQS) and subsequent regulatory compliance evaluations. Similar data became available at the Westmorland and El Centro stations beginning in the third quarter of 2015 and at the Calexico-Ethel station in the first quarter of 2016. Detailed information regarding these monitors is provided below.

Calexico-Ethel - The Calexico-Ethel monitoring station was installed in 1994 and is operated and maintained by CARB. Located above sea level, it has an absolute location of latitude 32° 40’ 34” and longitude 115° 28’ 59”. Its relative location is 1029 Belcher Street within the property boundary on the southeast corner of the Calexico High School football field parking lot. To the north is located an athletic sports field used for football, baseball, and track. The monitoring station is surrounded by a suburban neighborhood directly to the south, southeast, and southwest and is approximately 0.75 miles (1.2 kilometers) directly north of the international border crossing. The site currently records measurements for ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), $PM_{2.5}$, PM_{10}, lead (Pb), and toxics.

El Centro - The El Centro monitoring station was installed in 1986. Located above sea level, its absolute location is latitude 32° 47’ 32” and longitude 115°33’ 47”. Its relative location is 150

[18] The Calexico-Grant station was permanently decommissioned after July 2007.

[19] The minimum number of monitors required by USEPA regulations (40 CFR Part 58, Appendix D) for the purpose of PM_{10} air quality monitoring in an area is based on the population of the area and on the nature of the PM_{10} air quality in the area. For the Imperial County area, the five PM_{10} monitors currently operated by CARB and ICAPCD are well in excess of the 1-2 monitors needed to satisfy the federal minimum requirements (CARB. 2015. Annual Monitoring Network Report for Twenty-five Districts in California. Volume I. June. Available at: http://www.co.imperial.ca.us/AirPollution/Monitoring/2015%20Annual%20Network%20Plan_Volume%201.pdf. Accessed: June 2018.).

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South 9th Street on the roof of the ICAPCD building. The monitoring station is surrounded by governmental and commercial buildings. It is the first monitoring site north of the city of Calexico, continuing the south to north monitoring network for Imperial County. The El Centro monitoring station is classified as urban with large agricultural areas to the east and west of the city's boundaries. This site records measurements for O_3, CO, NO_2, $PM_{2.5}$, and PM_{10}.

Brawley - The current Brawley monitoring station, which was installed in 2003 as a new station, replaced the old one which was installed in 1982. It is located below sea level and has an absolute location of latitude 32° 58' 42" and longitude 115° 32' 21". Its relative location is 220 Main Street atop the Imperial County courthouse in the middle of the city of Brawley, surrounded by commercial buildings. Like other cities within Imperial County, Brawley is surrounded by agricultural lands to the east, north, and west. The Brawley station is the third northernmost station within the Imperial County monitoring network. This site records measurements for $PM_{2.5}$ and PM_{10}.

Westmorland - The Westmorland monitoring station was installed in 1994. Located below sea level, its absolute location is latitude 33° 1' 57" and longitude 115° 37' 25". Its relative location is 570 Cook Street in Westmorland. The site is the second northernmost station within the Imperial County monitoring network. It lies west of the Brawley monitor, but southwest of the Niland monitor. Residential and agricultural areas lie within 10 meters and 400 meters of the site. The site originally monitored both O_3 and PM_{10} concentrations; however, in November 2012, the station experienced an electrical fire and the O_3 monitor was placed out of commission.

Niland - The Niland monitoring station was installed in 1996. Located below sea level, its absolute location is latitude 33° 12' 49" and longitude 115° 32' 43". Its relative location is 7711 English Road. It is adjacent to English Road which is an unpaved and lightly traveled road (approximately 100 vehicles per day). The monitoring site is surrounded by agricultural land to the south, southwest, and southeast. A single residence exists to the west of the station, across English Road. The monitoring station is southeast of Riverside County and the Salton Sea and is the most northerly site within the Imperial County monitoring network. The site records measurements for O_3 and PM_{10}.

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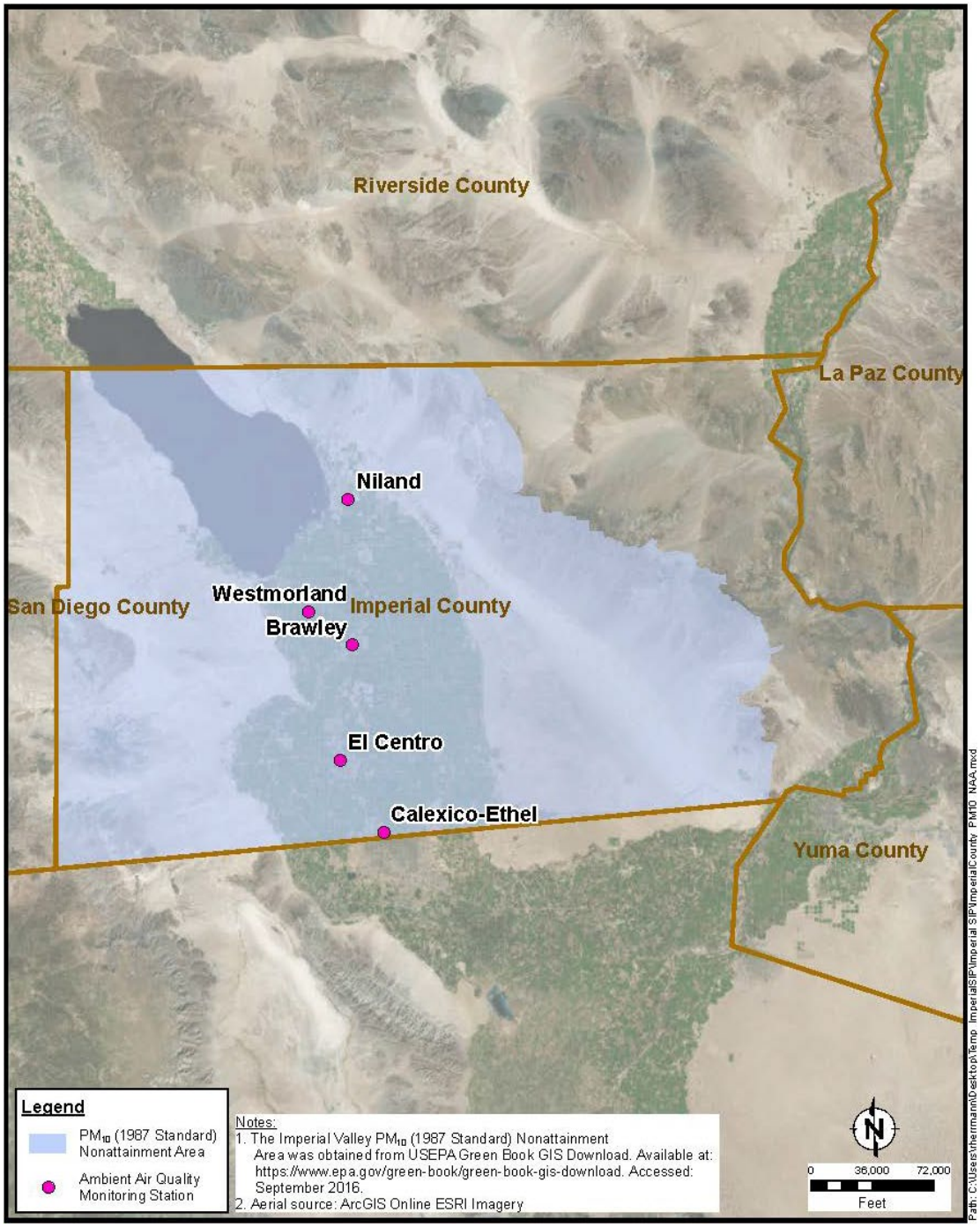

Figure 2-1. Locations of Imperial County PM_{10} monitoring stations

2.3 Ambient Air Quality Data (2014-2016)

SSI and BAM monitor measurements acquired during 2014-2016 are plotted by station in Figure 2-2 and tabulated in Appendix C, Table C-1.[20] The plots reveal that the overwhelming

[20] Table C-2 in Appendix C presents data completeness information by monitor parameter occurrence code and year.

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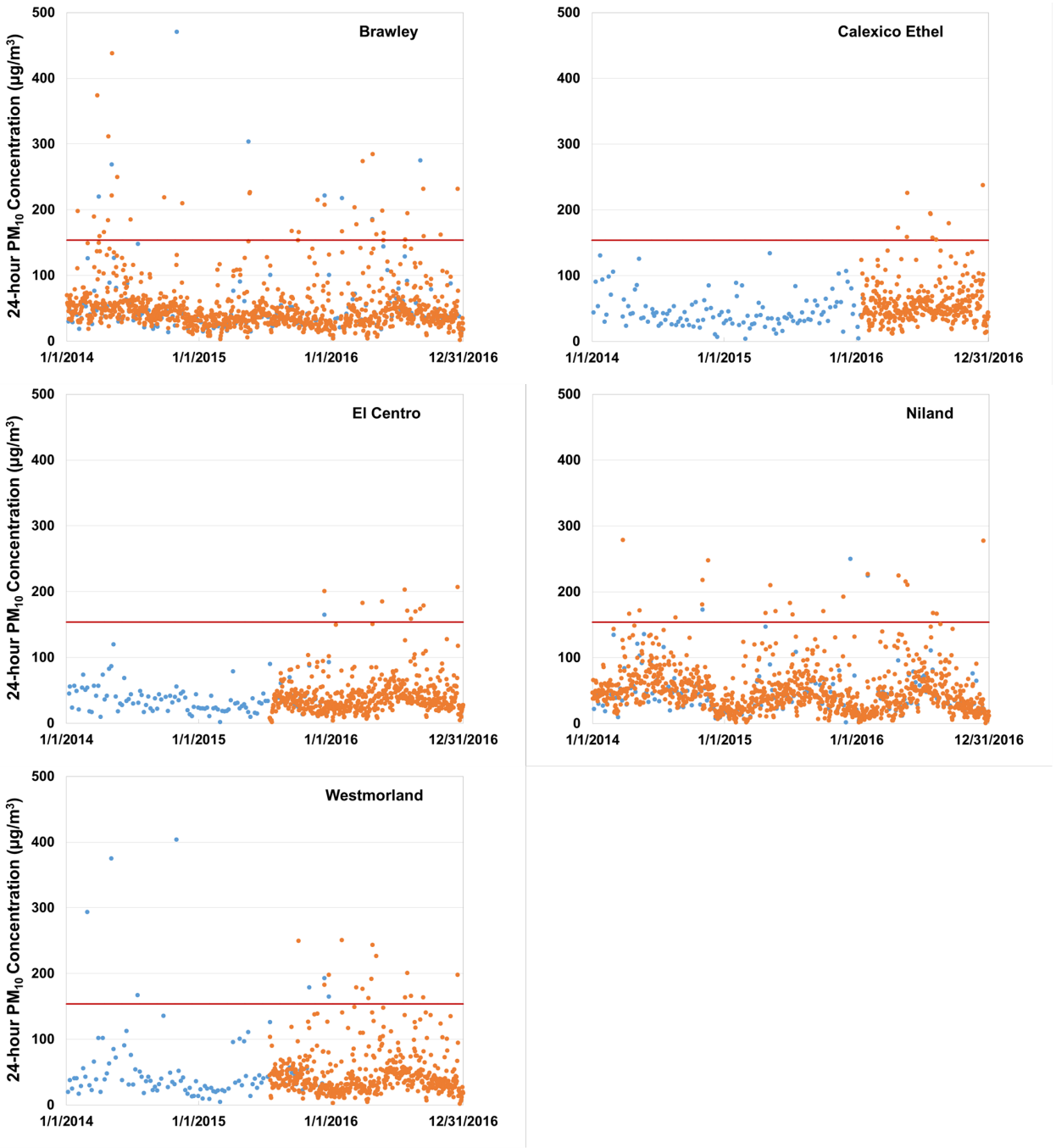
majority of 24-hour ambient PM_{10} concentration measurements are well below the 150 µg/m^3 NAAQS: only three to nine percent of measurements at those stations were above 100 µg/m^3 during 2014-2016, and only 21 to 48 percent were above 50 µg/m^3.

Figure 2-2. Time series plots of 24-hour PM_{10}



Time-series plots of 24-hour PM_{10} ambient air concentration in Imperial County during 2014-2016. Blue-colored measurements are from 1-in-6 day monitors, while orange-colored measurements are from daily monitors. Tabulated results are provided in Appendix C, Table C-1.

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2.3.1 Exceptional Events

The USEPA promulgated a Natural Events Policy (NEP) in 1996, allowing exclusion of "PM_{10} air quality data…attributable to uncontrollable natural events from the decisions regarding an area's nonattainment status."[21] This policy enabled local air districts to exclude from the decisions regarding an area's attainment status documented high ambient PM_{10} air quality data that were caused by uncontrollable natural events such as (i) volcanic, seismic activity, (ii) wild land fires, and/or (iii) high wind episodes.[22] The NEP has been incorporated into and superseded by the 2007 Exceptional Event Rule, discussed below.

As of May 21, 2007, states petitioning the USEPA to exclude any air quality monitoring data from regulatory determinations related to compliance with the NAAQS must comply with the USEPA's updated Exceptional Event policy.[23] The rule defines an Exceptional Event as one that "affects air quality, is not reasonably controllable or preventable, is caused by a natural event or by human activity that is unlikely to recur at a particular location, and is determined by the USEPA to be an exceptional event." A clear causal relationship must be established between a measured exceedance of a NAAQS and an exceptional event in order to exclude the exceedance from regulatory determination of an area's attainment status. In September of 2016, the Exceptional Events Rule was updated[24] in order to increase the efficiency of the process by which these events are demonstrated and reviewed. One specific change to the rule was a revision of its language to more closely align with that of the CAA. This included removing the "but for" criterion and adding the "affects air quality" and "historical fluctuations" criteria. Other changes to the rule include clarifying the analyses, content, and organization for demonstrations of exceptional events, requiring that the air agency send an initial notification to USEPA of a potential exceptional event demonstration, and removing specific exceptional event-related deadlines, among others. The final action of approving the revisions to the rule supersedes both the 2007 Exceptional Events Rule and the 2013 Interim Exceptional Events Implementation Guidance.

[21] United States Environmental Protection Agency. 1996. Areas Affected by PM-10 Natural Events. Memorandum from Mary D. Nichols to USEPA Division Directors. June 6. Available at: https://www3.epa.gov/ttn/naaqs/aqmguide/collection/cp2/19960530_nichols_pm10_natural_events.pdf. Accessed: June 2018.

[22] As a requirement for data flagging and data exclusion from NAAQS compliance determination, the NEP required states to develop area-specific Natural Events Action Plans (NEAPs) designed to protect public health through public education, public notification, and efforts to minimize emissions from contributing anthropogenic sources during natural events. The ICAPCD satisfied this requirement by collaborating with local governments and stakeholders to develop the Imperial County NEAP document in 2005. The Imperial County NEAP, which dealt specifically with natural events caused by high winds and wildland fires, was adopted by the ICAPCD Board of Directors on August 9, 2005. The Imperial County NEAP development process involved the development of BACM measures to satisfy the requirements of controlling and abating wind-generated dust from anthropogenic sources.

[23] United States Environmental Protection Agency. 2007. *Treatment of Data Influenced by Exceptional Events; Final Rule*. Federal Register. Vol. 72. No. 55. March 22, 2007. p. 13560.

[24] United States Environmental Protection Agency. 2016. *Treatment of Data Influenced by Exceptional Events; Final Rule*. Federal Register. Vol. 81. No. 191. October 3, 2016. p. 68216.

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2.3.2 Exceedances of the 24-Hour PM_{10} NAAQS (2014-2016)

In the 2014 to 2016 time period, Imperial County experienced 58 days with PM_{10} concentrations in excess of the 24-hour NAAQS. As shown in Table 2-1, all of these exceedances were due to Exceptional Events. These events were primarily caused by gusty westerly winds brought on by low pressure systems. A smaller fraction of the events were the result of monsoonal fronts passing through the region. Additional details regarding these events are provided in Appendix D. These events were documented, publicly noticed, and are being submitted to the USEPA in separate submittals. In contrast to the variation in the number of high readings over these three years, we note that Imperial County emissions (and related underlying activity) did not change appreciably over this period.

Table 2-1. Expected Exceedances of 24-hour PM_{10} NAAQS at Imperial County Air Quality Monitoring Stations from 2014 to 2016

Station Name	POC [1]	Expected Exceedances [2,3], including Exceptional Events			Expected Exceedances [2,3], excluding Exceptional Events		
		2014	2015	2016	2014	2015	2016
Brawley	1	21	13	18	0	0	0
	3	13	6	21	0	0	0
Calexico-Ethel	1	0	0	0	0	0	0
	3	--	--	9	--	--	0
El Centro	2	0	6 [4]	--	0	0	--
	4	--	1	10	--	0	0
Niland	1	6	6	6	0	0	0
	3	7	7	9	0	0	0
Westmorland	1	25	31	--	0	0	--
	3	--	3	18	--	0	0

Notes:

[1] Parameter Occurrence Codes (POCs) 1 and 2 represent 1-in-6 day monitoring, whereas POCs 3 and 4 represent continuous, daily monitoring.

[2] Expected exceedance data is observed exceedance data adjusted to account for exceedances measured at monitors with incomplete data or those sampling less frequently than daily.

[3] "--" indicates monitor not in service or data not reported.

[4] A potential discrepancy with how this value is reported within AQS is being resolved by USEPA Region IX.

2.4 Section 110 and Part D Requirements – Monitoring and Analysis

CAA Section 110 contains the general requirements for SIPs and Part D specifies additional requirements applicable to nonattainment areas. Both Section 110 and Part D describe the elements of a SIP and include, among other things, a monitoring network and air quality analysis. These two requirements have been adequately addressed in this Chapter.

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With the submittal of this redesignation request and maintenance plan, Imperial County meets all SIP requirements applicable to the area under Section 110 and Part D, as required by CAA Section 107(d)(3)(E), and requests that approval action on these items occurs simultaneously with this redesignation request. Refer to the checklist in Chapter 6 for a summary of how all applicable requirements have been addressed.

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3 Control Strategies - Permanent and Enforceable Emission Reductions

Reclassification of the Imperial Valley Planning Area to Serious nonattainment in 2004 prompted the ICAPCD to begin the development of revised Regulation VIII fugitive dust control rules at the BACM level. This process was initiated ahead of SIP development[25] to accelerate BACM implementation and to meet the requirements and schedule of the District's National Events Action Plan (NEAP) (approved in August 2005). In March 2004, the ICAPCD began a review and assessment of BACM in other areas. Rule development, initiated at a stakeholder meeting in October 2004, was conducted in a public process that involved a local Technical Advisory Committee[26] as well as state and federal air agencies.[27] The process resulted in the adoption in November 2005 of revised Regulation VIII fugitive dust control measures, which form the core of the Imperial County PM_{10} control strategy.[28] Provisions in these rules went into effect in January 2006.[29]

The control strategy consists of rules adopted in 2005 and 2012 that have been determined by the USEPA as meeting BACM-level stringency for sources previously identified as significant. An updated significant source analysis shows that no new emission sources would qualify as significant that weren't identified previously. Therefore, no new control measures are being proposed with this Plan.

After its initial review of the newly updated Regulation VIII in February 2010, the USEPA proposed only a partial approval of the rules. The District challenged this decision, and the dispute led to litigation within the U.S. Court of Appeals, and ultimately to a Settlement Agreement. The terms of the Settlement Agreement included agreed-upon revisions to the rules and a schedule for resubmittal to and approval by the USEPA. A more thorough description of the Settlement Agreement is provided in Section 1.4.2. Both ICAPCD and the USEPA adhered to the terms of the Settlement Agreement and the revised rules were ultimately approved by the USEPA in early 2013 and determined to meet BACM-level stringency for significant sources of PM_{10}, a requirement for Serious nonattainment areas under the CAA. Ultimately, four out of the seven Regulation VIII rules were amended including Rules 800, 804, 805, and 806. The changes to these rules included more specific definitions of agricultural dust management practices, opacity, and stabilization requirements for

[25] The USEPA did not take final action regarding nonattainment of the Imperial Valley Planning Area until December 2007.

[26] Including representatives from the Coalition of Labor and Business, the Farm Bureau, the Bureau of Land Management, Border Patrol, the Imperial Irrigation District (IID), the Imperial County Public Works Department (ICPWD), as well as farmers and private industry stakeholders.

[27] Meetings with the CARB and the USEPA were held on March 23, 2005 and on August 10, 2005. Informal comments were also submitted by the California Department of Transportation.

[28] Note that additional controls of PM_{10} emissions in Imperial County are outlined in ICAPCD Rule 420 (beef feedlots) and Rule 701 (agricultural burning). These rules, which were most recently updated in October 2006 and August 2002, respectively, are SIP approved.

[29] The only exception was that control of county unpaved roads under Rule 805 was phased over a 10-year period.

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high-traffic agricultural roads and more detailed requirements for land managers to control dust from off-highway vehicle (OHV) areas. More recently, in April 2016, Rule 804 was updated to accommodate the changing conditions and potential future emissions at the Salton Sea. More on the amendments to Rule 804 is provided below.

An update to Imperial County's significant source analysis shows that no new PM_{10} emission sources would qualify as significant that haven't been identified previously as such (see Appendix E for details). This finding implies that all significant sources of PM_{10} in Imperial County are currently being controlled to BACM-level stringency. Therefore, no new control measures are being proposed with this Plan.

The section below provides a summary of the current Regulation VIII fugitive dust rules. Only a brief description of the control measures of the Regulation VIII rules are presented in this section; the complete rules are provided in Appendix F.

3.1 Regulation VIII Rules

3.1.1 Rule 800: General Requirements for Control of Fine Particulate Matter

Purpose and Requirements: The purpose of Regulation VIII is to reduce the amount of PM_{10} entrained in the ambient air as a result of anthropogenic fugitive dust sources generated from within Imperial County. The rules of Regulation VIII require that landholders and other responsible parties take specific actions in order to prevent, reduce, or mitigate PM_{10} emissions. The rules apply to human activities or human-caused conditions capable of generating fugitive dust. The purpose of Rule 800 specifically is to define all the relevant terms that appear throughout the regulation, such as what constitutes "fugitive dust", the characteristics of "open areas", and the requirements for labeling a surface as "stabilized." Also included in this rule are a compliance schedule, descriptions of exempt activities, and the test methods for determining if responsible parties are in compliance with the rules' requirements.

Rule Revisions: Rule 800 was revised as part of the Settlement Agreement to both edit and add new definitions to the list of defined terms. Terms that were added or revised include "Disturbed Surface Area", "Off-Road Event and/or Competitions", "Off-Highway Vehicle" (changed from "Off-Road Vehicle"), and "Recreational Off-Highway Vehicle Use Area". An important update to the compliance schedule added a requirement that any person who owns or operates a Recreational OHV Use Area must draft and submit a dust control plan. Before the revision, only the Bureau of Land Management or United States Border Patrol were required to do so. Additionally, updates to the rule require that a public agency must meet and confer with ICAPCD before they can designate a property as a "New Recreational OHV Use Area." The rule includes descriptions of all the necessary steps required to do this.

3.1.2 Rule 801: Construction and Earthmoving Activities

*Purpose and Requirements***.** The purpose of Rule 801 is to reduce the amount of PM_{10} that is emitted into the air as a result of construction and other earthmoving activities, such as land clearing, excavating, land leveling, grading, demolishing, etc. All persons who own or operate a construction site or who perform any earthmoving activities are required to limit visible dust emissions (VDE) to 20 percent opacity by complying with the following measures:

- Phase work to minimize the amount of disturbed surface area at one time;

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- Apply water or chemical stabilization;
- Construct and maintain wind barriers around the activity site;
- Restrict vehicular access to the area by fencing or signage;
- Mitigate track out/carry out of Bulk Materials[30] at the site in compliance with Rule 803; and
- Transport Bulk Material to, from, and around the site in compliance with Rule 802.

Dust Control Plan. Owners or operators of construction/earthmoving sites greater than or equal to 10 acres for residential developments and greater than or equal to 5 acres for non-residential development are required to provide written notification to the ICAPCD 10 days prior to the commencement of activities, and to develop a dust control plan. The plan is expected to document the type and location of the project, the expected start and completion dates of the dust generating activities, the total area of land surface to be disturbed, the actual and potential sources of fugitive dust emissions on the site (including the location of Bulk Material handling and storage areas, paved and unpaved roads, entrances and exits where track out/carry out may occur, etc.), and all the fugitive dust control measures to be implemented before, during, and after any dust-generating activity.

3.1.3 Rule 802: Bulk Materials

Purpose and Requirements. The purpose of Rule 802 is to reduce the amount of PM_{10} that is emitted into the air as a result of outdoor handling, storage, and transport of Bulk Material. The rule requires implementation of the following controls in order to limit VDE to 20 percent opacity:

- For Bulk Material handling (e.g. stacking, loading, unloading, conveying, etc.), control measures include spraying with water, applying and maintaining chemical stabilization, and protecting from wind erosion by sheltering or enclosing;
- For Bulk Material storage, control measures include confinement of the material using a physical barrier (e.g. covering with tarps, plastic, etc.) and confinement by applying water or other chemical/organic stabilizers/suppressants;
- For Bulk Material transport/hauling, control measures include complete covering or enclosing of all haul truck loads, proper selection and maintenance of the cargo compartments of haul trucks to ensure no spillage or loss of Bulk Materials from holes or openings in the compartment's floor, side, or tailgate, and adequate cleaning of the cargo compartment of all haul trucks at the delivery site after removal of Bulk Material.

3.1.4 Rule 803: Carry-Out and Track-Out

*Purpose and Requirements***.** The purpose of Rule 803 is to reduce the amount of PM_{10} that is entrained in the ambient air as a result of Track-Out and Carry-Out[31] occurring on paved public roads. The rule requires mitigation of the deposition of Bulk Material by tracking out/carrying out onto a paved road surface by implementation of the following controls:

[30] Bulk Material is any organic and/or inorganic material consisting of or containing particulate matter with greater than or equal to 5 percent silt content, including materials such as earth, rock, silt, sediment, sand, gravel, soil, fill, aggregate, dirt, mud, or debris.

[31] Track-out/carry out refers to any Bulk Material that adhere to and agglomerate on the exterior surfaces of motor vehicles and/or equipment (including tires) that may then fall onto the pavement.

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- Any Bulk Material tracked out or carried out onto a paved road is to be cleaned up at the end of the workday (or immediately if within an urban area and Track-Out or Carry-Out extends a cumulative distance of greater than or equal to 50 feet);
- All sites with access to a paved road and with greater than or equal to 150 Average Vehicle Trips per Day[32] (AVTD) are to (i) install one or more Track-Out prevention devices and (ii) apply and maintain paving, chemical stabilization, or gravel for a distance of greater than or equal to 50 consecutive feet, at access points where unpaved roads adjoin paved roads.

3.1.5 Rule 804: Open Areas

Purpose and Requirements. The purpose of Rule 804 is to reduce the amount of PM_{10} that is emitted from non-agricultural[33] open areas, such as vacant portions of residential or commercial lots. The rule applies to any open area of greater than or equal to 0.5 acres within urban areas, or greater than or equal to 3 acres within rural areas, that contain greater than or equal to 1,000 square feet of disturbed surface area. Rule 804 requires all persons who own or otherwise have jurisdiction over an open area to prevent vehicle use in the open area by posting "No Trespassing" signs or installing physical barriers to prevent trespassing. In addition, surface stabilization is required in open areas to limit VDE to 20 percent opacity by (i) applying water or dust suppressant(s) to all unvegetated areas, (ii) establishing vegetation on all previously disturbed areas, (iii) paving, applying and maintaining gravel, or applying and maintaining chemical stabilizers/suppressants, and/or (iv) by applying alternative BACM, so long as the alternative BACM has been tested and approved by ICAPCD.

Rule Revisions. Rule 804 was revised as a result of the Settlement Agreement to include an exemption for recreational OHV use areas on public lands which are already subject to Rule 800. The 2016 revisions to Rule 804 included a fourth option for controlling dust in open areas by adding language which allows for the development and approval of new types of BACM or "alternative" BACM. This amendment was strategically proposed as a contingency measure for controlling dust on unstabilized playa exposed as the Salton Sea recedes. A more detailed explanation of the Rule 804 revisions and the Salton Sea is found in Chapter 5.

3.1.6 Rule 805: Paved and Unpaved Roads

*Purpose and Requirements***.** The purpose of Rule 805 is to reduce the amount of PM_{10} that is windblown or entrained from new or modified paved roads, from unpaved traffic areas and all non-farm[34] unpaved roads, or from road construction or road modification projects in Imperial County. The rule requirements are the following:

- For unpaved haul/access roads, unpaved traffic areas larger than 1 acre and with greater than or equal to 75 AVTD, unpaved roads with greater than or equal to 50 AVTD, and canal roads with greater than or equal to 20 AVTD, VDE must be limited to 20 percent opacity by applying at least one of the stabilization methods described below;

[32] Or ≥20 AVTD by vehicles with three or more axles.
[33] Emissions from agricultural open areas are controlled by regulations outlined in Rule 806.
[34] Emissions from agricultural unpaved roads are controlled by regulations outlined in Rule 806.

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- Parties responsible for the use of canal roads with greater than or equal to 20 AVTD are further required to implement one of a number of additional measures that include maintenance of canal bank surfaces, conversion of open canals to pipeline, installation of remote-control delivery gates to eliminate manual gate operation by maintenance personnel in vehicles along canal banks, or lining of canals to eliminate maintenance associated with the control of silt or weed;
- Construction of new unpaved roads is prohibited within any area with a population greater than or equal to 500, except for temporary activity and if the road is stabilized to limit VDE to 20 percent opacity;
- New or modified paved roads must be constructed with curbing adjacent to the travel lanes, or with shoulders of width two to six feet (depending on the frequency of road usage) that are either paved or that meet the conditions of a stabilized surface.

Stabilization Methods. BACMs for fugitive PM_{10} dust emitted from unpaved roads include stabilization of the unpaved surfaces by (i) paving, (ii) applying chemical stabilization as directed by the product manufacturer, (iii) applying and maintaining gravel, recrushed/recycled asphalt, or other material of low silt content (less than five percent) to a depth of three or more inches, or (iv) wetting by applying water one or more times daily.

Rule Implementation. Rule 805 requires each city or county agency with primary responsibility for any existing unpaved road to provide to the ICAPCD (by March 31, 2006) a compliance plan and a compliance schedule demonstrating implementation of Rule 805 to all unpaved roads within its jurisdiction at an incremental rate of no less than 10 percent per fiscal year during the time period of 2006-2015. General compliance with Rule 805 is required past 2015. The plan identifies the control measures selected for each unpaved road segment, and report of yearly progress is to be made to the APCD by July 31 of each year through 2015.

Rule Revisions. Rule 805 was revised as a result of the Settlement Agreement to include an exemption for recreational OHV use areas on public lands which are already subject to Rule 800. Additionally, a requirement for existing unpaved public roads was edited to mandate that the portions of road being stabilized each year are new, so that all roads were to be stabilized by 2015. This was done to prevent re-stabilization of the same length of roadway multiple times. Another update in this rule added a requirement that a list of all mitigated roads be supplied to ICAPCD and that these public roads must comply with the requirements of a stabilized unpaved road, as defined in the BACM section of Rule 805.

3.1.7 Rule 806: Conservation Management Practices

*Purpose and Requirements***.** The purpose of Rule 806 (effective since January 1, 2006) is to reduce the amount of PM_{10} emitted from agricultural operations in Imperial County. The rule requires all owners or operators of Agricultural Operation Sites of greater than or equal to 40 acres to implement in each Agricultural Parcel at least one Conservation Management Practice (CMP, described below) for each of the following categories: (i) land preparation and cultivation, (ii) harvest activities, (iii) unpaved roads, (iv) unpaved traffic areas, (v) cropland-other CMPs, and (vi) windblown dust control CMPs. Owners and operators are required to prepare, for each Agricultural Operation Site, a CMP Plan that must be made available to the ICAPCD upon request within 72 hours of notice.

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Conservation Management Practices for Fugitive Dust (PM_{10}). One or more of a number of listed CMPs must be implemented to satisfy the requirements of Rule 806. Owners or operators of Agricultural Operation Sites may develop and implement alternative CMPs, provided that the achieved PM_{10} emission reductions are at least equivalent to those obtained from CMPs listed for the applicable operation. An alternative CMP must receive approval by the ICAPCD after review of its technical merit before it may be included in a CMP Plan. A subset of the allowed CMPs is reported below for each category covered by Rule 806; a comprehensive listing of the practices is available on the ICAPCD webpage.[35]

- For the control of PM_{10} emissions from land preparation and cultivation, owners or operators may implement alternate tilling, non-tillage, or chemical tillage, chemigation/fertigation, covering of crops, land fallowing, mulching, or night farming;
- For the control of PM_{10} emissions from harvesting, owners or operators may implement green chopping, hand harvesting, night harvesting, pre-harvesting soil preparation, no-burning, or equipment changes/technological improvements;
- For the control of PM_{10} emissions from unpaved roads and unpaved traffic areas, owners or operators may implement graveling, paving, restricted access, speed limits, track-out control, or wind barriers.
- For the control of PM_{10} emissions from cropland-others, owners or operators may implement alternate tilling, mulching, organic practices, reduced tilling, and other CMPs in this category.
- For the control of windblown dust, the owner or operator must minimize the time that newly tilled soil is smooth when preparing a field for planting. This should be done by leaving the field surface with larger clods until immediately before bedding and planting the field. For fields that are in between crops or permanently fallow, at least one other CMP must be implemented, and options include surface roughening, creating wind barriers, managing crop residues, and other practices.

Rule Revisions. Rule 806 was revised as a result of the Settlement Agreement to include additional specifications on how certain agricultural activities are to be conducted in order to limit fugitive dust emissions. These activities include grinding prunings and orchard removals instead of burning them, surface roughening, planting rows of vegetation perpendicular to the direction of wind to create barriers, and many more. These new CMPs were added to existing categories of PM_{10} emission sources, as well as to two new ones: those deemed as “cropland-other” and those specific to windblown dust.

3.2 Record of Control Implementation

Any person subject to the requirements of any one of the Regulation VIII rules is required to compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). The records are expected to document the type of treatment or control measure, extent of coverage, frequency of application, and date applied. Records must be kept for at least two years and be made available to ICAPCD upon request.

[35] Available at: http://www.co.imperial.ca.us/AirPollution/index.asp?fileinc=compag. Accessed: June 2018.

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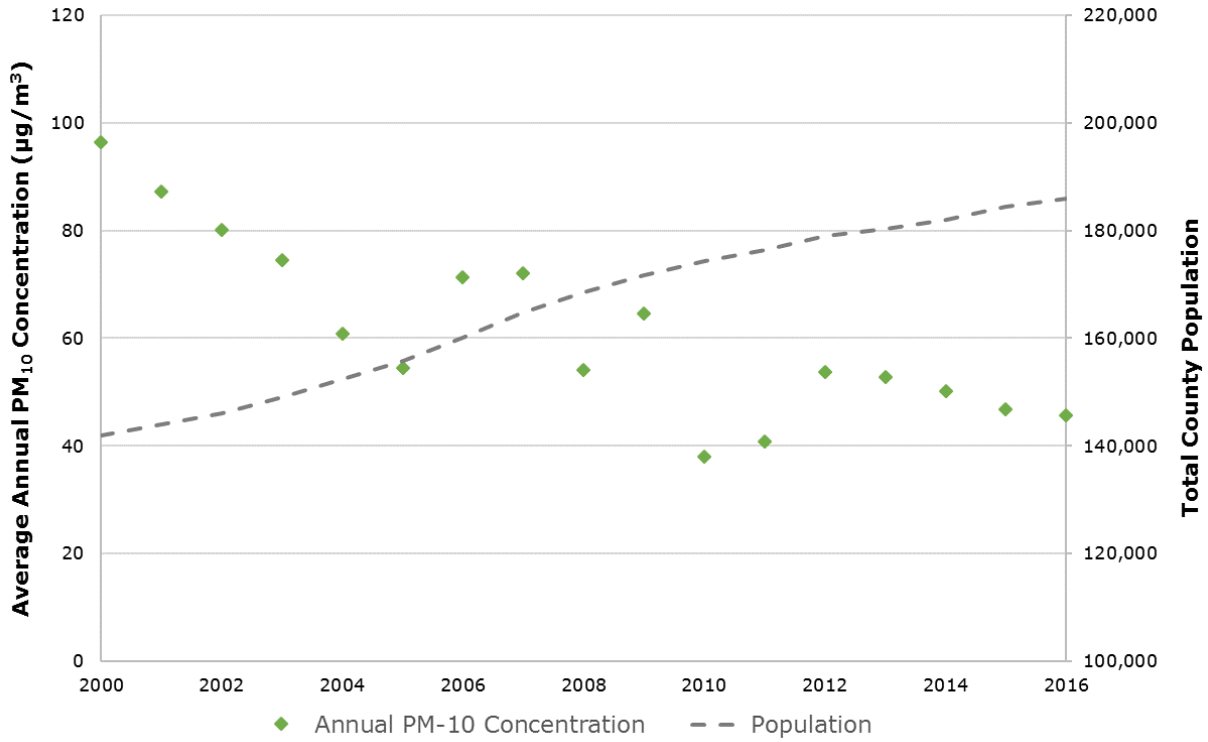
3.3 Permanent and Enforceable Emission Reductions

The USEPA eliminated an annual PM_{10} NAAQS in 2006,[36] though it is instructive to track annual PM_{10} values in order to observe trends. As shown in Figure 3-1, implementation of the Regulation VIII fugitive dust rules has led to a continual decline in annual average PM_{10} concentrations in Imperial County despite a steady increase in population.

Figure 3-1. Annual Average PM_{10} Concentration and Population in Imperial County from 2000 to 2016



The data in the above plot was provided by CARB. The annual average PM_{10} concentrations depicted in the plot represent the highest values measured at all Imperial County monitoring stations in each calendar year. Exceptional events have been excluded from the data sets.

The decrease in average annual PM_{10} concentration in Imperial County that is shown in Figure 3-1 is the result of the permanent, enforceable reductions that have been achieved due to implementation of the aforementioned rules. Since 2000, the average annual PM_{10} concentration in Imperial County, when exceptional events are excluded, has fallen from 96 µg/m^3 to 46 µg/m^3 in 2016. This represents an approximate 52 percent decrease in the general PM_{10} levels in Imperial County over that period. When exceptional events are included, the reduction is still substantial with an approximate 39 percent decrease over the 16-year period. It is technically possible for reductions of this magnitude to be attributed to other factors, such as a reduction in economic activity or unusually favorable meteorological conditions, but this is not

[36] Prior to its revocation, the annual PM_{10} NAAQS was 50 µg/m^3.

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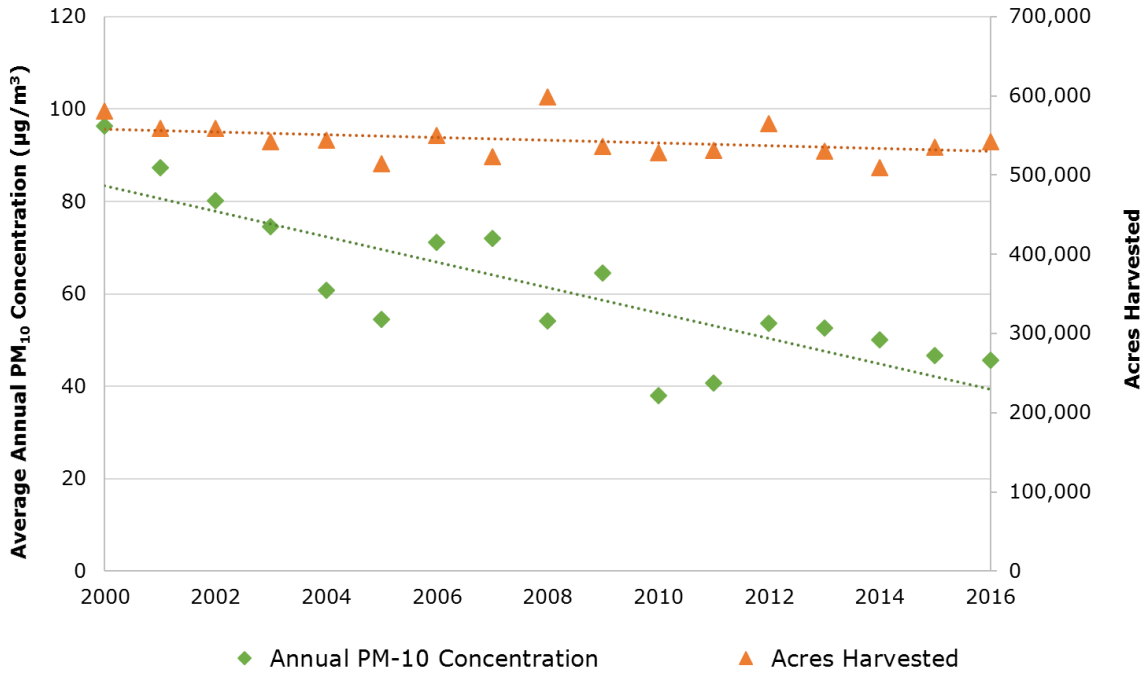
the case for Imperial County. In fact, these reductions have occurred despite a relatively small change in agricultural activity (as measured by total acres harvested), which can be used as a proxy for the local economy overall since agriculture is the largest industry in Imperial County.[37] Figure 3-2 displays the same PM_{10} concentration data shown in Figure 3-1, but also includes data from the annual Imperial County Agricultural Crop and Livestock Reports.[38]

Figure 3-2. Annual Average PM_{10} Concentration and Acres Harvested in Imperial County from 2000 to 2016



As the crop data show, the amount of agricultural activity in Imperial County has remained fairly constant since 2000. The number of acres harvested decreased by only 1.5 percent when comparing the numbers for 2016 and 2000. As a result, the relatively large decrease in average PM_{10} levels is likely attributable to other factors, such as the revisions to the Regulation VIII rules in the early 2000s and the subsequent effect on the Imperial County PM_{10} emission inventory.[39]

[37] El Centro Chamber of Commerce and Visitors Bureau. *Community*. Available at: https://web.archive.org/web/20101103174411/http://elcentrochamber.org/the-city-of-el-centro/community/. Accessed: June 2018.

[38] Total harvested acres. Data obtained from Imperial County annual Agricultural Crop and Livestock Reports, 2000-2016. Available at http://www.co.imperial.ca.us/ag/?page=iccr. Accessed: August 2018.

[39] According to CARB's Comprehensive Emissions Projection Analysis Model (CEPAM), total Imperial County PM_{10} emissions decreased by approximately 11 percent between 2000 and 2016. CARB's CEPAM is available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. Accessed: August 2018.

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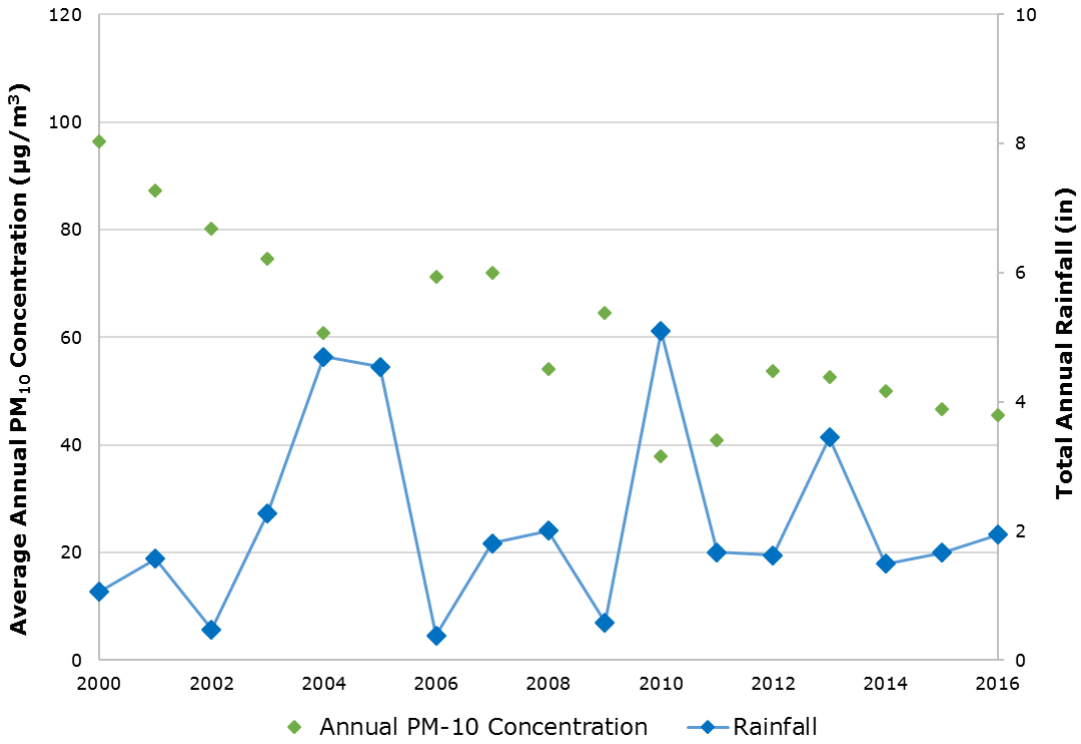
Another factor that can affect fugitive dust emissions (and as a result, ambient levels of PM_{10}) is rainfall. Outdoor surfaces with higher levels of moisture tend to emit less fugitive dust compared to drier surfaces of the same type. Thus, rain acts as a type of control for fugitive dust emissions, and enough rainfall can contribute to decreased PM_{10} levels. Figure 3-3 was created to aide in visualization of the relationship between ambient PM_{10} and precipitation. It displays the same PM_{10} concentration data shown in Figure 3-1 with annual rainfall data overlaid.[40]

Figure 3-3. Annual Average PM_{10} Concentration and Rainfall from 2000 to 2016



The data in the plot shows the average of the total rainfall in each year for all National Centers for Environmental Information Monitoring Stations in Imperial County with data available for the given year. The sharp increases in rainfall in 2004, 2005, and 2010 correlate with relative decreases in the annual average PM_{10} concentrations (excluding exceptional events), suggesting that the increased rainfall may have had an effect. However, it is important to note that while 2004 and 2005 were two of the top three rainiest years in the plotted period, they do not represent the lowest levels of ambient PM_{10}. Every year from 2010 to 2016 had the same or lower average PM_{10} concentrations (excluding exceptional events) than 2004 or 2005, despite also having lower amounts of rain. This illustrates that the observed reductions in the annual average PM_{10} concentrations in the most recent years are not attributable to favorable meteorology, but instead are the result of the permanent, enforceable reductions in PM_{10} emissions from sources where the District has focused control efforts.

[40] Data queried from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information for Imperial, County. Available at: https://www.ncdc.noaa.gov/cdo-web/. Accessed: June 2018.

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3.4 Section 110 and Part D Requirements – Control Strategy and Enforcement

CAA Section 110 contains the general requirements for SIPs and Part D specifies additional requirements applicable to nonattainment areas. Both Section 110 and Part D describe the elements of a SIP and include, among other things, enforcement mechanisms, and regulations which have been adopted by the state to attain or maintain the NAAQS. In its rulemakings on the Imperial County 2009 PM_{10} SIP and the subsequent Regulation VIII rule revisions, the USEPA ultimately confirmed that PM_{10} sources previously identified as significant were controlled to BACM-level stringency through Imperial County's rulebook.[41,42] An update to Imperial County's significant source analysis shows that no new PM_{10} emission sources would qualify as significant that haven't been identified previously as such (see Appendix E for details). This finding implies that all significant sources of PM_{10} in Imperial County are currently being controlled to BACM-level stringency. Therefore, no new control measures are being proposed with this Plan.

With the submittal of this redesignation request and maintenance plan, Imperial County meets all SIP requirements applicable to the area under Section 110 and Part D, as required by CAA Section 107(d)(3)(E), and requests that approval action on these items occurs simultaneously with this redesignation request. Refer to the checklist in Chapter 6 for a summary of how all applicable requirements have been addressed.

[41] United States Environmental Protection Agency. 2010. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Final rule.* Federal Register. Vol. 75. No. 130. July 8, 2010. p. 39366.

[42] United States Environmental Protection Agency. 2013. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Final rule.* Federal Register. Vol. 78. No. 77. April 22, 2013. p. 23677.

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4 Maintenance Plan

Section 107(d)(3)(E) of the CAA specifies that for an area to be redesignated as attainment, the USEPA must approve a maintenance plan that meets the requirements of Section 175A. The purpose of the maintenance plan is to provide for the maintenance of the 24-hour PM_{10} NAAQS for at least ten years after the redesignation (not ten years after the redesignation submittal). CAA Section 107(d)(3)(D) allows the USEPA Administrator up to 18 months from receipt of a complete submittal to process a redesignation request. To accommodate the USEPA's review time, this maintenance plan covers the period of the USEPA's approval (2018 to 2020) through the following ten years and features a maintenance demonstration, commitment to a future monitoring network, verification of continued attainment, a contingency plan, and provisions for contingency plan implementation.

Section 4.0 provides the proposed Imperial County PM_{10} Maintenance Plan. Section 4.1 presents the PM_{10} emission inventories for the attainment year (2016) and the period covered by this maintenance plan (2018-2030), as well as the transportation conformity budgets, all updated to include the latest planning assumptions. The maintenance plan also provides a commitment to maintain a future PM_{10} monitoring network in the Imperial Valley Planning Area to verify continued attainment of the NAAQS (Sections 4.2 and 4.3). Finally, Section 4.4 presents a contingency plan that addresses potential future air quality issues. The Imperial Valley PM_{10} Maintenance Plan defined in Section 4.0 of this document meets the criteria specified in CAA Sections 107 and 175A and upon approval by USEPA will complete the five criteria required for granting the Imperial County's request for redesignation to attainment of the PM_{10} NAAQS.

4.1 Maintenance Demonstration

According to USEPA guidance,[43] a maintenance plan may demonstrate future maintenance of the NAAQS by either showing that future emissions will not exceed the level of the attainment inventory or by modeling to show that the future mix of sources and emissions rates will not cause a violation of the NAAQS. The District has chosen the first approach to demonstrate future maintenance of the NAAQS.

4.1.1 Emissions Inventories

The inventories supporting this Plan were developed from CARB's California Emissions Projection Analysis Model (CEPAM), Version 1.05. Appendix G provides a full overview of the emission inventory development process. Appendix H presents comprehensive emission inventories for PM_{10} (including filterable and condensable components) as well as PM_{10} precursors.

Table 4-1 presents the PM_{10} emissions inventory for Imperial County for the attainment year, 2016, which shows average total daily emissions of approximately 284.17 tons PM_{10} per day. Consistent with the 2009 PM_{10} SIP, area-wide dust sources and windblown dust are responsible

[43] United States Environmental Protection Agency. 1992. Procedures for Processing Requests to Redesignate Areas to Attainment. Memorandum from John Calcagni to USEPA Regional Directors. September 4. Available at: https://www.epa.gov/sites/production/files/2016-03/documents/calcagni_memo_-_procedures_for_processing_requests_to_redesignate_areas_to_attainment_090492.pdf. Accessed: June 2018.

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for the vast majority of PM_{10} emissions in the County. Table 4-2 presents the PM_{10} emission inventory for Imperial County for the period covered by this maintenance plan, 2018 through 2030. As can be seen, the overall inventory is projected to remain fairly constant throughout the 2018-2030 maintenance period, only increasing 0.6 percent from 2016 to 2030. These modest increases are primarily due to the paved road dust, mineral processes, and construction and demolition emissions categories—sources that currently do not qualify as significant (as shown in Appendix E) and whose impact on the 24-hour PM_{10} NAAQS is generally *de minimis*.

As discussed previously, the 24-hour PM_{10} NAAQS is exceeded in Imperial County only under high wind conditions where fugitive dust from outlying desert and mountain areas becomes entrained. During these events, the temporary influx of particulate matter to the County increases 24-hour average concentrations much more than an equivalent increase of emissions of 0.6 percent. When exceptional events are excluded from the 2014-2016 design value calculation, as is provided for in the Exceptional Events Rule, the resulting design value for Imperial County, 149 $\mu g/m^3$, is approximately 3.8 percent less than the standard.[44] With this headroom, the slight increase in emissions from these sources would not be expected to cause an exceedance of the NAAQS.

[44] This is when assuming a standard value of 154.9 $\mu g/m^3$, since USEPA data handling procedures would round this value down to 150 $\mu g/m^3$, a value not above the standard.

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Table 4-1. PM_{10} Attainment Inventory for Imperial County, 2016 (tons per day)

Category[1]	2016
Electric Utilities	0.09
Manufacturing and Industrial	0.03
Food and Agricultural Processing	0.01
Service and Commercial	0.07
Food and Agriculture	0.30
Mineral Processes	3.67
Other (Industrial Processes)	0.01
Residential Fuel Combustion	0.05
Farming Operations	8.48
Construction and Demolition	3.02
Paved Road Dust	1.16
Unpaved Road Dust	51.88
Fugitive Windblown Dust	212.52
Managed Burning and Disposal	1.30
Cooking	0.08
On-road Mobile	0.43
Other Mobile	1.07
TOTAL	**284.17**

Notes:

[1] Sources with emissions less than 0.005 tons/day have been omitted from the table.

Abbreviations: BLM – Bureau of Land Management

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Table 4-2. PM_{10} Future Year Inventory for Imperial County, 2018-2030 (tons per day)

Category	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electric Utilities	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Manufacturing and Industrial	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Food and Agricultural Processing	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service and Commercial	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08
Food and Agriculture	0.31	0.32	0.32	0.33	0.33	0.34	0.34	0.35	0.35	0.36	0.36	0.37	0.37
Mineral Processes	3.95	4.08	4.22	4.35	4.48	4.61	4.75	4.89	5.03	5.17	5.32	5.47	5.62
Other (Industrial Processes)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residential Fuel Combustion	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Farming Operations	8.37	8.31	8.25	8.22	8.20	8.17	8.14	8.11	8.09	8.06	8.03	8.00	7.98
Construction and Demolition	3.29	3.40	3.51	3.59	3.66	3.71	3.76	3.82	3.90	3.98	4.06	4.14	4.22
Paved Road Dust	1.27	1.24	1.28	1.30	1.38	1.35	1.39	1.43	1.40	1.42	1.45	1.47	1.50
Unpaved Road Dust	51.85	51.84	51.83	51.82	50.22	50.21	50.20	50.20	50.19	50.18	50.18	50.17	50.16
Fugitive Windblown Dust	212.51	212.50	212.50	212.49	212.49	212.48	212.48	212.47	212.47	212.46	212.46	212.45	212.45
Managed Burning and Disposal	1.27	1.26	1.25	1.24	1.23	1.23	1.22	1.22	1.21	1.20	1.20	1.19	1.19
Cooking	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10
On-road Mobile	0.44	0.43	0.44	0.44	0.46	0.45	0.46	0.48	0.47	0.48	0.49	0.50	0.51
Other Mobile	1.05	1.05	1.04	1.04	1.04	1.55	1.55	1.55	1.56	1.57	1.57	1.58	1.59
TOTAL	**284.65**	**284.77**	**284.99**	**285.19**	**283.84**	**284.44**	**284.66**	**284.88**	**285.02**	**285.24**	**285.48**	**285.71**	**285.96**

Notes:

[1] Sources with emissions less than 0.005 tons/day have been omitted from the table.

Abbreviations:

BLM – Bureau of Land Management

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As discussed previously and analyzed in Appendix A, CARB has concluded that PM_{10} precursor contributions can be considered insignificant for the purposes of this redesignation request and maintenance plan. Furthermore, as shown in Figure 4-1 and Table 4-3, emissions of main PM_{10} precursors are expected to decrease between the attainment year (2016) and the end of the maintenance period (2030). As a result, PM_{10} precursors are not expected to negatively impact maintenance of the PM_{10} NAAQS during the maintenance period.

Figure 4-1. PM_{10} Precursor Emissions for Imperial County, 2016-2030

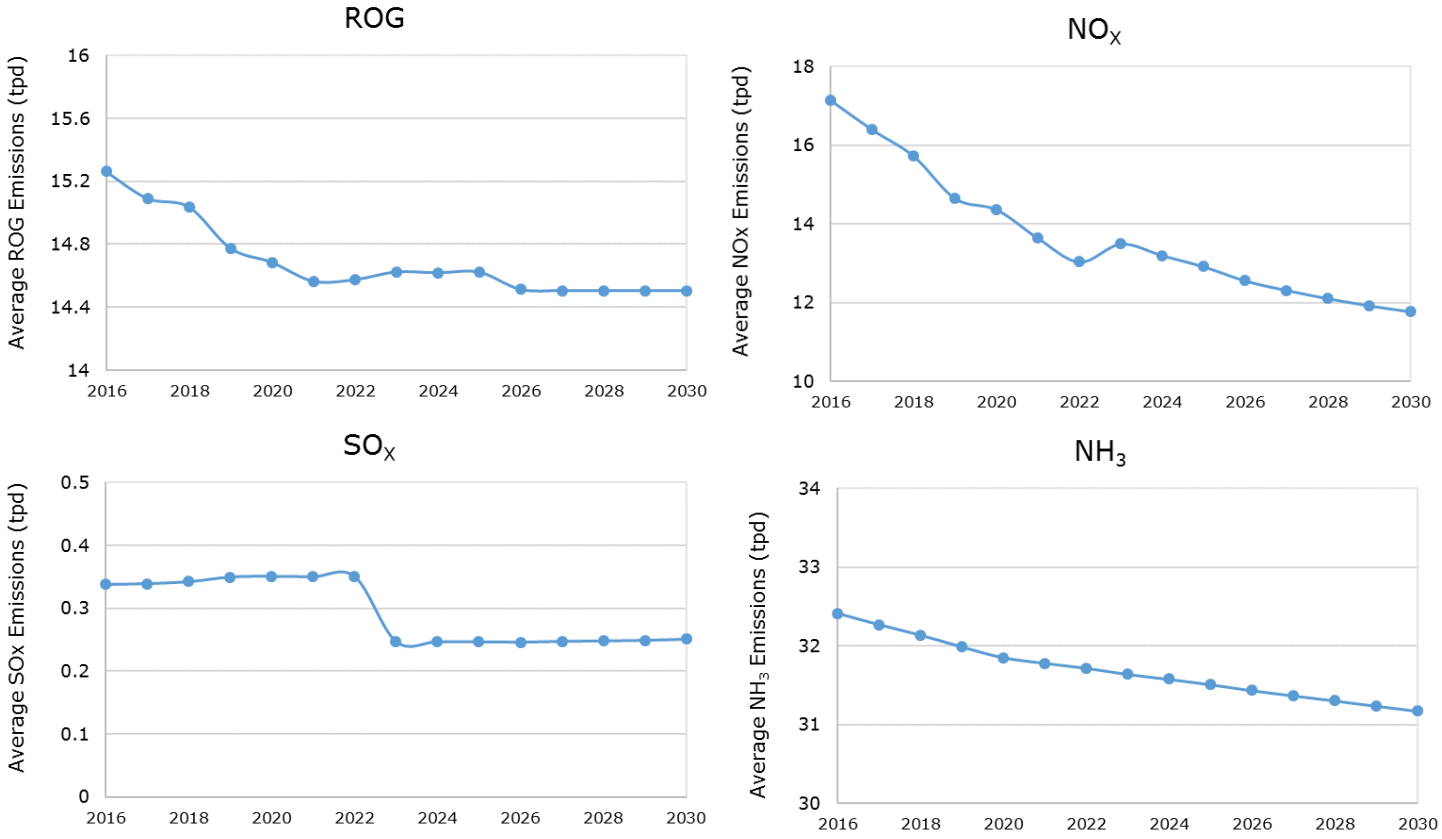

Table 4-3. PM_{10} Precursor Emission Totals for Imperial County, 2016 and 2030

	ROG Emissions (tpd)		NO_X Emissions (tpd)		SO_X Emissions (tpd)		NH_3 Emissions (tpd)	
	2016	**2030**	**2016**	**2030**	**2016**	**2030**	**2016**	**2030**
	15.26	14.51	17.14	11.77	0.34	0.25	32.41	31.17
% Change from 2016 to 2030	**-5.0%**		**-31.4%**		**-25.8%**		**-3.8%**	

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4.1.2 Transportation Conformity

Section 176(c) of the CAA establishes transportation conformity requirements that are intended to ensure that transportation activities do not interfere with air quality progress.[45] The CAA requires that transportation plans, programs, and projects that obtain federal funds or approvals *conform to* applicable SIPs before being approved by a Metropolitan Planning Organization (MPO). Conformity to a SIP means that proposed activities must not:

1) Cause or contribute to any new violation of any standard,
2) Increase the frequency or severity of any existing violation of any standard in any area, or
3) Delay timely attainment of any standard or any required interim emission reductions or other milestones in any area.

A SIP analyzes the region's total emissions inventory from all sources for purposes of demonstrating RFP, attainment, or maintenance. The portion of the total emissions inventory from on-road highway and transit vehicles in these analyses becomes the "motor vehicle emissions budget." Motor vehicle emission budgets are defined in the transportation conformity regulation[46] as the "portion of the total allowable emissions defined in [a SIP] for a certain date for the purpose of meeting reasonable further progress milestones or demonstrating attainment or maintenance of the NAAQS…[that is] allocated to highway and transit vehicle use and emissions." For conformity purposes, the motor vehicle emissions budget for PM_{10} includes, in addition to vehicular exhaust, tire, and brake wear emissions, re-entrained dust from travel on paved and unpaved roads (71 FR 12498), as well as emissions from road construction if found significant (§ 93.122(e)(2)). Motor vehicle emissions budgets are the mechanism for ensuring that transportation planning activities conform to the SIP. Budgets are set for each criteria pollutant or its precursors, for all RFP base and attainment years. Subsequent transportation plans and programs produced by transportation planning agencies are required to conform to the SIP by demonstrating that the emissions from the proposed plan, program, or project do not exceed the budget levels established in the applicable SIP.

The Imperial County transportation conformity budget is derived from projected PM_{10} emissions within the Southern California Association of Governments (SCAG) Imperial County PM_{10} nonattainment area (Imperial County PM_{10} NAA). Although this area differs from the Imperial County area as shown in Figure 4-2, it captures the overwhelming majority (95%) of transportation emissions generated within Imperial County.

[45] Federal transportation conformity regulations are found in 40 CFR Part 51, subpart T, and in 40 CFR Part 93, subpart A, Conformity to State or Federal Implementation Plans of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. of the Federal Transit Laws.

[46] 40 CFR Part 93, Subpart A, §93.101—Definitions. Available at: http://law.justia.com/us/cfr/title40/40-20.0.1.1.7.1.1.2.html. Accessed: November 2016.

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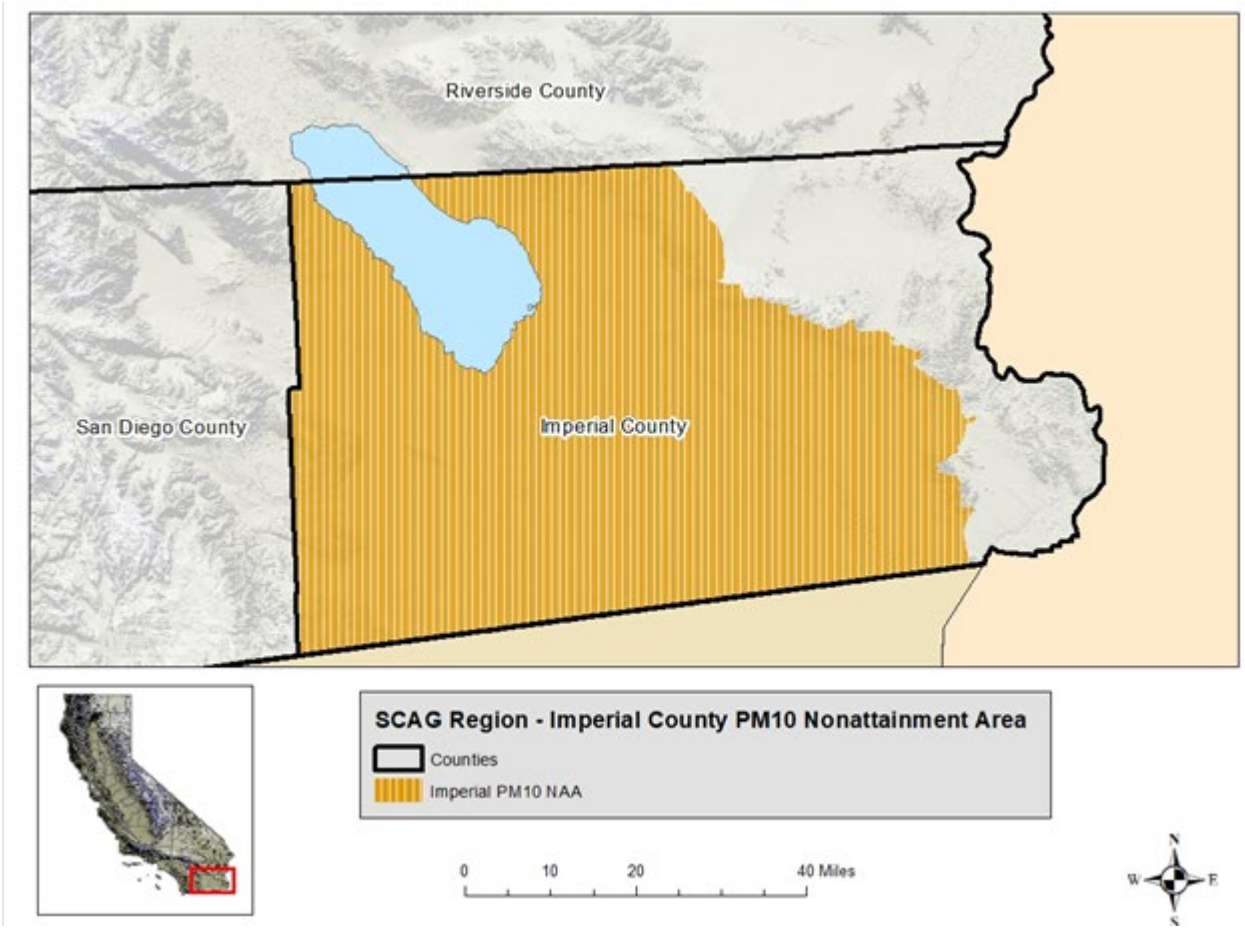
Figure 4-2. Imperial County PM_{10} Nonattainment Area as represented in SCAG Model



4.1.2.1 PM_{10} Emission Category and Precursor Requirements for Conformity

Guidance on the motor vehicle emission categories and precursors that must be considered in transportation conformity determinations is found in the transportation conformity regulation and final rules implementing amendments to the regulation.

Direct PM_{10} Emissions

Section 93.102(b)(1) of the Conformity Regulation indicates that directly emitted PM_{10} motor vehicle emissions from the tailpipe, brake wear, and tire wear must be considered in conformity determinations.

Re-Entrained Paved and Unpaved Road Dust PM_{10} Emissions

The March 10, 2006, Final Rule amending the transportation conformity regulation to establish criteria for project-level $PM_{2.5}$ and PM_{10} conformity determinations (71 FR 12498) indicates road dust must be included in regional conformity determinations: “EPA has intended for road dust emissions to be included in all conformity analyses of direct PM_{10} emissions.”

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Transportation-Related Construction Dust PM_{10} Emissions

Section 93.122(f) of the Conformity Regulation requires regional conformity determinations to include fugitive dust PM_{10} emissions from highway and transit construction activities if these sources are deemed significant contributors to the PM_{10} problem.

4.1.2.2 Assessment of Significance

To facilitate the assessment of significance of sources of mobile PM_{10} dust sources, Table 4-4 lists the mobile PM_{10} dust source categories in the Imperial County PM_{10} NAA and the corresponding percent contribution when compared to the entire PM_{10} emission inventory for the region. Please see Appendix G for a detailed description of the methodology used to estimate emissions found in Table 4-4.

Re-Entrained Paved and Unpaved Road Dust PM_{10} Emissions

As indicated in Table 4-4, re-entrained paved road dust accounts for less than one percent of the region's total direct PM_{10} emissions inventory in the budget years (0.4% in 2016 and 0.5% in 2030), while unpaved road dust accounts for less than seven percent (6.5% in 2016 and 5.9% in 2030). The March 10, 2006, Final Rule amending the transportation conformity regulation to establish criteria for project-level $PM_{2.5}$ and PM_{10} conformity determinations (71 FR 12498) indicates road dust must be included in regional conformity determinations: "EPA has intended for road dust emissions to be included in all conformity analyses of direct PM_{10} emissions." Consequently, this plan makes a finding that PM_{10} emissions from transportation-related paved and unpaved road dust are significant.

Transportation-Related Construction Dust PM_{10} Emissions

As indicated in Table 4-4, road construction dust is less than one percent (0.2% in 2016 and 0.3% in 2030) of the region's total direct PM_{10} emissions inventory in the budget years. Consequently, this plan makes a finding that PM_{10} emissions from transportation-related construction dust are insignificant.

Table 4-4. Annual Average Mobile PM_{10} Dust Categories Contribution to Total PM_{10} Emissions (Tons per Annual Day)

Source Category	2016	Percent of PM_{10} Inventory[b]	Significant?	2030	Percent of PM_{10} Inventory[b]	Significant?
Vehicular Exhaust, Tire, and Brake Wear	0.4	0.2%	Yes	0.5	0.2%	Yes
Re-Entrained Paved Road Dust (Total)	1.2	0.4%	Yes	1.5	0.5%	Yes
Re-Entrained Unpaved Road Dust (City and County Roads)	18.4	6.5%	Yes	16.8	5.9%	Yes
Road Construction Dust	0.6	0.2%	No	0.8	0.3%	No
Total[a]	20.5	NA	NA	19.6	NA	NA

[a] Values from CEPAM v1.05 may not add up due to rounding.
[b] Total PM_{10} emissions in the Imperial County PM_{10} NAA are 284.2 tons per annual day in 2016 and 286.0 tons per annual day in 2030.
Source: CEPAM 1.05 and EMFAC2014

The projected PM_{10} transportation emission inventory for the 2030 horizon year reveals that PM_{10} emissions from road construction; vehicular exhaust, tire wear, and brake wear; and re-entrained paved road dust emissions are projected to increase steadily at a slow rate relative to

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2016 year, while re-entrained unpaved road dust emissions are projected to decrease and then remain constant. The Imperial County motor vehicle emissions budgets (i.e., the transportation conformity budgets) reported in Table 4-5 were chosen here to be equal to the projected levels of emissions from the contributing source categories.

4.1.2.3 PM_{10} Conformity Budgets

Conformity budgets must be set for the attainment year for each NAAQS as well as the last year of the maintenance plan. The year 2016 represents a year in attainment and 2030 is the last year of the maintenance plan. The transportation conformity budgets developed for this plan include more recent travel activity projections provided by the SCAG. This travel activity is consistent with SCAG's Final 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy (2016 RTP/SCS).

Average daily emissions are used in the plan consistent with how the PM_{10} standard is measured. Consequently, conformity budgets were calculated in EMFAC2014 using annual average daily emissions for the analysis years listed above. Please see Appendix G for a detailed description of the methodology used to estimate emissions found in Table 4-5.

The transportation conformity budgets in Table 4-5, which were established in consultation with SCAG, the Federal Highway Administration, ICAPCD, CARB, and USEPA satisfy the requirements established in 40 CFR Part 93, Section 118(e)(4). The budgets apply as a "ceiling" or limit on transportation emissions in Imperial County in the year for which they are defined and for all subsequent years until another year for which a different budget is defined (or until a SIP revision modifies the budget).

The motor vehicle emission budgets, presented in the last row in Table 4-5, have been prepared consistent with the on-road emissions inventory by rounding the values to the nearest integer using conventional rounding.

Table 4-5. Annual Average Transportation Conformity Budgets for the Imperial County PM_{10} NAA (Tons per Annual Day)

Source Category	2016	2030
Vehicular Exhaust, Tire, and Brake Wear	0.4	0.5
Re-Entrained Paved Road Dust (Total)	1.2	1.5
Re-Entrained Unpaved Road Dust (City and County Roads)	18.4	16.8
Total[a]	20.0	18.8
Motor Vehicle Emission Budget[b]	**20**	**19**

[a] Values from CEPAM v1.05 may not add up due to rounding.
[b] Motor Vehicle Emission Budgets calculated with EMFAC2014 are rounded up to the nearest tpd.
Source: CEPAM 1.05 and EMFAC2014

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4.2 Future Monitoring Network

USEPA guidance[47] states that once an area has been redesignated, the state should continue to operate an appropriate air quality monitoring network in accordance with 40 CFR Part 58 to verify the attainment status of the area. More specifically, daily PM_{10} sampling is required in the area reporting the peak PM_{10} concentration. As discussed in Section 2.2, the District and CARB presently operate SSI and BAM monitors at the Calexico-Ethel, El Centro, Brawley, Westmorland, and Niland air quality monitoring stations. The District in conjunction with CARB will assure the on-going quality of the measured data by performing the operational procedures for data collection including routine calibrations, pre-run and post-run test procedures, and routine service checks. An annual review of the District's entire air quality monitoring network is required by federal regulations to determine if the network is effectively meeting the objectives of the monitoring program. Recently, this responsibility has been taken on by CARB with their annual monitoring network report.[48] If relocation or a closure is recommended in the annual network review, reports are submitted to the USEPA to document compliance with siting criteria. The data collection procedures already in place, in conjunction with the annual review program, will ensure that future PM_{10} ambient concentrations are monitored in the Imperial Valley Planning Area. The District is committed to continue monitoring in the Imperial Valley Planning Area in accordance with 40 CFR Part 58 to verify the attainment status of the area.

4.3 Verification of Continued Attainment

USEPA guidance[49] requires the District to indicate how it will track the progress of its maintenance plan over time. Two options suggested by the guidance include 1) periodic updates to the emissions inventory and 2) periodic review of the inputs and assumptions used for the emission inventory and subsequent updates to the inventory if those inputs or assumptions have significantly changed. The emissions inventory for Imperial County is currently maintained as part of a broader statewide inventory effort led by CARB, as CARB is required to inventory sources of air pollution within California under various state and federal laws.[50] As part of this effort, CARB works with local air districts to create and maintain inventory data. Since portions of the statewide inventory are updated with varying regularity, the District is committing to the second of the two above options to verify continued attainment, that is, the District will review the inputs and assumptions used for the emission inventory on an annual basis. If the District finds that these inputs have changed significantly, the District will solicit

[47] United States Environmental Protection Agency. 1992. Procedures for Processing Requests to Redesignate Areas to Attainment. Memorandum from John Calcagni to USEPA Regional Directors. September 4. Available at: https://www.epa.gov/sites/production/files/2016-03/documents/calcagni_memo_-_procedures_for_processing_requests_to_redesignate_areas_to_attainment_090492.pdf. Accessed: June 2018.

[48] California Air Resources Board. 2015. Annual Monitoring Network Report for Twenty-five Districts in California. June. Available at: http://www.co.imperial.ca.us/AirPollution/Monitoring/2015%20Annual%20Network%20Plan_Volume%201.pdf. Accessed: June 2018.

[49] United States Environmental Protection Agency. 1992. Procedures for Processing Requests to Redesignate Areas to Attainment. Memorandum from John Calcagni to USEPA Regional Directors. September 4. Available at: https://www.epa.gov/sites/production/files/2016-03/documents/calcagni_memo_-_procedures_for_processing_requests_to_redesignate_areas_to_attainment_090492.pdf. Accessed: June 2018.

[50] California Air Resources Board. 2013. Needs and Legal Requirements for the Emission Inventory. Available at: https://www.arb.ca.gov/ei/drei/maintain/legalrequirements.pdf. Accessed: June 2018.

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CARB to update the existing inventory and will evaluate the revised inventory against the inventories presented in this maintenance plan.

In addition to the verification actions listed above, the District will assess on a regular basis the PM_{10} air quality data collected from its future monitoring network. Specifically, the PM_{10} 24-hour average concentrations will be compared directly with the PM_{10} NAAQS and will be continually assessed for potential impacts by exceptional events.

4.4 Contingency Plan

CAA Section 175A(d) requires maintenance plans to identify contingency provisions to offset any unexpected increases in emissions and ensure maintenance of the NAAQS. Per the 1992 USEPA guidance[51] regarding contingency plans for areas seeking redesignation, the following are required elements for contingency:

- Clearly identified control measures;
- A schedule and procedure for adoption and implementation of the measures;
- A defined time limit by which the state must take action; and
- An established action level that triggers the contingency measures.

4.4.1 Contingency Plan Trigger

Contingency provisions are traditionally held in reserve and are implemented only if air quality deteriorates beyond a specific level. In general, exceedances or violations of the NAAQS are acceptable triggers for contingency plan implementation. Imperial County, however, often experiences exceedances of the PM_{10} NAAQS[52] caused by high wind dust events, despite the implementation of reasonable controls. To address Imperial's unique circumstances and to ensure appropriate implementation of the contingency plan, the District has developed a process for determining when the trigger for implementation of the continency plan has occurred.

Under this contingency plan trigger process, implementation of the contingency plan will be required when the number of exceedances recorded at a monitor averaged over three consecutive years, is greater than 1.05. The contingency plan trigger process, however, allows certain exceedances to be excluded from this calculation. This aspect of the process is intended to distinguish between exceedances that are not within the District's control, and therefore need not be considered in determining whether the contingency plan has been triggered, and those that are within the District's control, and therefore should be considered.

The process would exclude exceedances from the contingency plan trigger calculation in conjunction with the process for Initial Notification of Potential Exceptional Event (Initial Notification) set forth in 40 CFR 50.14(c)(2). At the conclusion of each quarter, the District will

[51] United States Environmental Protection Agency. 1992. Procedures for Processing Requests to Redesignate Areas to Attainment. Memorandum from John Calcagni to USEPA Regional Directors. September 4. Available at: https://www.epa.gov/sites/production/files/2016-03/documents/calcagni_memo_-_procedures_for_processing_requests_to_redesignate_areas_to_attainment_090492.pdf. Accessed: June 2018.

[52] 40 CFR Part 50, Appendix K defines an exceedance to mean a daily value that is above the level of the 24-hour standard after rounding to the nearest 10 $\mu g/m^3$.

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have 60 days to prepare and submit to CARB a list of exceedances that occurred during the previous quarter, designating those proposed as potential exceptional event exceedances, flagging the data, and providing an initial event description in AQS. The District will also include a copy of previously submitted Initial Notification data and an update on exceedances that occurred in the previous 12 quarters that describes the status of the CARB and USEPA reviews of those events. Once submitted to CARB, CARB will have 60 days to review, during which time they may request additional readily available information from the District. Following CARB's review, CARB will forward the information to USEPA.

In addition to the Initial Notification data, for those exceedances the District believes should be excluded from the contingency plan trigger calculation, the District and/or CARB will provide additional information as an appendix summary table to the Initial Notification as follows:

Analysis/Product	**Criteria**
Hourly and 24-hour average PM_{10} concentrations from following areas: - Imperial County - Coachella Valley - Yuma	Exceedances at multiple monitors in the specified areas (i.e. >2 exceedances/day)
NOAA LCD hourly observation tables - Imperial Co Airport - El Centro NAF - Upwind sites	Wind speed $\geq$ 25 mph consistent w/ increase in hourly PM_{10}
NOAA LCD hourly observation tables - Imperial Co Airport - El Centro NAF - Upwind sites	Reduced visibility < 10 miles consistent w/ increase in hourly PM_{10}
NWS wind/dust advisories or warnings for following areas: - Imperial County - San Diego Mountains - San Diego Deserts - Coachella Valley - Yuma	Issuance of advisory or warning in the specified forecast areas consistent w/ increase in hourly PM_{10}
Summaries of dust complaints and/or notice of violations	No dust complaints are received, or dust complaints do not involve anthropogenic source(s) located upwind of an exceeding monitor.

If any of these five criteria are not met, or if other available data contradict the assessment, the District and/or CARB will include additional information and analysis in the appendix to the quarterly report to support exclusion of the data from determinations of whether the contingency plan has been triggered. The District will confer with USEPA to determine the type of

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information needed to determine the cause of the exceedance prior to submittal of the quarterly report. This additional information might include:

- a detailed analysis of upwind wind speed and direction;
- PM_{10} and/or $PM_{2.5}$ concentrations from non-regulatory monitors in the area;
- HYSPLIT back-trajectory analysis;
- satellite image or remote sensing analysis;
- an evaluation of upwind source area (including further evaluation of dust complaints/NOVs or known contributing anthropogenic sources);
- PM speciation or $PM_{10}/PM_{2.5}$ ratio analysis; and/or
- other event specific analysis needed to appropriately determine cause of exceedance.

USEPA will review the quarterly reports submitted by CARB and the District. USEPA will notify the District if submitted documentation is insufficient to support exclusion from the contingency plan trigger calculation, and will include such exceedances in calculating the trigger for the contingency plan. If the contingency plan is triggered, the District will begin implementation as described in the next section. If the District and/or CARB subsequently provide additional information to USEPA such that the criteria for exclusion from the contingency plan trigger calculation are satisfied, USEPA will notify the District that the contingency plan trigger will be adjusted. If the resulting value is less than 1.05, implementation of the contingency plan can be halted unless triggered in a subsequent quarter. Figure 4-3 provides a visual depiction of the timeline of events for this proposed process.

4.4.2 Contingency Provisions

If USEPA determines that contingency provisions have been triggered in Imperial County, the District would have 18 months from the USEPA notification date to evaluate the cause of the exceedance and to take the appropriate action. This process would consist of first analyzing the exceedances that caused the violation to determine its possible causes. Based on the potential sources causing the increase in ambient PM_{10}, certain measures would be examined to determine if there exist emission reductions not already used for demonstrating maintenance.

To initiate this process, ICAPCD will first consult with community and local industry members to determine if any voluntary or incentive-based control measures could be implemented to achieve reductions in PM_{10} emissions. If these measures do not adequately address the causes of the exceedances, then the District will look to its collection of fugitive dust rules (ICAPCD Rules 800-806 or collectively, Regulation VIII), or other rules, as appropriate, for measures that can be improved or expanded to achieve additional PM_{10} emissions reductions. For example, if it were determined that non-exceptional event exceedances could be attributed to windblown dust (a known significant source of PM_{10} in the Imperial Valley Planning Area), then a contingency control measure based on revisions to Rule 804 (Open Areas) could be implemented. Table 4-6 includes a summary of potential sources that could contribute to exceedances and the ICAPCD rules that would be explored as options for control through improvement or expansion of applicability. The examples provided are specific to sources of fugitive dust, as it accounts for the majority of PM_{10} emissions in Imperial County.

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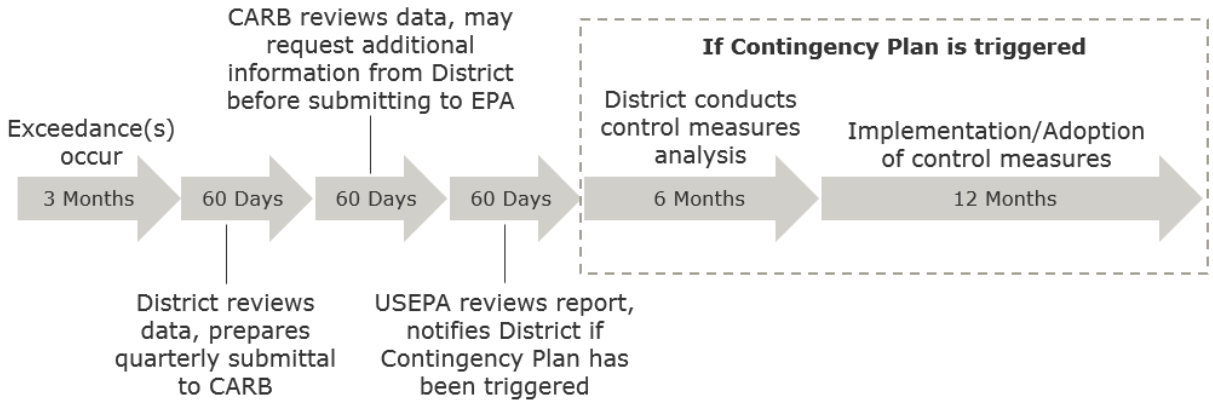
Table 4-6. Example Emission Sources and Corresponding Rules to Improve/Expand Applicability for Additional Control	
Emission Source	**ICAPCD Rule**
Construction and Earthmoving Activities	801
Bulk Materials	802
Carry-out and Track-out	803
Open Areas	804
Paved and Unpaved Roads	805
Agricultural Operations	806

The District will aim to complete its analysis of the exceedances and available contingency measures within six months of USEPA's notification that contingency was triggered. This will then be followed by a 12-month period during which the contingency measures will be adopted and implemented. Figure 4-3 displays this timeline, including the events leading up to implementation.

Figure 4-3. Timeline of Events Leading to Implementation of Contingency Measures



4.4.3 Contingency Plan Implementation

The District is committed to maintaining its regular review of the ambient PM_{10} monitoring data to assess continued maintenance of the 24-hour standard. If the Contingency Plan Trigger is reached (i.e., a potential violation of the 24-hour PM_{10} NAAQS, consistent with 40 CFR Part 50 Appendix K, Section 2.3(c) following an initial review of exceedances through the Initial Notification of an Exceptional Event Process described above), the District commits to initiating the contingency provisions described above, including identifying measures, either through expanding existing rules or utilizing measures from outside the rulebook to achieve the necessary reductions within 18 months of USEPA's notification. Consistent with CAA Section 175A(b), the District also commits to submitting a second maintenance plan eight years after formal redesignation by USEPA to show maintenance for at least the next 10-year period.

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5 Salton Sea Considerations

Located in the northwest corner of Imperial County, the Salton Sea lies in the bed of an ancient lake that has been repeatedly desiccated and reformed by flooding within the Lower Colorado Basin. The current Sea was formed by a break in the bank of a canal carrying water from the Colorado River to the Imperial Valley in 1905. The water level of the Sea has been sustained since then by agricultural drainage waters flowing from lands under cultivation in the Coachella and Imperial Valleys. In 2002, a water transfer agreement was executed by the Imperial Irrigation District (IID), the Coachella Valley Water District (CVWD), and urban water agencies in Southern California that arranges for the transfer of agricultural water to urban areas for domestic use. This and related agreements, collectively referred to as the Quantification Settlement Agreement (QSA), will significantly reduce drainage flows to the Salton Sea after 2017, the year until which IID must maintain existing salinity levels in the Sea by supplying mitigation water.

The Salton Sea will continue to shrink, especially as drainage flows from local agricultural use are significantly reduced in 2017 and beyond. Stabilizing the parts of the playa expected to be emissive as they are exposed will minimize dust. The State's Salton Sea Management Program (SSMP) and Phase I Plan and IID's Salton Sea Air Quality Management Program (SS AQM Program) are designed to proactively provide reasonable controls as the playa is exposed. 2016 Amendments to ICAPCD Rule 804 allow establishment of alternate BACM on exposed playa that is not stabilized; this provides an adopted contingency mechanism for any emissive playa that is not stabilized as it is exposed.

An increase in salinity levels in the Salton Sea threatens both fish and waterfowl habitat values. Under legislation enacted in 2003, the Secretary of Resources in consultation with the Department of Water Resources, appropriate air agencies, and other relevant agencies was required to undertake a restoration study to determine a preferred alternative for the restoration of the Salton Sea ecosystem and the permanent protection of wildlife dependent on that ecosystem. In June 2007, a final Programmatic Environmental Impact Report[53] that analyzed each of eight alternative restoration options was certified and a preferred alternative was recommended to the state legislature. Under all of the alternatives studied, a portion of the Sea bed would be exposed. These exposed areas could become sources of windblown dust, depending on the granularity of the exposed soils and the behavior of salt crystals on the soil surface.

The control of windblown dust from exposed sea bed or playa has benefitted dramatically from control efforts tested in a similar environment at Owens Lake, California. Owens Lake was completely desiccated in the 1920s by the diversion of all incoming flows to an aqueduct

[53] California Department of Water Resources, *et. al*. 2007. Salton Sea Ecosystem Restoration Program. Final Programmatic Environmental Impact Report. Available at: https://www.water.ca.gov/Programs/Integrated-Regional-Water-Management/Salton-Sea-Unit. Accessed: June 2018.

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constructed by the Los Angeles Department of Water and Power. Due to the highest PM_{10} concentrations recorded in the United States from windblown dust, the Owens Lake region has been subject to federal CAA nonattainment planning requirements since 1991. Under the most recently approved PM_{10} attainment plan, almost 45 square miles of lakebed surface are being treated with gravel cover, shallow flooding, and managed vegetation BACM. The plan also calls for controls on an additional 3.62 square miles by December 31, 2017, and recognizes modifications to existing BACM, including "reduced thickness gravel", "brine shallow flooding", and "tillage with BACM backup."[54]

Differences in soil and wind conditions between Owens Lake and the Salton Sea suggest that windblown dust issues may be less of a problem at the Salton Sea than experienced at Owens Lake. Salts at Owens Lake are dominated by sodium carbonate, which tends to fracture easily into very fine particles, while sodium chloride, which is harder and less vulnerable to abrasion, constitutes the majority of the salt at the Salton Sea. Additionally, peak wind speeds and the number of hours per year with wind speeds above recognized windblown dust generation thresholds are substantially higher at Owens Lake than at the Salton Sea. On the basis of these two conditions, worse case PM_{10} windblown emission rates—and resultant ambient PM_{10} concentrations—are expected to be lower at the Salton Sea than are recorded at Owens Lake.

Several state statutes and water use permits provide significant authority to ICAPCD and CARB to control windblown PM_{10} emissions from the Salton Sea. Section 2081.7 of the California Fish and Game Code makes the state Department of Water Resources responsible for any environmental impacts related to the use or transfer of water from the Imperial Valley to out-of-basin users that would cause declines in Salton Sea levels or increases in salinity. The California State Water Resources Control Board permit that authorizes transfer of agricultural water to urban water districts[55] requires IID to comply with all PM_{10} ICAPCD rules, including Rule 804. This rule requires the owner of undeveloped property[56] to use BACM to maintain stabilized soil surfaces and to prevent the emission of visible dust in concentrations greater than those which produce 20 percent or more opacity. Rule 804 was recently amended to accommodate the changing conditions at the Salton Sea. Details regarding the changes are provided in Section 5.3.

In May 2015, Governor Brown of California established the Salton Sea Task Force with the objective of preserving two aspects of the environment that are affected by the water levels of the Sea: the area's ecosystem and its air quality. This is made possible by managing the various sources of water inflow to the Sea in order to maintain its salinity and area of exposed playa, both of which are most heavily influenced by changes in the Sea's volume. The Salton

[54] Ramboll Environ. 2016. Great Basin Unified Air Pollution Control District 2016 Owens Valley Planning Area PM_{10} State Implementation Plan. April. Available at: https://www.gbuapcd.org/District/AirQualityPlans/OwensValley/. Accessed: June 2018.

[55] Order WRO 2002-0013, In the Matter of Imperial Irrigation District's (IID) and San Diego County Water Authority's (SDCWA) Amended Joint Petition for Approval of a Long-Term Transfer of Conserved Water From IID to SDCWA and To Change The Point of Diversion, Place of Use, and Purpose of Use Under Permit 7643 Issued on Application 7482 of IID, State Water Resources Control Board, December 20, 2002.

[56] 0.5 acres or more in urban areas or 3.0 acres or more in rural areas, and contains at least 1000 square feet of disturbed surface areas.

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Sea Task Force has committed to developing a plan that consists of clearly defined and measurable goals. Its main short-term goal is to create between 9,000 and 12,000 acres of habitat and dust suppression projects. Later on, the medium-term plan is to expand these projects to cover an area of 18,000 to 25,000 acres. Achieving these goals will require effort from various regulatory agencies and other groups. At the initiation of the task force, Governor Brown appointed members to it from the Natural Resources Agency, the California Environmental Protection Agency, the State Water Resources Control Board, CARB, and the California Energy Commission. Additional oversight from the Colorado River Regional Water Board, ICAPCD, and South Coast Air Quality Management District (SCAQMD) will be provided alongside the work from these groups in order to monitor and assess progress and ensure that the goals are met in a timely manner.

The objectives of the Salton Sea Task Force will be implemented through the Salton Sea Management Program (SSMP). Moving forward the SSMP, in March 2017 the task force released a draft technical memorandum titled, "Phase I: Ten-Year Plan". This document outlines the first 10-year phase of the SSMP and also addresses the development of additional management measures that will be implemented in later phases. In November 2017, certain provisions of the Phase I Plan, specifically the acreages to be controlled on an annual basis, were incorporated into water order WRO 2002-0013.[57] Additional details regarding the Phase I Plan are provided in Section 5.1.

Representatives from ICAPCD serve on the Air Quality Committee of the SSMP and with fellow committee members are tasked with coordinating with agencies and existing mitigation programs to develop a comprehensive air quality program for the SSMP. One such existing mitigation program is the IID's Salton Sea Air Quality Mitigation Program (SS AQM Program). In July 2016, IID released a document outlining the SS AQM Program and IID's approach to addressing air quality mitigation requirements associated with the QSA.[58] Details regarding the SS AQM Program are provided in Section 5.2.

The requirements to control PM_{10} emissions from exposed playa surfaces incorporated into state law and water transfer permits will mitigate potential impacts on air quality from implementation of the QSA.

5.1 Salton Sea Management Program - Phase I: 10 Year Plan

In March 2017, the State of California (through the Salton Sea Task Force) published a draft of a document entitled "Phase 1: 10 Year Plan" (provided as Appendix I). This technical memorandum outlines the first phase of the SSMP and serves as a guide for state and federal actions towards developing projects designed to minimize environmental and human health impacts resulting from water level reductions at the Salton Sea. A major component of this plan is to expedite both the construction of wildlife habitats and the suppression of fugitive dust at the Sea, specifically at areas where playa is exposed or will be exposed in the near future due to

[57] One can find additional information about these revisions here: http://www.waterboards.ca.gov/waterrights/water_issues/programs/salton_sea/. Accessed: June 2018.

[58] Formation Environmental, LLC. *et al*. 2016. Salton Sea Air Quality Mitigation Program. Prepared for Imperial Irrigation District. July. Available at: http://www.iid.com/Home/ShowDocument?id=11827. Accessed: June 2018.

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decreasing water levels. The 10 year plan lays out specific goals for the acreage of playa to be covered by these types of projects annually between 2019 and 2029. The locations for habitat development projects will be selected based on landscape characteristics, such as water and soil availability, compatibility within the overall habitat already present, and degree of soil emissivity. The locations for dust suppression projects will be determined in coordination with the Imperial Irrigation District's SS AQM Program, as well as ICAPCD, CARB, and SCAQMD. Collaborative efforts among these groups will ensure that the projects implemented to achieve the acreage goals are compatible with the interests of all parties involved and feasible within established budgets. The projects will be conducted through the existing Water Transfer Joint Powers Authority budget process.

For areas deemed amenable to dust suppression projects, the SSMP will include an air quality component modeled after the SS AQM Program, focusing on the portions of it that deal with researching and monitoring at the Sea to determine particular dust suppression needs in order to identify and implement potential solutions for them. The current vision for the SSMP includes both water-dependent and waterless methods for dust suppression, though continuous monitoring and evaluation will take place to determine which techniques to use for specific areas. The Phase I Plan includes a breakdown of cost estimates to go along with the acreage goals for the dust suppression and habitat development projects. Overall, construction is proposed to cover 29,800 of the 48,300 acres of newly exposed playa by 2029. For Phase I, the projects will be implemented in areas on the north and south ends of the lake, with efforts to focus on exposed playa that have demonstrated emissivity. The estimated cost of these Phase I projects is $303 million.

5.2 Salton Sea Air Quality Mitigation Program

In order to determine if and when new control measures at the Salton Sea should be implemented, conditions there must be monitored. Based on these observations, an effective dust control strategy can be developed to address the specific emission source areas. With this approach in mind, IID created the SS AQM Program, the most comprehensive Salton Sea air quality mitigation program established to date (provided as Appendix J). As mentioned previously, as part of the Salton Sea Task Force the SSMP and the Air Quality Committee are tasked with integrating existing mitigation programs into an overarching air quality program for the Salton Sea. Therefore, this program is relevant to the future of air quality in Imperial County.

The SS AQM Program contains three distinct components which identify, prioritize, and guide implementation of various dust control measures for use on the exposed playa at the Salton Sea. The first component consists of an annual PM_{10} Emissions Inventory and Monitoring Program, which includes goals of mapping the current and projected exposed playa, monitoring its surface characteristics, and measuring its emission potential. Accomplishing these goals each year leads to the report of the annual inventory monitoring results. This information is then used to prioritize the playa dust source areas for control. From this, the second major component of the program can be executed: the dust control strategy. This includes developing and testing different dust control measures which have been tailored to the specific climate and soil conditions at the Salton Sea. These test results are then considered along with Salton Sea restoration projects, renewable energy and habitat projects, and agricultural and other land use

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projects in order to develop the Annual Proactive Dust Control Plan. These plans are completed within the first quarter of every year by IID, in collaboration with Imperial County and ICAPCD.

Finally, the third component of the SS AQM Program is the implementation of the Annual Proactive Dust Control Plan. The IID takes into account the details of the plan, along with any potential regulatory orders from ICAPCD or SCAQMD, in order to reach a final board action. Once the plan is implemented, the dust control performance is monitored and, if necessary, the measures are enhanced to achieve a more stabilized surface. The performance of the dust control measures is partially evaluated through ambient air monitoring. Since February 2010, six monitoring stations surrounding the Salton Sea have measured and recorded particulate matter concentrations in the ambient air. All six stations measure $PM_{2.5}$ and PM_{10} over five-minute and one-hour averaging periods. The data generated by these monitoring stations are used to produce the annual emissions inventories,[59] assemble dust control plans, and evaluate the performances of said plans and thus, represent an important aspect of the SS AQM Program.

It is important to note that the SS AQM Program does not alter or replace any of the Salton Sea air quality monitoring and mitigation requirements previously set forth. Rather, it expands upon them by providing additional contingency measures specific to newly exposed playa around the Sea. Those playa which are exposed as a direct result of water transfers under the QSA are subject to the air quality monitoring and mitigation requirements described within the QSA, and IID is specifically tasked with controlling the related dust. To ensure that this occurs, ICAPCD has the ability to issue regulatory orders to IID and other culpable entities if dust control measures on the Salton Sea playa are inadequate. On top of this, all other federal, state, and local rules and regulations pertaining to air quality still apply. Included among these is the previously mentioned Rule 804. This rule involves the control of fugitive dust sources from disturbed open areas, which by definition, includes emissive Salton Sea playa.

5.3 2016 Rule 804 Amendments

Rule 804 requires the owner of undeveloped property[60] to use BACM to maintain stabilized soil surfaces and to prevent the emission of visible dust in concentrations greater than those which produce 20 percent or more opacity. Recognizing the possibility that previously established BACM might not be efficient or effective at controlling dust on future exposed playa at the Salton Sea, ICAPCD proposed a strategic amendment to Rule 804, which became effective on April 12, 2016. Prior to the amendment, Rule 804 limited the available BACM to the following controls: apply water or dust suppressants to all unvegetated areas; establish vegetation on all previously disturbed areas; and pave, apply, and maintain gravel or chemical stabilizers or suppressants.[6] The amendment added language to allow for “Alternative BACM” to be permissible. In order for Alternative BACM to be approved, the amendment stipulates that a technical evaluation must be submitted to ICAPCD and an ICAPCD-witnessed field test must take place and demonstrate that the proposed Alternative BACM achieves PM_{10} emission reductions equivalent to the previously established BACM. In addition, the Alternative BACM

[59] The results from the 2016/2017 monitoring year are available online at: https://www.iid.com/water/library/qsa-water-transfer/mitigation-implementation/air-quality-mitigation. Accessed: June 2018.

[60] 0.5 acres or more in urban areas or 3.0 acres or more in rural areas, and contains at least 1000 square feet of disturbed surface areas.

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must achieve the stabilized surface and opacity requirements of the rule.[61] Once these conditions have been met, an Alternative BACM can be approved and used for Rule 804 compliance. This amendment allows for the testing and potential use of "new" dust control measures which might be better suited than the current BACM for addressing the changing conditions at the Salton Sea. In this sense, the amendment to Rule 804 is a proactive contingency measure.

[61] Imperial County Air Pollution Control District. 2016. Rule 804: Open Areas. Revised April 12, 2016. Available at: http://www.arb.ca.gov/DRDB/IMP/CURHTML/R804.PDF. Accessed: June 2018.

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6 Redesignation Request and Summary Checklist

The District is requesting redesignation of the Imperial Valley Planning Area from Serious nonattainment to attainment of the PM_{10} NAAQS under CAA Section 107(d)(3)(E) protocol.

Section 107(d)(3)(E) of the CAA requires the USEPA administrator to make five findings prior to granting a request for redesignation:

1. The USEPA has determined that the NAAQS has been attained.
2. The applicable implementation plan has been fully approved by the USEPA under Section 110(k).
3. The USEPA has determined that the improvement in air quality is due to permanent and enforceable reductions in emissions.
4. The State has met all applicable requirements for the area under Section 110 and Part D.
5. The USEPA has fully approved a maintenance plan, including a contingency plan, for the area under Section 175A.

As described in Chapter 2 of this document, PM_{10} air quality in the Imperial Valley Planning Area, excluding exceptional events, did not violate the NAAQS from 2014 through 2016. Specifically, Section 2.3 provides the confirmation that the 2014-2016 24-hour PM_{10} concentration data has attained the NAAQS. Section 1.4 characterizes the Imperial County 2009 PM_{10} SIP and subsequent Settlement Agreement with the USEPA and provides reference to the USEPA's approval of Imperial County's fugitive dust rules as BACM for significant sources. With the full execution of the provisions in the Settlement Agreement, Imperial County satisfied its requirements under CAA Section 110(k). In accordance with USEPA guidance, Imperial County requests that approval action on outstanding SIP elements occurs simultaneously with this redesignation request. Chapter 3 discusses how Imperial County's BACM fugitive dust rules have led to permanent and enforceable emissions reduction in the area. Sections 2.4 and 3.4 address the applicable requirements under CAA Section 110 and Part D and Chapter 4 presents the District's maintenance plan. Together these sections directly address and satisfy the requirements of CAA Section 107.

A checklist of requirements pertinent to this 2018 Redesignation Request and Maintenance Plan (as outlined both in CAA Section 107(d)(3)(E) and in the September 4, 1992 USEPA memorandum[62] regarding procedures for processing requests to redesignate areas to attainment) is presented in Table 6-1. In addition, because Imperial County is requesting approval action on outstanding SIP elements under CAA Section 110 and Part D as part of this redesignation request, those items have been included in Table 6-1 as well. Note that because Imperial County is shown in this document to have attained the 24-hour PM_{10} NAAQS, based on 2014-2016 monitoring data, RFP and milestone requirements are unnecessary, and specifically the five percent yearly emission reductions requirement does not apply to future years. As

[62] United States Environmental Protection Agency. 1992. Procedures for Processing Requests to Redesignate Areas to Attainment. Memorandum from John Calcagni to USEPA Regional Directors. September 4. Available at: https://www.epa.gov/sites/production/files/2016-03/documents/calcagni_memo_-_procedures_for_processing_requests_to_redesignate_areas_to_attainment_090492.pdf. Accessed: June 2018.

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documented in Table 6-1, all remaining requirements applicable to this 2018 Redesignation Request and Maintenance Plan have been successfully addressed.

Table 6-1. Plan Checklist

Plan Components	Required Elements	Document Reference	Comments
Redesignation Request	Attainment of the NAAQS; CAA Sec. 107(d)(3)(E)(i)	Section 2.3	Pending USEPA review and approval of exceptional event documentation
	USEPA approval of State Implementation Plan; CAA Sec. 107(d)(3)(E)(ii)	Sections 2.4 and 3.4	Pending as part of this submittal; see Section 110 and Part D portion of this table.
	Air quality improvements due to permanent and enforceable emissions reductions; CAA Sec. 107(d)(3)(E)(iii)	Section 3.3	Included.
	USEPA approval of a maintenance plan and contingency plan; CAA Sec. 107(d)(3)(E)(iv)	Chapter 4	Pending as part of this submittal.
	Section 110 and Part D requirements have been met; CAA Sec. 107(d)(3)(E)(v)	Sections 2.4 and 3.4	Pending as part of this submittal; see Section 110 and Part D portion of this table.
Maintenance Plan	Attainment Inventory; CAA Sec. 175A(a) and (USEPA, 1992)	Section 4.1.1	Included; emissions inventory for attainment year (2016)
	Maintenance Demonstration; CAA Sec. 175A(a) and (USEPA, 1992)	Section 4.1	Included; future year emissions inventories (2018-2030) provided in support of maintenance demonstration.
	Future Monitoring Network, featuring daily PM_{10} monitoring; CAA Sec. 175A(a) and (USEPA, 1992)	Section 4.2	Commitment established
	Verification of Continued Attainment; CAA Sec. 175A(a) and (USEPA, 1992)	Section 4.3	Commitment established
	Contingency Plan; CAA Sec. 175A(d) and (USEPA, 1992)	Section 4.4	Included

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Table 6-1. Plan Checklist

Plan Components	Required Elements	Document Reference	Comments
Section 110 and Part D Requirements	Emissions Inventory; CAA Sec. 172(c)(3)	Section 4.1.1 and Appendix H	Included.
	A plan that enables attainment of the PM_{10} federal air quality standard; CAA Sec. 189(b)(1)(A)	Chapters 2 and 3	This plan demonstrates that Imperial County attained the PM_{10} NAAQS, based on 2014-2016 monitoring data. Attainment was due, in part, to ICAPCD's adoption and subsequent implementation of Regulation VIII fugitive dust rules, which have been declared by USEPA as BACM for significant sources of PM_{10}.
	Annual reductions in PM_{10} or PM_{10} precursor emissions that are of no less than 5 percent until attainment; CAA Sec. 189(d)	Does not apply	Imperial County is shown in this document to have already attained the PM_{10} NAAQS. Therefore, this provision is not applicable to future years.
	BACM and BACT for significant sources and major stationary sources of PM_{10}, to be implemented no later than 4 years after reclassification of the area as serious; CAA Sec. 189(b)(1)(B)	Sections 1.4.1, 1.4.2, Chapter 3, and Appendix E	Reclassification of Imperial County to Serious nonattainment for PM_{10} occurred on August 2004. ICAPCD's Regulation VIII fugitive dust rules have been declared by USEPA as BACM for significant sources. A revised significance source analysis was included in this Plan and shows that no new emission sources would qualify as significant.
	Transportation conformity and motor vehicle emission budgets in accord with the plan; CAA Sec. 176	Section 4.1.2	Included.
	RFP and quantitative milestones; CAA Sec. 172(c)(2) and Sec. 189(c)	Does not apply	These requirements are not applicable in the present plan since Imperial County is already in attainment, based on 2014-2016 monitoring data.
	Contingency measures; CAA Sec. 172(c)(9)	Section 4.4	Included.

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Appendix A
PM_{10} Precursor Analysis for Imperial County

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Appendix A. Precursor Analysis

In addition to direct emissions, particulate matter is formed when gases are transformed into particles through chemical reactions in the atmosphere. We refer to these gases as precursors. Sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ammonia (NH_3) all contribute to the formation of particulate matter. For this analysis, we evaluated their contribution to the formation of PM_{10}.

PM_{10} contains coarse particles (larger than 2.5 µm in diameter), and fine particles (2.5 µm in diameter or smaller). The fine particles ($PM_{2.5}$) consist primarily of nitrate, sulfate, and elemental and organic carbon. Coarse particles usually contain earth crustal materials and fugitive dust produced by the break-up of larger solid particles. This can include wind-blown dust from agricultural processes, uncovered soil, and unpaved roads, as well as re-entrained road dust.

For this analysis, staff considered all available PM_{10} and $PM_{2.5}$ mass and speciation data. Because PM_{10} and $PM_{2.5}$ speciation data is only recorded once every 6 days, it is important to analyze more data points to evaluate whether PM_{10} precursors play a significant role to the PM_{10} exceedances in Imperial County. In order to assure that the most data points are considered, Staff reviewed the last ten years of data, from 1/1/2007 through 12/31/2016, to identify days with matching PM_{10} mass data and PM_{10} and $PM_{2.5}$ speciation data. In order to maximize the number of days with parallel PM_{10} mass and PM_{10} and $PM_{2.5}$ speciation data, we considered days with concentrations greater than 95 percent of the PM_{10} standard (>143 µg/m^3). For days near or over the PM_{10} standard that also coincided with a PM_{10} and $PM_{2.5}$ speciation sample day, Staff identified five days with PM_{10} concentrations ranging from 144 µg/m^3 to 305 µg/m^3 (Table 1).

Table 1. High PM_{10} days between 1/1/2007 and 12/31/2016 with matching PM_{10} and $PM_{2.5}$ speciation data

	Mass (µg/m^3)		Measured or Estimated PM_{10} Contribution (µg/m^3)				Estimated Precursor Contribution (µg/m^3)			
Date	**PM_{10}**	**$PM_{2.5}$**	**NO_3**	**SO_4**	**NH_4**	**Carbon**	**NO_X**	**SO_X**	**NH_3**	**VOC**
6/5/07	282	30	2.9	4.6	2.6	14.4	3.7	4.6	5.5	7.2
10/21/07	144	15	1.1	3.2	1.5	3.8	1.4	3.2	2.6	1.9
7/18/09	147.9	25	2.1	3.7	2.0	8.2	2.7	3.7	4.1	4.1
9/4/09	265.8	27	1.9	6.5	3.0	5.5	2.5	6.5	4.9	2.8
8/13/12	305.3	23	3.8	4.4	2.8	8.6	4.9	4.4	6.6	4.3
Average	229	24	2.4	4.5	2.4	8.1	3.0	4.5	4.7	4.1
Percent Contribution of the Average Precursor Contribution to the Average PM_{10} Mass							1.3	2.0	2.1	1.8

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PM_{10} nitrate and PM_{10} sulfate in Table 1 represent measured concentrations. PM_{10} ammonium represents the calculated value based on the amount needed to fully neutralize all measured nitrate and sulfate. PM_{10} carbon data are not measured at Calexico. Since most of the PM_{10} carbon is in the fine fraction, we used $PM_{2.5}$ carbon estimate as a surrogate for the PM_{10} carbon. We estimated $PM_{2.5}$ carbon as a difference between measured $PM_{2.5}$ mass and the sum of ammonium nitrate, ammonium sulfate, geological material, and elemental species concentrations.

The paragraphs that follow examine each precursor.

Sulfur Oxides - SO_x

Since sulfate can exist in the atmosphere in the form of sulfuric acid if it's not neutralized by ammonia, the SO_x contribution is evaluated by estimating sulfate contribution to the elevated PM_{10} concentrations. On average, sulfate contributes 4.5 $\mu g/m^3$ or 2 percent of PM_{10} mass.

Nitrogen Oxides - NO_x

Since NO_x contributes directly to ammonium nitrate formation, its impact on the PM_{10} design value was evaluated by summing all measured nitrate plus ammonium needed to fully neutralize measured nitrate. On average, the two components together contribute 3 $\mu g/m^3$ or 1.3 percent to the PM_{10} mass.

Ammonia – NH3

Since in the absence of ammonia, nitrate would only exist as a gas, ammonia contribution to the elevated PM10 concentrations is represented by all measured ammonium plus all measured nitrate ion. On average, the two components together contribute 4.7 $\mu g/m^3$ or 2.1 percent to the PM_{10} mass.

Volatile Organic Compounds - VOC

There are two routes by which VOCs can contribute to ambient PM_{10}. The first is through various chemical reactions leading to the formation of Secondary Organic Aerosols (SOAs). The second is through photochemical reactions that create oxidants such as ozone and hydroxyl radicals, which in turn oxidize NO_X emissions leading to the formation of particulate ammonium nitrate. As noted above, ammonium nitrate is not a significant component of $PM_{2.5}$. Therefore, the impact of VOC emissions on the PM_{10} design value through nitrate formation is also insignificant and our analysis will be limited to the impact of VOC emissions on SOA formation. Between January 2015 and February 2016 CARB contracted with Professor Schauer's group at the University of Wisconsin, Madison (UWM), to conduct a yearlong organic molecular marker study in the San Joaquin Valley. We used these data to estimate SOA contribution to the

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measured carbon concentrations. The estimated contribution ranged from 17 percent to 45 percent depending on the site and averaging time (annual, exceedance, or winter average). In order to consider a worst-case scenario, we assumed that 50 percent of organic matter is due to SOAs. Applying this assumption to measured concentrations, we estimated that VOCs contribute 4.1 $\mu g/m^3$ or 1.8 percent of PM_{10} mass. This value represents the highest possible SOA concentration.

In order to evaluate the appropriateness of this estimate, we used the organic aerosol tracer tool located at the Western Regional Air Partnership (WRAP) Technical Support System (TSS) website (http://vista.cira.colostate.edu/tss/). This tool allows us to investigate the contribution of primary and secondary anthropogenic and biogenic sources on modeled carbon at Class I areas. Annual average biogenic and anthropogenic SOA concentrations at the Joshua Tree National Park, the closest Class I area monitor to Calexico, were estimated to be about 0.58 and 0.09 $\mu g/m^3$, respectively for the 2002-2004 baseline. Therefore, our estimate of 4.1 $\mu g/m^3$ is reasonable and conservative.

Whether a $PM_{2.5}$ precursor is significant for the 24-hour $PM_{2.5}$ standard is determined by evaluating if a precursor contributes 1.3 $\mu g/m^3$ or more to the 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$ (or approximately 3.7%). Taking into consideration that the level of the 24-hr PM_{10} standard is much higher than the level of the $PM_{2.5}$ standard (150 $\mu g/m^3$ vs. 35 $\mu g/m^3$), the threshold level for PM_{10} is presumed to be higher than for $PM_{2.5}$. As shown in Table 1, since on average each precursor is found to contribute less than 2.1% to the PM_{10} concentrations, their contribution is considered insignificant.

We also considered whether precursor contribution would be higher for PM_{10} design values over the 229 $\mu g/m^3$ average estimated in Table 2. Figures 1 and 2 illustrate relationships between $PM_{2.5}$ and PM_{10} in Imperial Valley. It is evident from the charts that elevated $PM_{2.5}$ concentrations, in general, correspond to PM_{10} concentrations below the level of the standard. When PM_{10} levels exceed the 24-hour standard of 150 $\mu g/m^3$, $PM_{2.5}$ contributes a small percent of the PM_{10} mass. This suggests that high PM_{10} levels are driven by fugitive dust and secondary PM_{10} components are not expected to increase with PM_{10} mass increasing beyond the level of PM_{10} standard.

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Figure 1. Relationship between PM_{10} and $PM_{2.5}$ at Calexico, 2007 -2016

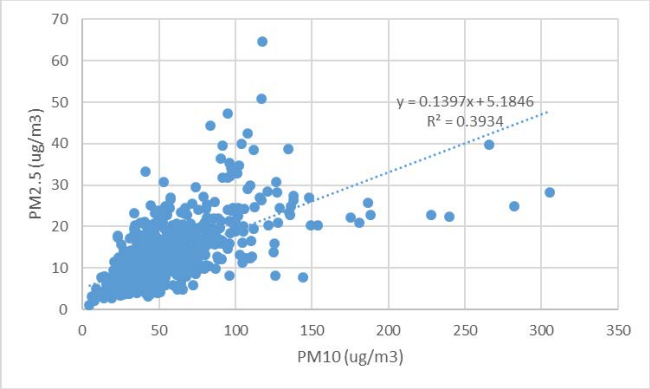
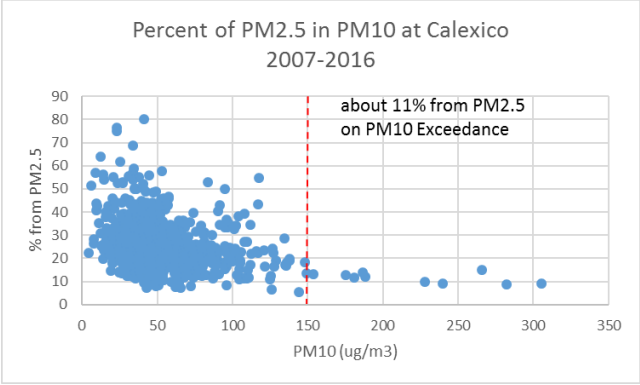


Figure 2. Percent of $PM_{2.5}$ in PM_{10} at Calexico, 2007-2016



Elevated PM_{10} concentrations in Imperial County are dominated by primary PM_{10} emissions from wind-blown dust rather than by secondarily formed PM_{10}. This precursor contribution analysis demonstrates that secondary formation is negligible compared with directly emitted PM_{10}. Reductions in emissions of PM_{10} precursors would not be effective in reducing PM_{10} concentrations and would lead to insignificant air quality changes. We conclude that precursor controls do not need to be included in the evaluation of potential control measures.

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Appendix B
Executed Settlement Agreement

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SETTLEMENT AGREEMENT

WHEREAS, on August 11, 2004, the United States Environmental Protection Agency ("EPA") reclassified the Imperial Valley Planning Area ("Imperial Valley") as a "serious" nonattainment area for coarse particulate matter ("PM10") national ambient air quality standards ("NAAQS") under the Clean Air Act, 69 Fed. Reg. 48,792 (Aug. 11, 2004), triggering the Clean Air Act requirement in 42 U.S.C. § 7513a(b)(1)(B) that the State of California submit to EPA within four years a state implementation plan containing provisions for the implementation of best available control measures ("BACM") for the control of PM10;

WHEREAS, in 2005 the Imperial County Air Pollution Control District ("Air District") adopted Rules 800 through 806 (known as "Regulation VIII") intended to limit emissions of PM10 within Imperial County;

WHEREAS, in 2006 the California Air Resources Board submitted the 2005 version of Regulation VIII to EPA as a revision to the state implementation plan;

WHEREAS, on July 8, 2010, EPA published a final rule in the Federal Register approving in part and disapproving in part the 2005 version of Regulation VIII, *see* 75 Fed. Reg. 39,366 (July 8, 2010) ("Final Rule");

WHEREAS, the Air District filed a petition for review of the Final Rule in the United States Court of Appeals for the Ninth Circuit (Case No. 10-72709);

WHEREAS, the California Department of Parks and Recreation ("Parks") filed a petition for review of the Final Rule in the United States Court of Appeals for the Ninth Circuit (Case No. 10-72729);

WHEREAS, the petitions for review were consolidated (referred to hereinafter as "the Existing Litigation");

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WHEREAS, briefing on the Existing Litigation has concluded and oral argument was held on February 15, 2012;

WHEREAS, on February 17, 2012 the United States Court of Appeals for the Ninth Circuit issued an Order (Docket No. 83) that referred the Existing Litigation to mediation, vacated submission of the Existing Litigation to the Court until further order, and noted that in the event that mediation efforts fail, the panel will finalize a disposition of the Existing Litigation without further briefing or argument from the parties;

WHEREAS, the Air District, Parks (hereinafter referred to together as "Petitioners"), and EPA (collectively, "the Parties") have a mutual interest in ensuring that the Air District's Regulation VIII satisfies the Clean Air Act's requirements for best available control measures for the control of PM10 air pollution, 42 U.S.C. § 7513a(b)(1)(B);

WHEREAS, EPA's determination of whether an exceedance of the PM10 NAAQS is an "exceptional event" within the meaning of section 319 of the Act, 42 U.S.C. § 7619, and EPA's regulations at 40 C.F.R. §§50.1 and 50.14 requires that EPA consider, among other criteria, whether the exceedance was "reasonably controllable or preventable" and EPA's consideration of this factor, evaluates, among other criteria, whether "reasonably available reasonable and appropriate measures" are in place to control anthropogenic PM10 sources and to abate or minimize the exposure of the public associated with the exceptional event (hereinafter referred to as "reasonable control");

WHEREAS, the Air District intends to prepare and transmit to the California Air Resources Board for submittal to EPA a revision to the state implementation plan as required by Clean Air Act section 189(d), 42 U.S.C. § 7513a(d);

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WHEREAS, in order to avoid the uncertainty, delay, and costs associated with continued litigation, the Air District, Parks, and EPA wish to implement this Settlement Agreement;

NOW THEREFORE, the Parties agree as follows:

1. The parties to this Settlement Agreement ("Agreement") are the Petitioners and EPA. Nothing in this Agreement shall be construed to make any other person or entity not executing this Agreement a third-party beneficiary to this Agreement.

2. This Agreement applies to, is binding upon, and inures to the benefit of the Petitioners (and their successors, assigns, and designees) and EPA.

3. This Agreement shall not constitute an admission or evidence of any fact, wrongdoing, misconduct, or liability on the part of the Parties, their officers, or any person affiliated with them.

4. Within fourteen days (14) after this Agreement is finalized pursuant to Paragraph 22 of this Agreement, the Parties shall file a motion and proposed order (attached hereto as Attachment A) in the Ninth Circuit Court of Appeals requesting that the case continue to be withheld from submission to the panel pending completion of, and subject to, the terms of this Agreement.

5. Any deadline stated herein that falls on a Saturday, a Sunday, or a legal holiday shall be extended to the next day which is not one of the aforementioned days.

6. Within 90 days after this Agreement is executed by all Parties, but before finalization pursuant to Paragraph 22 of this Agreement, the Air District shall submit to its Governing Board revisions to the Regulation VIII rules that are substantially the same in substance as set forth in Attachment B to this Agreement, and supporting documentation (including off-highway vehicle BACM demonstration).

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7. Within fourteen (14) days of the Governing Board's adoption of the revised Regulation VIII rules, the Air District shall submit the revised Regulation VIII rules and supporting documentation (including off-highway vehicle BACM demonstration) to the California Air Resources Board and request expedited submittal to EPA for incorporation into the California state implementation plan.

8. Within sixty (60) days of the California Air Resources Board's submittal of the revised Regulation VIII rules and supporting documentation (including off-highway vehicle BACM demonstration) to EPA as a revision to the California state implementation plan, the EPA Region 9 Regional Administrator will sign for publication in the Federal Register a notice of proposed rulemaking that proposes taking action on the submittal pursuant to Clean Air Act section 110(k), 42 U.S.C. § 7410(k). If the rules are substantially the same in substance as set forth in Attachment B to this Agreement, the notice to be signed by the Regional Administrator shall propose full approval of the submittal pursuant to Clean Air Act sections 110(k) and 189(b)(1)(B), 42 U.S.C. §§ 7410(k), 7513a(b)(1)(B). EPA shall include in the notice of proposed rulemaking a statement that EPA's preliminary view is that the revised Regulation VIII rules constitute "reasonable control" of the sources covered by Regulation VIII for the purpose of evaluating whether an exceedance of the PM10 NAAQS is an "exceptional event" including reasonable and appropriate control measures on significant contributing anthropogenic sources. This statement does not extend to exceedances of NAAQS other than the PM10 NAAQS, or to events that differ significantly in terms of meteorology, sources, or conditions from the events that are at issue in the Existing Litigation. Once signed, EPA shall promptly deliver the notice of proposed rulemaking to the Office of Federal Register for review and publication.

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9. If the Regional Administrator proposes full approval of the submittal referenced in Paragraph 8, then concurrently with signature of the notice in Paragraph 8, the Regional Administrator shall sign for publication in the Federal Register a notice making an interim final determination to defer imposition of sanctions pursuant to the Administrative Procedure Act, 5 U.S.C. § 553(d)(1). However, as is standard for such determinations, EPA may lift the deferral of sanctions if EPA receives significant and substantive public comments that change its assessment described in the determination and the proposed approval of the revised Regulation VIII rules.

10. Within sixty (60) days of the close of public comment on EPA's proposed rule referenced in Paragraph 8 of this Agreement, the EPA Region 9 Regional Administrator will sign for publication in the Federal Register a notice of final rulemaking taking action pursuant to Clean Air Act section 110(k), 42 U.S.C. § 7410(k). Once signed, EPA shall promptly deliver the notice of final rulemaking to the Office of Federal Register for review and publication.

11. Within ninety (90) days after publication in the Federal Register of EPA's notice of final rulemaking on a section 189(d) plan for the Imperial Valley PM10 serious nonattainment area, the Petitioners shall act to terminate the Existing Litigation by filing motions to dismiss their petitions with prejudice pursuant to Fed. R. App. Pro. 42, with each party to bear its own costs and attorneys' fees.

12. If EPA does not comply with any requirement of Paragraphs 8 through 10 of this Agreement, or if the final action required by Paragraph 10 does not finalize approval of the revised Regulation VIII rules, then the Air District and Parks may at their election, move to request that the Ninth Circuit Court of Appeals submit the Existing Litigation to the panel and proceed to a decision on the Existing Litigation. The Parties agree that this Paragraph 12

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constitutes the Petitioners' sole remedy under this Agreement if EPA does not comply with any requirement of Paragraphs 8 through 10.

13. If EPA takes any final action to require the State of California, on behalf of the Air District, to submit any plan required under Clean Air Act section 189(d), 42 U.S.C. § 7513a(d), prior to the dismissal described in Paragraph 11 of this Agreement, then the Air District may at its election, move to request that the Ninth Circuit Court of Appeals submit the Existing Litigation to the panel and proceed to a decision on the Existing Litigation. The Parties agree that this Paragraph 13 constitutes the Petitioners' sole remedy under this Agreement if EPA takes any final action to require a section 189(d) plan from the State of California on behalf of Imperial County.

14. If the California Air Resources Board does not submit the revised Regulation VIII rule submission to EPA within sixty (60) days after receiving it, then any of the Parties may at their election move to request that the Ninth Circuit Court of Appeals submit the Existing Litigation to the panel and proceed to a decision on the Existing Litigation.

15. In any event, no later than four years after the implementation date(s) within Imperial County for the revised Regulation VIII rules, the Petitioners shall act to terminate the Existing Litigation by filing motions to dismiss their petitions with prejudice pursuant to Fed. R. App. Pro. 42, with each party to bear its own costs and attorneys' fees.

16. This Agreement constitutes a full and final resolution of all matters related to the Existing Litigation, subject to the rights of the Parties to terminate this Agreement as referenced herein. Petitioners agree to release, discharge, and covenant not to assert (by way of the commencement of an action, the joinder of EPA in an existing action or in any other fashion) any and all claims, causes of action, suits or demands of any kind whatsoever in law or equity which

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they may have had, or may now or hereafter have, against the United States based upon matters related to the Existing Litigation.

17. If EPA's final action taken pursuant to Paragraph 10 of this Agreement is full approval, then Petitioners shall not bring a legal challenge to such action. Nothing in this Agreement shall preclude Petitioners from bringing a legal challenge to a final action taken pursuant to Paragraph 10 of this Agreement, other than full approval.

18. Nothing in this Agreement shall be construed to limit or modify the discretion accorded to EPA by the Clean Air Act, or by general principles of administrative law, nor shall it in any way be deemed to limit EPA's discretion in adopting any final rule.

19. Nothing in this Agreement shall be construed to limit or modify EPA's discretion to alter, amend, or revise any regulations, guidance, or interpretation EPA may issue in accordance with or on matters related to this Agreement from time to time or to promulgate or issue superseding regulations, guidance, or interpretations, or to limit any right that the Petitioners may have to seek judicial review in a subsequent case of any such action by EPA.

20. The Parties agree that they do not waive or limit any defense relating to the Existing Litigation if the Ninth Circuit Court of Appeals submits the Existing Litigation to the panel and the panel proceeds to a decision. EPA specifically reserves the right to argue that the Existing Litigation is moot in the event that any request to the Ninth Circuit Court of Appeals to submit the Existing Litigation to the panel occurs after EPA's final rulemaking referenced in Paragraph 10 of this Agreement and such final rulemaking is a full approval of the revised Regulation VIII rules.

21. No provision of this Agreement shall be interpreted as or constitute a commitment or requirement that EPA obligate or pay funds in contravention of the Anti-Deficiency Act, 31

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U.S.C. § 1341, or take actions in contravention of the Administrative Procedure Act, 5 U.S.C. §§ 551-559, 701-706, the Clean Air Act, or any other law or regulation, either substantive or procedural.

22. The Parties agree and acknowledge that before this Agreement is final, EPA must provide notice in the Federal Register and an opportunity for comment pursuant to Clean Air Act § 113(g), 42 U.S.C. § 7413(g). After this Agreement has undergone an opportunity for notice and comment, the Administrator and/or the Attorney General, as appropriate, shall promptly consider any such written comments in determining whether to withdraw or withhold consent to this Agreement, in accordance with section 113(g) of the Clean Air Act. If the federal government elects to withdraw or withhold consent to this Agreement, Petitioners shall have the right to withdraw from this Agreement. This Agreement shall become final on the date that EPA provides written notice of such finality to Petitioners.

23. The Parties may modify any deadline or other term of this agreement by written stipulation.

24. Any notices required or provided for by this Agreement shall be in writing, and shall be deemed effective (i) upon receipt if sent by U.S. Post or (ii) upon the date sent if sent by overnight delivery, facsimile, or email. In addition, to be effective, any such notice must be sent to the following:

For the Air District:

Rick Rothman
Bingham McCutchen LLP
355 South Grand Avenue, Suite 4400
Los Angeles, CA 90071-3106
tele: (213) 680-6400
fax: (213) 680-6499
email: rick.rothman@bingham.com

EEC ORIGINAL PKG

Michael Rood
County of Imperial
Office of the County Counsel
County Administration Center
940 Main Street, Suite 205
El Centro, CA 92243-2869
tele: (760) 482-4400
fax: (760) 353-9347
email: michaelrood@co.imperial.ca.us

For Parks:

Hayley Peterson
Office of the Attorney General
110 West A Street, Suite 1100
San Diego, CA 92101
tele: (619) 645-2540
fax: (619) 645-2012
email: hayley.peterson@doj.ca.gov

Legal Office
California Department of Parks and Recreation
1416 9th Street, 14th Floor
Sacramento, CA 95814

For EPA:

Christina L. Richmond
Environmental Defense Section
Environment and Natural Resources Division
United States Department of Justice
P.O. Box 7611
Washington, D.C. 20026-3986
tele: (202) 514-3376
fax: (202) 514-8865
email: christina.richmond2@usdoj.gov

Geoffrey L. Wilcox
Office of General Counsel
United States Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N. W.
Mail Code: 2344A
Washington, DC 20460

EEC ORIGINAL PKG

tele: (202) 564-5601
fax: (202) 564-5603
email: wilcox.geoffrey@epa.gov

Kara Christenson
Office of Regional Counsel
United States Environmental Protection Agency
75 Hawthorne Street
San Francisco, CA 94105
tele: (415) 972-3881
fax: (415) 947-3570
email: christenson.kara@epa.gov

or such other person as any party may subsequently identify in writing to the other parties.

25. The various terms, paragraphs, and sections contained herein shall be deemed separable and severable. If any provision of this Agreement is deemed invalid or unenforceable, the balance of the Agreement shall remain in full force and effect.

26. It is hereby expressly understood and agreed that this Agreement was jointly drafted by Petitioners and EPA. Accordingly, the Parties hereby agree that any and all rules of construction to the effect that ambiguity is construed against the drafting Party shall be inapplicable in any dispute concerning the terms, meaning, or interpretation of this Agreement.

27. Each undersigned representative of the Parties to this Agreement certifies that he or she is fully authorized by the party to enter into and execute the terms and conditions of this Agreement, and to legally bind such party to this Agreement.

28. This Agreement may be executed in any number of counterpart originals, each of which shall be deemed to constitute an original agreement, and all of which shall constitute one agreement. The execution of one counterpart by any party shall have the same force and effect as if that party had signed all other counterparts.

EEC ORIGINAL PKG

FOR THE AIR DISTRICT:

Date: _____

_____
MICHAEL W. KELLEY
Chairman of the Board
Imperial County Air Pollution Control District

FOR PARKS:

Date: _____

_____
RUTH COLEMAN
Director
California Department of Parks and Recreation

FOR EPA:

Date: 7/27/2012

Christina L. Richmond /ta
CHRISTINA L. RICHMOND, Trial Attorney
Environmental Defense Section
Environment and Natural Resources Division
United States Department of Justice

EEC ORIGINAL PKG

FOR THE AIR DISTRICT:

Date: 7/17/12

Michael W. Kelley

MICHAEL W. KELLEY
Chairman of the Board
Imperial County Air Pollution Control District

FOR PARKS:

Date: _____

_____

RUTH COLEMAN
Director
California Department of Parks and Recreation

FOR EPA:

Date: _____

_____

CHRISTINA L. RICHMOND, Trial Attorney
Environmental Defense Section
Environment and Natural Resources Division
United States Department of Justice

EEC ORIGINAL PKG

FOR THE AIR DISTRICT:

Date: _____

MICHAEL W. KELLEY
Chairman of the Board
Imperial County Air Pollution Control District

FOR PARKS:

Date: 7/25/12

~~RUTH COLEMAN~~ Janelle Beland
~~Director~~ Acting Director
California Department of Parks and Recreation

FOR EPA:

Date: _____

CHRISTINA L. RICHMOND, Trial Attorney
Environmental Defense Section
Environment and Natural Resources Division
United States Department of Justice

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Appendix C
2014-2016 Monitoring Data for Imperial County

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
1/1/2014	--	--	--	70	--	--	--	--	--	47
1/2/2014	--	--	--	58	--	--	--	--	--	38
1/3/2014	--	--	--	56	--	--	--	--	--	66
1/4/2014	--	--	--	55	--	--	--	--	--	47
1/5/2014	44	--	30	46	--	--	20	--	22	38
1/6/2014	--	--	--	34	--	--	--	--	--	40
1/7/2014	--	--	--	51	--	--	--	--	--	43
1/8/2014	--	--	--	65	45	--	--	--	--	41
1/9/2014	--	--	--	56	--	--	--	--	--	50
1/10/2014	--	--	--	54	--	--	--	--	--	65
1/11/2014	91	--	46	61	56	--	38	--	44	62
1/12/2014	--	--	--	70	--	--	--	--	--	49
1/13/2014	--	--	--	43	--	--	--	--	--	38
1/14/2014	--	--	--	32	--	--	--	--	--	48
1/15/2014	--	--	--	35	--	--	--	--	--	34
1/16/2014	--	--	--	42	--	--	--	--	--	41
1/17/2014	54	--	29	39	24	--	25	--	30	41
1/18/2014	--	--	--	45	--	--	--	--	--	51
1/19/2014	--	--	--	59	--	--	--	--	--	49
1/20/2014	--	--	--	54	--	--	--	--	--	42
1/21/2014	--	--	--	54	--	--	--	--	--	45
1/22/2014	--	--	--	55	--	--	--	--	--	47
1/23/2014	131	--	--	79	57	--	41	--	--	43
1/24/2014	--	--	--	53	--	--	--	--	--	60
1/25/2014	--	--	--	43	--	--	--	--	--	57
1/26/2014	--	--	--	48	--	--	--	--	--	49
1/27/2014	--	--	--	66	--	--	--	--	--	51
1/28/2014	--	--	--	53	--	--	--	--	--	44
1/29/2014	94	--	40	54	49	--	41	--	27	51
1/30/2014	--	--	--	111	--	--	--	--	--	89
1/31/2014	--	--	--	198	--	--	--	--	--	86
2/1/2014	--	--	--	31	--	--	--	--	--	36
2/2/2014	--	--	--	29	--	--	--	--	--	35
2/3/2014	--	--	--	32	--	--	--	--	--	61
2/4/2014	30	--	19	29	21	--	17	--	19	34
2/5/2014	--	--	--	42	--	--	--	--	--	46
2/6/2014	--	--	--	56	--	--	--	--	--	47
2/7/2014	--	--	--	29	--	--	--	--	--	35
2/8/2014	--	--	--	60	--	--	--	--	--	58
2/9/2014	--	--	--	46	--	--	--	--	--	47
2/10/2014	41	--	35	50	--	--	29	--	30	45
2/11/2014	--	--	--	34	--	--	--	--	--	29
2/12/2014	--	--	--	52	--	--	--	--	--	39
2/13/2014	--	--	--	65	54	--	--	--	--	56
2/14/2014	--	--	--	82	--	--	--	--	--	50
2/15/2014	--	--	--	--	--	--	--	--	--	62
2/16/2014	99	--	58	82	74	--	56	--	--	58
2/17/2014	--	--	--	61	--	--	--	--	--	62
2/18/2014	--	--	--	67	--	--	--	--	--	50
2/19/2014	--	--	--	73	--	--	--	--	--	66
2/20/2014	--	--	--	64	--	--	--	--	--	38

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
2/21/2014	--	--	--	60	--	--	--	--	--	50
2/22/2014	71	--	53	73	51	--	43	--	44	58
2/23/2014	--	--	--	59	--	--	--	--	--	59
2/24/2014	--	--	--	74	--	--	--	--	--	59
2/25/2014	--	--	--	67	--	--	--	--	--	58
2/26/2014	--	--	--	71	--	--	--	--	--	44
2/27/2014	--	--	--	39	--	--	--	--	--	38
2/28/2014	106	--	126	149	54	--	294	--	135	144
3/1/2014	--	--	--	39	--	--	--	--	--	47
3/2/2014	--	--	--	19	--	--	--	--	--	17
3/3/2014	--	--	--	27	--	--	--	--	--	19
3/4/2014	--	--	--	33	--	--	--	--	--	26
3/5/2014	--	--	--	35	--	--	--	--	--	28
3/6/2014	--	--	41	60	18	--	30	--	39	58
3/7/2014	--	--	--	73	--	--	--	--	--	46
3/8/2014	--	--	--	39	--	--	--	--	--	22
3/9/2014	--	--	--	30	--	--	--	--	--	15
3/10/2014	--	--	--	36	--	--	--	--	--	58
3/11/2014	--	--	--	55	--	--	--	--	--	44
3/12/2014	--	--	26	35	17	--	23	--	10	19
3/13/2014	--	--	--	48	--	--	--	--	--	60
3/14/2014	--	--	--	51	--	--	--	--	--	39
3/15/2014	--	--	--	49	--	--	--	--	--	39
3/16/2014	--	--	--	44	--	--	--	--	--	48
3/17/2014	--	--	--	190	--	--	--	--	--	87
3/18/2014	--	--	77	113	57	--	66	--	53	80
3/19/2014	--	--	--	55	--	--	--	--	--	29
3/20/2014	--	--	--	40	--	--	--	--	--	46
3/21/2014	--	--	--	53	--	--	--	--	--	52
3/22/2014	--	--	--	59	--	--	--	--	--	69
3/23/2014	--	--	--	59	--	--	--	--	--	51
3/24/2014	--	--	47	69	42	--	39	--	35	50
3/25/2014	--	--	--	137	--	--	--	--	--	127
3/26/2014	--	--	--	374	--	--	--	--	--	279
3/27/2014	38	--	--	94	--	--	--	--	--	115
3/28/2014	--	--	--	51	--	--	--	--	--	52
3/29/2014	--	--	--	57	--	--	--	--	--	49
3/30/2014	64	--	220	150	57	--	102	--	84	80
3/31/2014	--	--	--	106	--	--	--	--	--	102
4/1/2014	--	--	--	160	--	--	--	--	--	101
4/2/2014	--	--	--	137	--	--	--	--	--	38
4/3/2014	--	--	--	30	--	--	--	--	--	39
4/4/2014	--	--	--	50	--	--	--	--	--	53
4/5/2014	24	--	49	35	10	--	20	--	29	48
4/6/2014	--	--	--	28	--	--	--	--	--	30
4/7/2014	--	--	--	42	--	--	--	--	--	42
4/8/2014	--	--	--	46	--	--	--	--	--	53
4/9/2014	--	--	--	58	--	--	--	--	--	53
4/10/2014	--	--	--	56	--	--	--	--	--	87
4/11/2014	54	--	53	62	74	--	102	--	--	74
4/12/2014	--	--	--	103	--	--	--	--	--	167

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
4/13/2014	--	--	--	166	--	--	--	--	--	130
4/14/2014	--	--	--	58	--	--	--	--	--	66
4/15/2014	--	--	--	50	--	--	--	--	--	66
4/16/2014	--	--	--	57	--	--	--	--	54	73
4/17/2014	42	--	38	52	36	--	39	--	--	59
4/18/2014	--	--	--	47	--	--	--	--	--	57
4/19/2014	--	--	--	38	--	--	--	--	--	60
4/20/2014	--	--	--	36	--	--	--	--	--	44
4/21/2014	--	--	--	51	--	--	--	--	--	64
4/22/2014	--	--	--	131	--	--	--	--	--	134
4/23/2014	43	--	53	81	42	--	48	--	57	75
4/24/2014	--	--	--	75	--	--	--	--	--	73
4/25/2014	--	--	--	184	--	--	--	--	--	--
4/26/2014	--	--	--	312	--	--	--	--	--	149
4/27/2014	--	--	--	23	--	--	--	--	--	54
4/28/2014	--	--	--	47	--	--	--	--	--	53
4/29/2014	79	--	89	141	83	--	63	--	48	82
4/30/2014	--	--	--	58	--	--	--	--	--	75
5/1/2014	--	--	--	39	--	--	--	--	--	32
5/2/2014	--	--	--	37	--	--	--	--	--	37
5/3/2014	--	--	--	46	--	--	--	--	--	62
5/4/2014	--	--	--	55	--	--	--	--	--	74
5/5/2014	86	--	269	222	87	--	375	--	121	100
5/6/2014	--	--	--	438	--	--	--	--	--	--
5/7/2014	--	--	--	54	--	--	--	--	--	72
5/8/2014	--	--	--	40	--	--	--	--	--	69
5/9/2014	--	--	--	50	--	--	--	--	--	72
5/10/2014	--	--	--	104	--	--	--	--	--	--
5/11/2014	126	--	127	135	120	--	85	--	103	172
5/12/2014	--	--	--	50	--	--	--	--	--	29
5/13/2014	--	--	--	59	--	--	--	--	--	33
5/14/2014	--	--	--	45	--	--	--	--	--	61
5/15/2014	--	--	--	53	--	--	--	--	--	64
5/16/2014	--	--	--	78	--	--	--	--	--	65
5/17/2014	35	--	81	113	41	--	72	--	92	110
5/18/2014	--	--	--	100	--	--	--	--	--	106
5/19/2014	--	--	--	130	--	--	--	--	--	95
5/20/2014	--	--	--	250	--	--	--	--	--	122
5/21/2014	--	--	--	36	--	--	--	--	--	32
5/22/2014	--	--	--	56	--	--	--	--	--	42
5/23/2014	36	--	30	34	18	--	--	--	136	44
5/24/2014	--	--	--	58	--	--	--	--	--	62
5/25/2014	--	--	--	41	--	--	--	--	--	39
5/26/2014	--	--	--	51	--	--	--	--	--	72
5/27/2014	--	--	--	48	--	--	--	--	--	72
5/28/2014	--	--	--	48	--	--	--	--	--	72
5/29/2014	54	--	37	61	30	--	--	--	47	79
5/30/2014	--	--	--	48	--	--	--	--	--	71
5/31/2014	--	--	--	69	--	--	--	--	--	51
6/1/2014	--	--	--	29	--	--	--	--	--	42
6/2/2014	--	--	--	127	--	--	--	--	--	--

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
6/3/2014	--	--	--	45	--	--	--	--	--	42
6/4/2014	30	--	34	35	28	--	38	--	33	59
6/5/2014	--	--	--	59	--	--	--	--	--	82
6/6/2014	--	--	--	108	--	--	--	--	--	133
6/7/2014	--	--	--	38	--	--	--	--	--	95
6/8/2014	--	--	--	62	--	--	--	--	--	78
6/9/2014	--	--	--	88	--	--	--	--	--	90
6/10/2014	--	--	--	116	69	--	91	--	94	135
6/11/2014	--	--	--	73	--	--	--	--	--	103
6/12/2014	--	--	--	62	--	--	--	--	--	89
6/13/2014	--	--	--	97	--	--	--	--	--	99
6/14/2014	--	--	64	81	--	--	--	--	--	85
6/15/2014	--	--	--	61	--	--	--	--	--	100
6/16/2014	--	--	--	83	34	--	113	--	46	61
6/17/2014	49	--	88	92	--	--	--	--	--	122
6/18/2014	--	--	--	34	--	--	--	--	--	55
6/19/2014	43	--	--	57	--	--	--	--	--	71
6/20/2014	--	--	--	62	--	--	--	--	--	87
6/21/2014	--	--	--	54	--	--	--	--	--	74
6/22/2014	39	--	45	48	37	--	31	--	37	49
6/23/2014	--	--	--	45	--	--	--	--	--	61
6/24/2014	--	--	--	62	--	--	--	--	--	64
6/25/2014	--	--	--	53	--	--	--	--	--	84
6/26/2014	--	--	--	185	--	--	--	--	--	130
6/27/2014	--	--	--	96	--	--	--	--	--	100
6/28/2014	44	--	58	64	44	--	76	--	66	88
6/29/2014	--	--	--	46	--	--	--	--	--	65
6/30/2014	--	--	--	54	--	--	--	--	--	60
7/1/2014	--	--	--	60	--	--	--	--	--	71
7/2/2014	--	--	--	68	--	--	--	--	--	77
7/3/2014	--	--	--	116	--	--	--	--	--	120
7/4/2014	24	--	32	37	30	--	31	--	34	48
7/5/2014	--	--	--	40	--	--	--	--	--	64
7/6/2014	--	--	--	48	--	--	--	--	--	89
7/7/2014	--	--	--	54	--	--	--	--	--	83
7/8/2014	--	--	--	62	--	--	--	--	--	75
7/9/2014	--	--	--	63	--	--	--	--	--	82
7/10/2014	27	--	40	44	--	--	54	--	--	46
7/11/2014	--	--	--	53	--	--	--	--	--	83
7/12/2014	--	--	--	34	--	--	--	--	--	49
7/13/2014	--	--	--	64	--	--	--	--	--	69
7/14/2014	--	--	--	44	--	--	--	--	--	56
7/15/2014	--	--	--	47	--	--	--	--	--	48
7/16/2014	43	--	148	63	--	--	167	--	116	142
7/17/2014	--	--	--	66	--	--	--	--	--	101
7/18/2014	--	--	--	40	31	--	--	--	--	89
7/19/2014	--	--	--	45	--	--	--	--	--	51
7/20/2014	--	--	--	28	--	--	--	--	--	37
7/21/2014	--	--	--	34	--	--	--	--	--	50
7/22/2014	33	--	39	46	--	--	51	--	52	61
7/23/2014	--	--	--	51	--	--	--	--	--	52

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
7/24/2014	--	--	--	59	49	--	--	--	--	--
7/25/2014	--	--	--	90	--	--	--	--	--	--
7/26/2014	--	--	--	49	--	--	--	--	--	--
7/27/2014	--	--	--	103	--	--	--	--	--	--
7/28/2014	42	--	42	46	43	--	43	--	--	--
7/29/2014	--	--	--	53	--	--	--	--	--	--
7/30/2014	--	--	--	58	--	--	--	--	56	91
7/31/2014	--	--	--	64	--	--	--	--	--	95
8/1/2014	--	--	--	70	--	--	--	--	--	89
8/2/2014	--	--	--	45	--	--	--	--	--	50
8/3/2014	47	--	21	28	17	--	18	--	20	31
8/4/2014	--	--	--	25	--	--	--	--	--	43
8/5/2014	--	--	--	28	--	--	--	--	--	46
8/6/2014	--	--	--	49	--	--	--	--	--	108
8/7/2014	--	--	--	69	--	--	--	--	--	64
8/8/2014	--	--	--	49	--	--	--	--	--	52
8/9/2014	26	--	--	53	28	--	36	--	47	61
8/10/2014	--	--	--	34	--	--	--	--	--	40
8/11/2014	--	--	--	43	--	--	--	--	--	63
8/12/2014	--	--	--	63	--	--	--	--	--	102
8/13/2014	--	--	--	59	--	--	--	--	--	59
8/14/2014	--	--	--	40	--	--	--	--	--	61
8/15/2014	54	--	47	63	41	--	43	--	69	90
8/16/2014	--	--	--	39	--	--	--	--	--	58
8/17/2014	--	--	--	32	--	--	--	--	--	50
8/18/2014	--	--	--	102	--	--	--	--	--	161
8/19/2014	--	--	--	97	--	--	--	--	--	80
8/20/2014	--	--	--	63	--	--	--	--	--	53
8/21/2014	25	--	--	36	23	--	37	--	49	54
8/22/2014	--	--	--	29	--	--	--	--	--	30
8/23/2014	--	--	--	23	--	--	--	--	--	24
8/24/2014	--	--	--	25	--	--	--	--	--	29
8/25/2014	--	--	--	41	--	--	--	--	--	26
8/26/2014	--	--	--	41	--	--	--	--	--	45
8/27/2014	30	--	19	34	19	--	23	--	25	32
8/28/2014	--	--	--	45	--	--	--	--	--	38
8/29/2014	--	--	--	40	--	--	--	--	--	42
8/30/2014	--	--	--	41	--	--	--	--	--	75
8/31/2014	--	--	--	48	--	--	--	--	--	91
9/1/2014	--	--	--	32	--	--	--	--	--	79
9/2/2014	35	--	24	34	38	--	28	--	46	60
9/3/2014	--	--	--	44	--	--	--	--	--	59
9/4/2014	--	--	--	48	--	--	--	--	--	64
9/5/2014	--	--	--	53	--	--	--	--	--	59
9/6/2014	--	--	--	37	--	--	--	--	--	52
9/7/2014	--	--	--	26	--	--	--	--	--	27
9/8/2014	24	--	22	35	22	--	22	--	25	35
9/9/2014	--	--	--	42	--	--	--	--	--	39
9/10/2014	--	--	--	34	--	--	--	--	--	41
9/11/2014	--	--	--	44	--	--	--	--	--	49
9/12/2014	--	--	--	48	--	--	--	--	--	32

EEC ORIGINAL PKG

Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
9/13/2014	--	--	--	54	--	--	--	--	--	69
9/14/2014	45	--	--	41	44	--	32	--	31	42
9/15/2014	--	--	--	65	--	--	--	--	--	63
9/16/2014	--	--	--	37	--	--	--	--	--	49
9/17/2014	--	--	--	33	--	--	--	--	--	33
9/18/2014	--	--	--	73	--	--	--	--	--	104
9/19/2014	--	--	--	40	--	--	--	--	--	83
9/20/2014	33	--	35	51	36	--	40	--	50	64
9/21/2014	--	--	--	43	--	--	--	--	--	38
9/22/2014	--	--	--	52	--	--	--	--	--	61
9/23/2014	--	--	--	53	--	--	--	--	--	63
9/24/2014	--	--	--	44	--	--	--	--	--	66
9/25/2014	--	--	--	56	--	--	--	--	--	66
9/26/2014	25	--	55	68	--	--	136	--	--	130
9/27/2014	--	--	--	219	--	--	--	--	--	--
9/28/2014	--	--	--	41	--	--	--	--	--	37
9/29/2014	--	--	--	43	--	--	--	--	--	37
9/30/2014	--	--	--	45	--	--	--	--	61	75
10/1/2014	--	--	--	51	--	--	--	--	--	59
10/2/2014	--	--	47	67	40	--	--	--	28	63
10/3/2014	--	--	--	40	--	--	--	--	--	37
10/4/2014	56	--	--	42	--	--	--	--	--	42
10/5/2014	--	--	--	40	--	--	--	--	--	45
10/6/2014	--	--	--	53	--	--	--	--	--	70
10/7/2014	--	--	--	33	--	--	--	--	--	82
10/8/2014	23	--	14	20	19	--	27	--	40	49
10/9/2014	--	--	--	33	--	--	--	--	--	56
10/10/2014	--	--	--	44	--	--	--	--	--	46
10/11/2014	--	--	--	34	--	--	--	--	--	41
10/12/2014	--	--	--	32	--	--	--	--	--	42
10/13/2014	--	--	--	51	--	--	--	--	--	48
10/14/2014	60	--	47	59	42	--	49	--	59	82
10/15/2014	--	--	--	56	--	--	--	--	--	76
10/16/2014	--	--	--	56	--	--	--	--	--	61
10/17/2014	--	--	--	46	--	--	--	--	--	87
10/18/2014	--	--	--	55	--	--	--	--	--	79
10/19/2014	--	--	--	35	--	--	--	--	--	62
10/20/2014	32	--	38	53	32	--	35	--	45	60
10/21/2014	--	--	--	60	--	--	--	--	--	70
10/22/2014	--	--	--	58	--	--	--	--	--	66
10/23/2014	--	--	--	60	--	--	--	--	--	55
10/24/2014	--	--	--	76	--	--	--	--	--	65
10/25/2014	--	--	--	48	--	--	--	--	--	52
10/26/2014	21	--	24	32	--	--	32	--	29	42
10/27/2014	--	--	--	47	--	--	--	--	--	55
10/28/2014	--	--	--	65	40	--	--	--	--	52
10/29/2014	--	--	--	57	--	--	--	--	--	49
10/30/2014	--	--	--	54	--	--	--	--	--	64
10/31/2014	--	--	--	116	--	--	--	--	--	181
11/1/2014	--	--	471	131	56	--	404	--	173	218
11/2/2014	--	--	--	24	--	--	--	--	--	22

EEC ORIGINAL PKG

Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
11/3/2014	--	--	--	36	--	--	--	--	--	27
11/4/2014	33	--	--	46	--	--	--	--	--	25
11/5/2014	--	--	--	31	--	--	--	--	--	28
11/6/2014	--	--	--	43	--	--	--	--	--	24
11/7/2014	63	--	43	46	35	--	52	--	54	56
11/8/2014	--	--	--	52	--	--	--	--	--	86
11/9/2014	--	--	--	42	--	--	--	--	--	44
11/10/2014	--	--	--	42	--	--	--	--	--	72
11/11/2014	--	--	--	45	--	--	--	--	--	55
11/12/2014	--	--	--	67	--	--	--	--	--	69
11/13/2014	49	--	42	54	45	--	37	--	35	45
11/14/2014	--	--	--	47	--	--	--	--	--	63
11/15/2014	--	--	--	89	--	--	--	--	--	60
11/16/2014	--	--	--	210	--	--	--	--	--	248
11/17/2014	--	--	--	36	--	--	--	--	--	52
11/18/2014	--	--	--	48	--	--	--	--	--	72
11/19/2014	85	--	42	54	48	--	42	--	40	44
11/20/2014	--	--	--	60	--	--	--	--	--	58
11/21/2014	--	--	--	20	--	--	--	--	--	21
11/22/2014	--	--	--	27	--	--	--	--	--	53
11/23/2014	--	--	--	42	--	--	--	--	--	40
11/24/2014	--	--	--	27	--	--	--	--	--	23
11/25/2014	51	--	--	34	39	--	23	--	28	33
11/26/2014	--	--	--	40	--	--	--	--	--	44
11/27/2014	--	--	--	34	--	--	--	--	--	29
11/28/2014	--	--	--	50	--	--	--	--	--	56
11/29/2014	--	--	--	66	--	--	--	--	--	55
11/30/2014	--	--	--	30	--	--	--	--	--	36
12/1/2014	37	--	19	22	20	--	17	--	22	28
12/2/2014	--	--	--	41	--	--	--	--	--	57
12/3/2014	--	--	--	15	--	--	--	--	--	--
12/4/2014	--	--	--	24	--	--	--	--	--	--
12/5/2014	--	--	--	37	--	--	--	--	--	28
12/6/2014	--	--	--	23	--	--	--	--	--	20
12/7/2014	11	--	--	14	14	--	26	--	8	11
12/8/2014	--	--	--	33	--	--	--	--	--	17
12/9/2014	--	--	--	26	--	--	--	--	--	11
12/10/2014	--	--	--	29	--	--	--	--	--	16
12/11/2014	--	--	--	36	--	--	--	--	--	29
12/12/2014	--	--	--	14	--	--	--	--	--	14
12/13/2014	7	--	--	15	11	--	13	--	8	7
12/14/2014	--	--	--	11	--	--	--	--	--	8
12/15/2014	--	--	--	24	--	--	--	--	--	12
12/16/2014	--	--	--	25	--	--	--	--	--	19
12/17/2014	--	--	--	18	--	--	--	--	--	15
12/18/2014	--	--	--	34	--	--	--	--	--	17
12/19/2014	40	--	--	37	25	--	14	--	9	11
12/20/2014	--	--	--	32	--	--	--	--	--	11
12/21/2014	--	--	--	32	--	--	--	--	--	21
12/22/2014	--	--	--	38	--	--	--	--	--	25
12/23/2014	--	--	--	33	--	--	--	--	--	17

EEC ORIGINAL PKG

Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
12/24/2014	--	--	--	24	--	--	--	--	--	18
12/25/2014	45	--	35	45	44	--	36	--	--	36
12/26/2014	--	--	--	16	--	--	--	--	--	22
12/27/2014	--	--	--	16	--	--	--	--	--	23
12/28/2014	--	--	--	21	--	--	--	--	--	14
12/29/2014	--	--	--	31	--	--	--	--	--	23
12/30/2014	--	--	--	40	--	--	--	--	--	30
12/31/2014	28	--	--	32	24	--	14	--	17	25
1/1/2015	--	--	--	50	--	--	--	--	--	22
1/2/2015	--	--	--	40	--	--	--	--	--	35
1/3/2015	--	--	--	61	--	--	--	--	--	54
1/4/2015	--	--	--	51	--	--	--	--	--	43
1/5/2015	--	--	--	44	--	--	--	--	--	24
1/6/2015	32	--	29	31	23	--	24	--	17	20
1/7/2015	--	--	--	38	--	--	--	--	--	19
1/8/2015	--	--	--	41	--	--	--	--	--	22
1/9/2015	--	--	--	49	--	--	--	--	--	35
1/10/2015	--	--	--	38	--	--	--	--	--	44
1/11/2015	--	--	--	19	--	--	--	--	--	26
1/12/2015	46	--	15	17	23	--	10	--	10	14
1/13/2015	--	--	--	18	--	--	--	--	--	11
1/14/2015	--	--	--	19	--	--	--	--	--	7
1/15/2015	--	--	--	24	--	--	--	--	--	12
1/16/2015	--	--	--	25	--	--	--	--	--	22
1/17/2015	--	--	--	27	--	--	--	--	--	15
1/18/2015	34	--	26	27	22	--	29	--	18	18
1/19/2015	--	--	--	35	--	--	--	--	--	21
1/20/2015	--	--	--	36	--	--	--	--	--	43
1/21/2015	--	--	--	24	--	--	--	--	--	31
1/22/2015	--	--	--	33	--	--	--	--	--	38
1/23/2015	--	--	--	38	--	--	--	--	--	47
1/24/2015	27	--	20	22	24	--	25	--	--	69
1/25/2015	--	--	--	13	--	--	--	--	--	19
1/26/2015	--	--	--	8	--	--	--	--	--	11
1/27/2015	--	--	--	16	--	--	--	--	--	7
1/28/2015	--	--	--	23	--	--	--	--	13	13
1/29/2015	--	--	--	26	--	--	--	--	--	19
1/30/2015	--	--	13	15	11	--	9	--	7	9
1/31/2015	--	--	--	10	--	--	--	--	--	5
2/1/2015	--	--	--	8	--	--	--	--	--	2
2/2/2015	--	--	--	24	--	--	--	--	--	8
2/3/2015	89	--	--	37	--	--	--	--	--	17
2/4/2015	--	--	--	41	--	--	--	--	--	27
2/5/2015	69	--	37	47	42	--	26	--	21	24
2/6/2015	--	--	--	45	--	--	--	--	--	31
2/7/2015	--	--	--	36	--	--	--	--	--	27
2/8/2015	--	--	--	31	--	--	--	--	--	28
2/9/2015	--	--	--	35	--	--	--	--	--	15
2/10/2015	--	--	--	25	--	--	--	--	--	--
2/11/2015	25	--	20	23	23	--	21	--	26	25
2/12/2015	--	--	--	23	--	--	--	--	--	13

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Imperial County 2018 PM_{10} Plan

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	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
2/13/2015	--	--	--	40	--	--	--	--	--	22
2/14/2015	--	--	--	40	--	--	--	--	--	22
2/15/2015	--	--	--	34	--	--	--	--	--	21
2/16/2015	--	--	--	23	--	--	--	--	--	23
2/17/2015	--	--	26	30	24	--	20	--	14	17
2/18/2015	--	--	--	41	--	--	--	--	--	25
2/19/2015	85	--	--	58	--	--	--	--	--	37
2/20/2015	--	--	--	60	--	--	--	--	--	42
2/21/2015	--	--	--	109	--	--	--	--	--	124
2/22/2015	--	--	--	85	--	--	--	--	--	88
2/23/2015	29	--	23	26	21	--	22	--	7	7
2/24/2015	--	--	--	28	--	--	--	--	--	21
2/25/2015	--	--	--	38	--	--	--	--	--	22
2/26/2015	--	--	--	53	--	--	--	--	--	33
2/27/2015	--	--	--	117	--	--	--	--	--	102
2/28/2015	--	--	--	43	--	--	--	--	--	62
3/1/2015	4	--	4	3	2	--	5	--	6	6
3/2/2015	--	--	--	8	--	--	--	--	--	2
3/3/2015	--	--	--	26	--	--	--	--	--	3
3/4/2015	--	--	--	13	--	--	--	--	--	5
3/5/2015	--	--	--	18	--	--	--	--	--	4
3/6/2015	--	--	--	19	--	--	--	--	--	6
3/7/2015	39	--	25	24	19	--	23	--	18	18
3/8/2015	--	--	--	24	--	--	--	--	--	26
3/9/2015	--	--	--	41	--	--	--	--	--	28
3/10/2015	--	--	--	32	--	--	--	--	--	25
3/11/2015	--	--	--	33	--	--	--	--	--	26
3/12/2015	--	--	--	28	--	--	--	--	--	20
3/13/2015	20	--	22	27	18	--	21	--	11	9
3/14/2015	--	--	--	26	--	--	--	--	--	22
3/15/2015	--	--	--	41	--	--	--	--	--	38
3/16/2015	--	--	--	36	--	--	--	--	--	32
3/17/2015	--	--	--	33	--	--	--	--	--	47
3/18/2015	--	--	--	31	--	--	--	--	--	39
3/19/2015	26	--	16	17	19	--	--	--	35	22
3/20/2015	--	--	--	22	--	--	--	--	--	17
3/21/2015	--	--	--	61	--	--	--	--	--	47
3/22/2015	--	--	--	31	--	--	--	--	--	47
3/23/2015	--	--	--	35	--	--	--	--	--	57
3/24/2015	--	--	--	64	--	--	--	--	--	120
3/25/2015	27	--	28	33	21	--	25	--	27	36
3/26/2015	--	--	--	24	--	--	--	--	--	26
3/27/2015	--	--	--	29	--	--	--	--	--	52
3/28/2015	--	--	--	25	--	--	--	--	--	49
3/29/2015	--	--	--	21	--	--	--	--	--	34
3/30/2015	--	--	--	38	--	--	--	--	--	38
3/31/2015	39	--	40	45	35	--	--	--	64	81
4/1/2015	--	--	--	61	--	--	--	--	--	66
4/2/2015	--	--	--	47	--	--	--	--	--	50
4/3/2015	--	--	--	36	--	--	--	--	--	29
4/4/2015	--	--	--	35	--	--	--	--	--	49

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Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
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	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
4/5/2015	--	--	--	52	--	--	--	--	--	97
4/6/2015	59	--	77	99	79	--	96	--	72	100
4/7/2015	--	--	--	107	--	--	--	--	--	65
4/8/2015	--	--	--	28	--	--	--	--	--	12
4/9/2015	--	--	--	22	--	--	--	--	--	23
4/10/2015	--	--	--	33	--	--	--	--	--	49
4/11/2015	--	--	--	34	--	--	--	--	--	39
4/12/2015	40	--	27	31	30	--	34	--	27	33
4/13/2015	--	--	--	36	--	--	--	--	--	40
4/14/2015	--	--	--	38	--	--	--	--	--	63
4/15/2015	--	--	--	109	--	--	--	--	--	122
4/16/2015	--	--	--	32	--	--	--	--	--	42
4/17/2015	--	--	--	30	--	--	--	--	--	34
4/18/2015	52	--	31	36	31	--	--	--	36	48
4/19/2015	--	--	--	38	--	--	--	--	--	43
4/20/2015	--	--	--	46	--	--	--	--	--	54
4/21/2015	--	--	--	67	--	--	--	--	--	47
4/22/2015	--	--	--	34	--	--	37	--	--	48
4/23/2015	--	--	--	35	--	--	--	--	--	36
4/24/2015	22	--	91	109	23	--	101	--	147	168
4/25/2015	--	--	--	101	--	--	--	--	--	113
4/26/2015	--	--	--	25	--	--	--	--	--	11
4/27/2015	--	--	--	20	--	--	--	--	--	37
4/28/2015	--	--	--	28	--	--	--	--	--	20
4/29/2015	--	--	--	37	--	--	--	--	--	34
4/30/2015	--	--	31	30	26	--	30	--	39	42
5/1/2015	--	--	--	38	--	--	--	--	--	42
5/2/2015	35	--	--	36	--	--	--	--	--	30
5/3/2015	--	--	--	44	--	--	--	--	--	39
5/4/2015	--	--	--	42	--	--	--	--	--	62
5/5/2015	--	--	--	40	--	--	--	--	--	38
5/6/2015	--	--	61	73	29	--	97	--	90	117
5/7/2015	134	--	--	127	--	--	--	--	--	210
5/8/2015	--	--	--	33	--	--	--	--	--	21
5/9/2015	--	--	--	15	--	--	--	--	--	23
5/10/2015	--	--	--	23	--	--	--	--	--	27
5/11/2015	--	--	--	32	--	--	--	--	--	37
5/12/2015	35	--	27	29	24	--	44	--	51	59
5/13/2015	--	--	--	44	--	--	--	--	--	43
5/14/2015	--	--	--	75	--	--	--	--	--	105
5/15/2015	--	--	--	6	--	--	--	--	--	12
5/16/2015	--	--	--	14	--	--	--	--	--	10
5/17/2015	--	--	--	21	--	--	--	--	--	23
5/18/2015	18	--	304	152	17	--	111	--	39	74
5/19/2015	--	--	--	31	--	--	--	--	--	51
5/20/2015	--	--	--	41	--	--	--	--	--	60
5/21/2015	--	--	--	225	--	--	--	--	--	171
5/22/2015	--	--	--	227	--	--	--	--	--	122
5/23/2015	--	--	--	17	--	--	--	--	--	40
5/24/2015	12	--	15	--	10	--	14	--	23	25
5/25/2015	--	--	--	--	--	--	--	--	--	32

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
5/26/2015	--	--	--	--	--	--	--	--	--	34
5/27/2015	--	--	--	43	--	--	--	--	--	46
5/28/2015	--	--	--	33	--	--	--	--	--	41
5/29/2015	--	--	--	37	--	--	--	--	--	62
5/30/2015	34	--	31	31	38	--	32	--	29	30
5/31/2015	--	--	--	29	--	--	--	--	--	58
6/1/2015	--	--	--	45	--	--	--	--	--	76
6/2/2015	27	--	--	59	--	--	--	--	--	60
6/3/2015	--	--	--	39	--	--	--	--	--	53
6/4/2015	--	--	--	34	--	--	--	--	--	45
6/5/2015	--	--	39	47	16	--	40	--	30	33
6/6/2015	--	--	--	29	--	--	--	--	--	56
6/7/2015	--	--	--	44	--	--	--	--	--	36
6/8/2015	--	--	--	53	--	--	--	--	--	58
6/9/2015	--	--	--	36	--	--	--	--	--	29
6/10/2015	--	--	--	21	--	--	--	--	--	27
6/11/2015	16	--	22	26	15	--	26	--	22	24
6/12/2015	--	--	--	36	--	--	--	--	--	42
6/13/2015	--	--	--	37	--	--	--	--	--	48
6/14/2015	--	--	--	36	--	--	--	--	--	31
6/15/2015	--	--	--	48	--	--	--	--	--	45
6/16/2015	--	--	--	53	--	--	--	--	--	49
6/17/2015	37	--	--	51	32	--	45	--	50	54
6/18/2015	--	--	--	61	--	--	--	--	--	60
6/19/2015	--	--	--	36	--	--	--	--	--	45
6/20/2015	--	--	47	58	--	--	--	--	--	49
6/21/2015	--	--	--	44	--	--	--	--	--	37
6/22/2015	--	--	--	49	--	--	--	--	--	57
6/23/2015	35	--	37	42	30	--	34	--	41	44
6/24/2015	--	--	--	61	--	--	--	--	--	78
6/25/2015	--	--	--	66	--	--	--	--	--	60
6/26/2015	--	--	--	61	--	--	--	--	--	54
6/27/2015	--	--	--	45	--	--	--	--	--	39
6/28/2015	--	--	--	40	--	--	--	--	--	33
6/29/2015	42	--	--	49	45	--	41	--	66	66
6/30/2015	--	--	--	88	--	--	--	--	--	183
7/1/2015	--	--	--	40	--	--	--	--	--	52
7/2/2015	--	--	--	40	--	--	--	--	--	37
7/3/2015	--	--	--	27	--	--	--	--	--	48
7/4/2015	--	--	--	58	--	--	--	--	--	86
7/5/2015	38	--	--	42	34	--	--	--	33	46
7/6/2015	--	--	--	39	--	--	--	--	--	65
7/7/2015	--	--	--	55	--	--	--	--	--	90
7/8/2015	--	--	--	128	--	--	--	--	--	166
7/9/2015	--	--	--	79	--	--	--	--	--	105
7/10/2015	--	--	--	28	--	--	--	--	--	48
7/11/2015	31	--	37	39	34	--	43	--	42	49
7/12/2015	--	--	--	25	--	--	--	--	--	43
7/13/2015	--	--	--	43	--	--	--	--	--	78
7/14/2015	--	--	--	41	--	--	--	--	--	71
7/15/2015	--	--	--	41	--	--	--	--	--	63

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
7/16/2015	--	--	--	40	--	8	--	45	--	76
7/17/2015	84	--	101	115	90	8	126	104	109	132
7/18/2015	--	--	--	29	--	6	--	38	--	24
7/19/2015	--	--	--	17	--	5	--	14	--	18
7/20/2015	--	--	--	14	--	5	--	11	--	12
7/21/2015	--	--	--	34	--	5	--	48	--	68
7/22/2015	--	--	--	52	--	2	--	90	--	58
7/23/2015	28	--	23	26	--	17	--	33	45	46
7/24/2015	--	--	--	34	--	20	--	26	--	33
7/25/2015	--	--	--	27	--	24	--	27	--	30
7/26/2015	--	--	--	51	--	28	--	52	--	79
7/27/2015	--	--	--	38	--	26	--	27	--	43
7/28/2015	--	--	--	36	--	38	--	46	--	53
7/29/2015	32	--	34	38	37	43	--	29	30	33
7/30/2015	--	--	--	38	--	44	--	56	--	74
7/31/2015	--	--	--	49	--	34	--	62	--	28
8/1/2015	--	--	--	30	--	35	52	53	--	60
8/2/2015	--	--	--	24	--	18	--	33	--	29
8/3/2015	--	--	--	37	--	40	--	46	--	39
8/4/2015	44	--	43	45	39	41	50	49	75	72
8/5/2015	--	--	--	51	--	49	--	47	--	54
8/6/2015	--	--	--	51	--	42	--	50	--	96
8/7/2015	--	--	--	79	--	30	--	43	--	76
8/8/2015	--	--	--	30	--	27	--	29	--	29
8/9/2015	--	--	--	26	--	24	--	26	--	35
8/10/2015	31	--	36	37	39	42	40	40	47	46
8/11/2015	--	--	--	43	--	44	--	44	--	45
8/12/2015	--	--	--	43	--	42	--	41	--	41
8/13/2015	--	--	--	40	--	43	--	49	--	88
8/14/2015	--	--	--	38	--	41	--	40	--	80
8/15/2015	--	--	--	34	--	31	--	30	--	54
8/16/2015	62	--	55	62	61	76	50	69	52	61
8/17/2015	--	--	--	67	--	66	--	58	--	97
8/18/2015	--	--	--	52	--	48	--	59	--	113
8/19/2015	--	--	--	41	--	35	--	47	--	79
8/20/2015	--	--	--	62	--	56	--	52	--	68
8/21/2015	--	--	--	72	--	64	--	67	--	74
8/22/2015	34	--	32	36	33	39	33	35	47	40
8/23/2015	--	--	--	29	--	38	--	32	--	33
8/24/2015	--	--	--	34	--	38	--	38	--	52
8/25/2015	--	--	--	60	--	67	--	63	--	45
8/26/2015	--	--	--	26	--	35	--	30	--	38
8/27/2015	--	--	--	37	--	32	--	31	--	66
8/28/2015	33	--	30	31	30	33	32	29	64	65
8/29/2015	--	--	--	32	--	27	--	30	--	49
8/30/2015	--	--	--	27	--	32	--	29	--	46
8/31/2015	--	--	--	33	--	31	--	40	--	111
9/1/2015	--	--	--	51	--	45	--	52	--	106
9/2/2015	--	--	--	37	--	33	--	47	--	111
9/3/2015	44	--	38	40	35	41	52	63	70	69
9/4/2015	--	--	--	46	--	39	--	54	--	70

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
9/5/2015	--	--	--	35	--	37	--	42	--	65
9/6/2015	--	--	--	22	--	22	--	22	--	43
9/7/2015	--	--	--	23	--	24	--	31	--	40
9/8/2015	--	--	--	--	--	64	--	70	--	128
9/9/2015	62	--	52	58	70	81	57	67	61	79
9/10/2015	--	--	--	34	--	40	--	36	--	42
9/11/2015	--	--	--	48	--	45	--	43	--	43
9/12/2015	--	--	--	32	--	29	--	37	--	40
9/13/2015	--	--	--	67	--	82	--	55	--	90
9/14/2015	--	--	--	168	--	63	--	119	--	117
9/15/2015	55	--	52	67	42	51	49	55	41	90
9/16/2015	--	--	--	36	--	18	--	26	--	7
9/17/2015	--	--	--	65	--	35	--	55	--	31
9/18/2015	--	--	--	48	--	38	--	60	--	39
9/19/2015	--	--	--	36	--	40	--	63	--	39
9/20/2015	--	--	--	25	--	24	--	32	--	25
9/21/2015	28	--	30	34	30	39	--	37	59	66
9/22/2015	--	--	--	30	--	32	--	23	--	22
9/23/2015	--	--	--	41	--	48	45	42	--	37
9/24/2015	--	--	--	47	--	44	--	50	--	51
9/25/2015	--	--	--	55	--	52	--	54	--	70
9/26/2015	--	--	--	46	--	42	--	53	--	54
9/27/2015	41	--	27	29	27	30	32	36	30	33
9/28/2015	--	--	--	32	--	34	--	33	--	56
9/29/2015	--	--	--	32	--	45	--	37	--	48
9/30/2015	--	--	--	50	--	46	--	48	--	69
10/1/2015	--	--	--	154	--	86	--	97	--	171
10/2/2015	--	--	--	43	--	34	--	45	--	43
10/3/2015	45	--	29	32	25	27	43	41	67	61
10/4/2015	--	--	--	166	--	45	--	250	--	110
10/5/2015	--	--	--	20	--	20	--	22	--	8
10/6/2015	--	--	--	22	--	20	--	20	--	17
10/7/2015	--	--	--	36	--	26	--	73	--	21
10/8/2015	--	--	--	36	--	28	--	48	--	48
10/9/2015	65	--	36	32	38	37	53	62	67	67
10/10/2015	--	--	--	29	--	43	--	42	--	43
10/11/2015	--	--	--	29	--	33	--	53	--	34
10/12/2015	--	--	--	43	--	50	--	57	--	38
10/13/2015	--	--	--	42	--	41	--	53	--	38
10/14/2015	--	--	--	44	--	33	--	47	--	41
10/15/2015	31	--	25	28	14	22	23	32	23	28
10/16/2015	--	--	--	14	--	15	--	10	--	5
10/17/2015	--	--	--	14	--	14	--	18	--	10
10/18/2015	--	--	--	27	--	23	--	68	--	55
10/19/2015	--	--	--	18	--	15	--	55	--	14
10/20/2015	--	--	--	24	--	21	--	37	--	19
10/21/2015	52	--	24	24	41	45	26	26	48	26
10/22/2015	--	--	--	27	--	42	--	32	--	82
10/23/2015	--	--	--	33	--	29	--	75	--	40
10/24/2015	--	--	--	27	--	21	--	26	--	33
10/25/2015	--	--	--	26	--	--	--	33	--	35

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
10/26/2015	--	--	--	30	--	33	--	38	--	28
10/27/2015	80	--	42	40	45	47	56	59	60	41
10/28/2015	--	--	--	68	--	47	--	69	--	69
10/29/2015	--	--	--	34	--	30	--	50	--	34
10/30/2015	--	--	--	80	--	104	--	127	--	47
10/31/2015	--	--	--	26	--	24	--	34	--	35
11/1/2015	--	--	--	43	--	55	--	39	--	41
11/2/2015	--	--	--	128	88	90	179	117	39	131
11/3/2015	--	--	--	66	--	36	--	74	--	43
11/4/2015	53	--	--	23	--	24	--	23	--	17
11/5/2015	--	--	23	24	--	20	--	32	--	18
11/6/2015	--	--	--	29	--	21	--	23	--	16
11/7/2015	--	--	--	20	--	18	--	28	--	19
11/8/2015	60	--	23	21	24	24	27	30	21	16
11/9/2015	--	--	--	60	--	71	--	53	--	88
11/10/2015	--	--	--	141	--	32	--	84	--	24
11/11/2015	--	--	--	21	--	15	--	28	--	25
11/12/2015	--	--	--	25	--	16	--	28	--	26
11/13/2015	--	--	--	34	--	24	--	28	--	43
11/14/2015	103	--	37	36	35	37	30	26	81	72
11/15/2015	--	--	--	85	--	45	--	66	--	73
11/16/2015	--	--	--	119	--	48	--	138	--	66
11/17/2015	--	--	--	38	--	37	--	39	--	33
11/18/2015	--	--	--	46	--	48	--	41	--	36
11/19/2015	--	--	--	35	--	39	--	34	--	30
11/20/2015	60	--	31	34	37	41	38	38	44	44
11/21/2015	--	--	--	26	--	26	--	30	--	29
11/22/2015	--	--	--	17	--	15	--	18	--	14
11/23/2015	--	--	--	50	--	51	--	40	--	42
11/24/2015	--	--	--	101	--	86	--	90	--	102
11/25/2015	--	--	--	215	--	93	--	139	--	193
11/26/2015	15	--	18	18	11	12	16	14	28	21
11/27/2015	--	--	--	14	--	11	--	11	--	15
11/28/2015	--	--	--	22	--	18	--	19	--	15
11/29/2015	--	--	--	19	--	18	--	14	--	14
11/30/2015	--	--	--	25	--	16	--	23	--	12
12/1/2015	--	--	--	26	--	18	--	21	--	17
12/2/2015	--	--	32	30	27	26	28	25	2	20
12/3/2015	--	--	--	27	--	33	--	23	--	15
12/4/2015	107	--	--	34	--	55	--	28	--	51
12/5/2015	--	--	--	28	--	20	--	23	--	20
12/6/2015	--	--	--	16	--	14	--	18	--	24
12/7/2015	--	--	--	34	--	33	--	27	--	30
12/8/2015	91	--	39	39	37	37	33	32	46	47
12/9/2015	--	--	--	53	--	56	--	50	--	42
12/10/2015	--	--	--	77	--	95	--	81	--	49
12/11/2015	--	--	--	84	--	79	--	82	--	89
12/12/2015	--	--	--	18	--	15	--	17	--	20
12/13/2015	--	--	--	48	--	23	--	44	--	53
12/14/2015	--	--	222	208	165	201	193	183	250	33
12/15/2015	--	--	--	19	--	18	--	27	--	26

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
12/16/2015	--	--	--	22	--	22	--	25	--	19
12/17/2015	--	--	--	31	--	32	--	30	--	15
12/18/2015	81	--	--	27	--	25	--	24	--	16
12/19/2015	--	--	--	24	--	29	--	30	--	39
12/20/2015	--	--	19	18	12	11	14	13	12	10
12/21/2015	--	--	--	26	--	30	--	26	--	16
12/22/2015	42	--	--	89	--	45	--	127	--	40
12/23/2015	--	--	--	30	--	17	--	50	--	24
12/24/2015	--	--	--	62	--	33	--	30	--	26
12/25/2015	--	--	--	72	--	71	--	80	--	21
12/26/2015	55	--	101	132	93	102	165	198	73	132
12/27/2015	--	--	--	16	--	22	--	18	--	26
12/28/2015	--	--	--	32	--	30	--	34	--	23
12/29/2015	--	--	--	10	--	26	--	23	--	12
12/30/2015	--	--	--	30	--	41	--	62	--	29
12/31/2015	--	--	--	26	--	31	--	29	--	18
1/1/2016	--	--	25	23	--	29	--	13	21	16
1/2/2016	--	--	--	45	--	34	--	52	--	41
1/3/2016	--	--	--	44	--	22	--	31	--	46
1/4/2016	--	--	--	23	--	30	--	25	--	17
1/5/2016	22	--	--	20	--	26	--	20	--	12
1/6/2016	--	--	--	9	--	9	--	18	--	16
1/7/2016	5	--	6	4	--	4	--	3	4	2
1/8/2016	--	--	--	21	--	21	--	13	--	7
1/9/2016	--	--	--	23	--	24	--	18	--	9
1/10/2016	--	--	--	22	--	27	--	23	--	10
1/11/2016	--	--	--	19	--	18	--	13	--	4
1/12/2016	--	--	--	19	--	15	--	12	--	3
1/13/2016	40	--	34	29	--	31	--	19	11	9
1/14/2016	--	--	--	--	--	45	--	25	--	9
1/15/2016	--	124	--	--	--	150	--	60	--	28
1/16/2016	--	37	--	--	--	26	--	23	--	23
1/17/2016	--	40	--	--	--	22	--	18	--	14
1/18/2016	--	103	--	--	--	46	--	28	--	19
1/19/2016	66	71	35	--	--	47	--	30	19	18
1/20/2016	--	58	--	--	--	28	--	18	--	12
1/21/2016	--	58	--	--	--	23	--	22	--	8
1/22/2016	--	65	--	--	--	25	--	21	--	6
1/23/2016	--	43	--	--	--	25	--	20	--	17
1/24/2016	--	46	--	--	--	14	--	12	--	9
1/25/2016	--	49	21	--	--	23	--	14	11	11
1/26/2016	--	45	--	--	--	19	--	14	--	10
1/27/2016	--	46	--	--	--	23	--	20	--	20
1/28/2016	--	52	--	34	--	31	--	24	--	11
1/29/2016	--	85	--	38	--	45	--	33	--	23
1/30/2016	--	95	--	72	--	80	--	66	--	64
1/31/2016	--	93	218	167	--	48	--	251	225	227
2/1/2016	--	48	--	135	--	40	--	141	--	55
2/2/2016	--	43	--	22	--	27	--	26	--	11
2/3/2016	--	42	--	21	--	24	--	19	--	9
2/4/2016	--	31	--	20	--	15	--	18	--	8

EEC ORIGINAL PKG

Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
2/5/2016	--	33	--	19	--	17	--	16	--	15
2/6/2016	--	17	18	15	--	9	--	11	13	8
2/7/2016	--	27	--	13	--	10	--	11	--	9
2/8/2016	--	23	--	23	--	20	--	21	--	10
2/9/2016	--	44	--	27	--	21	--	23	--	17
2/10/2016	--	44	--	35	--	26	--	31	--	18
2/11/2016	--	63	--	33	--	28	--	24	--	17
2/12/2016	--	66	42	39	--	32	--	40	18	15
2/13/2016	--	42	--	35	--	34	--	32	--	26
2/14/2016	--	24	--	30	--	18	--	25	--	19
2/15/2016	--	27	--	25	--	19	--	23	--	14
2/16/2016	--	66	--	30	--	34	--	32	--	15
2/17/2016	--	97	--	88	--	58	--	117	--	67
2/18/2016	--	76	52	56	--	42	--	48	20	23
2/19/2016	--	39	--	26	--	25	--	19	--	11
2/20/2016	--	51	--	27	--	34	--	20	--	12
2/21/2016	--	33	--	23	--	19	--	21	--	15
2/22/2016	--	77	--	51	--	42	--	47	--	34
2/23/2016	--	62	--	35	--	37	--	42	--	21
2/24/2016	--	44	32	28	--	23	--	26	17	14
2/25/2016	--	59	--	34	--	24	--	46	--	14
2/26/2016	--	73	--	33	--	30	--	40	--	17
2/27/2016	--	85	--	39	--	45	--	31	--	25
2/28/2016	--	91	--	48	--	46	--	34	--	44
2/29/2016	--	124	--	52	--	71	--	51	--	53
3/1/2016	--	115	64	72	--	83	--	77	48	52
3/2/2016	--	89	--	55	--	51	--	45	--	43
3/3/2016	--	69	--	47	--	40	--	40	--	46
3/4/2016	--	54	--	70	--	38	--	86	--	69
3/5/2016	--	58	--	51	--	47	--	68	--	56
3/6/2016	--	64	--	204	--	86	--	149	--	124
3/7/2016	--	42	72	45	--	26	--	32	38	41
3/8/2016	--	18	--	12	--	16	--	11	--	8
3/9/2016	--	28	--	24	--	11	--	31	--	15
3/10/2016	--	48	--	30	--	24	--	25	--	20
3/11/2016	--	89	--	178	--	47	--	179	--	140
3/12/2016	--	31	--	63	--	15	--	31	--	46
3/13/2016	--	32	44	45	--	26	--	37	48	54
3/14/2016	--	23	--	40	--	20	--	41	--	37
3/15/2016	--	57	--	41	--	32	--	39	--	24
3/16/2016	--	52	--	40	--	30	--	40	--	43
3/17/2016	--	52	--	38	--	34	--	27	--	56
3/18/2016	--	65	--	42	--	51	--	38	--	72
3/19/2016	--	60	28	31	--	43	--	29	45	45
3/20/2016	--	41	--	25	--	20	--	20	--	40
3/21/2016	--	76	--	65	--	50	--	55	--	117
3/22/2016	--	109	--	142	--	46	--	110	--	116
3/23/2016	--	37	--	30	--	23	--	32	--	33
3/24/2016	--	51	--	25	--	19	--	18	--	19
3/25/2016	--	43	33	32	--	25	--	32	45	40
3/26/2016	--	54	--	48	--	49	--	29	--	27

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
3/27/2016	--	39	--	27	--	30	--	24	--	27
3/28/2016	--	138	--	274	--	183	--	177	--	--
3/29/2016	--	58	--	104	--	40	--	110	--	79
3/30/2016	--	19	--	16	--	12	--	21	--	12
3/31/2016	--	29	26	26	--	13	--	29	22	25
4/1/2016	--	44	--	23	--	22	--	28	--	32
4/2/2016	--	58	--	31	--	44	--	29	--	31
4/3/2016	--	35	--	23	--	22	--	24	--	30
4/4/2016	--	42	--	34	--	32	--	41	--	44
4/5/2016	--	75	--	47	--	43	--	39	--	47
4/6/2016	--	65	55	57	--	40	--	54	47	54
4/7/2016	--	37	--	57	--	17	--	76	--	45
4/8/2016	--	13	--	8	--	7	--	8	--	5
4/9/2016	--	13	--	11	--	9	--	18	--	11
4/10/2016	--	12	--	4	--	10	--	5	--	5
4/11/2016	--	18	--	10	--	13	--	8	--	9
4/12/2016	--	19	11	13	--	11	--	9	8	8
4/13/2016	--	39	--	30	--	25	--	21	--	33
4/14/2016	--	61	--	113	--	48	--	163	--	118
4/15/2016	--	53	--	84	--	55	--	89	--	75
4/16/2016	--	31	--	34	--	18	--	26	--	14
4/17/2016	--	36	--	24	--	30	--	18	--	29
4/18/2016	--	47	30	27	--	21	--	22	20	21
4/19/2016	--	58	--	33	--	33	--	35	--	35
4/20/2016	--	48	--	34	--	35	--	32	--	42
4/21/2016	--	55	--	38	--	49	--	44	--	44
4/22/2016	--	87	--	134	--	85	--	192	--	115
4/23/2016	--	43	--	62	--	63	--	33	--	32
4/24/2016	--	65	186	184	--	48	--	141	96	126
4/25/2016	--	173	--	285	--	151	--	244	--	225
4/26/2016	--	47	--	28	--	34	--	29	--	25
4/27/2016	--	99	--	141	--	68	--	75	--	136
4/28/2016	--	69	--	75	--	53	--	128	--	63
4/29/2016	--	35	--	44	--	23	--	36	--	43
4/30/2016	--	45	44	42	--	38	--	72	25	31
5/1/2016	--	24	--	13	--	20	--	17	--	12
5/2/2016	--	35	--	38	--	59	--	30	--	22
5/3/2016	--	41	--	37	--	28	--	20	--	19
5/4/2016	--	45	--	41	--	42	--	53	--	50
5/5/2016	--	125	--	163	--	85	--	227	--	135
5/6/2016	--	18	25	23	--	11	--	30	12	13
5/7/2016	--	16	--	7	--	10	--	16	--	24
5/8/2016	--	15	--	10	--	8	--	24	--	15
5/9/2016	--	32	--	22	--	22	--	23	--	35
5/10/2016	--	34	--	26	--	32	--	26	--	43
5/11/2016	--	45	--	30	--	40	--	35	--	28
5/12/2016	--	44	35	35	--	45	--	41	37	41
5/13/2016	--	49	--	31	--	42	--	34	--	29
5/14/2016	--	50	--	77	--	45	--	84	--	123
5/15/2016	--	57	--	59	--	67	--	100	--	216
5/16/2016	--	40	--	59	--	44	--	103	--	90

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
5/17/2016	--	55	--	43	--	44	--	55	--	55
5/18/2016	--	44	18	20	--	31	--	17	30	25
5/19/2016	--	50	--	95	--	34	--	90	--	66
5/20/2016	--	159	--	--	--	74	--	--	--	211
5/21/2016	--	226	--	199	--	185	--	93	--	113
5/22/2016	--	46	--	47	--	20	--	53	--	53
5/23/2016	--	35	--	81	--	44	--	105	--	77
5/24/2016	--	67	144	154	--	50	--	148	74	103
5/25/2016	--	78	--	165	--	--	--	119	--	76
5/26/2016	--	33	--	26	--	--	--	38	--	38
5/27/2016	--	47	--	39	--	38	--	34	--	46
5/28/2016	--	43	--	39	--	48	--	37	--	45
5/29/2016	--	35	--	27	--	30	--	26	--	33
5/30/2016	--	41	30	30	--	38	--	30	31	34
5/31/2016	--	57	--	46	--	66	--	51	--	54
6/1/2016	--	59	--	51	--	51	--	44	--	58
6/2/2016	--	67	--	50	--	57	--	42	--	61
6/3/2016	--	55	--	37	--	43	--	38	--	38
6/4/2016	--	34	--	70	--	35	--	55	--	38
6/5/2016	--	36	108	121	--	38	--	64	79	96
6/6/2016	--	49	--	58	--	38	--	42	--	55
6/7/2016	--	56	--	48	--	56	--	49	--	70
6/8/2016	--	63	--	56	--	61	--	55	--	51
6/9/2016	--	60	--	48	--	55	--	50	--	51
6/10/2016	--	59	--	56	--	59	--	56	--	56
6/11/2016	--	62	58	65	--	64	--	68	63	78
6/12/2016	--	32	--	66	--	31	--	82	--	50
6/13/2016	--	44	--	22	--	24	--	32	--	32
6/14/2016	--	51	--	49	--	46	--	57	--	72
6/15/2016	--	124	--	106	--	68	--	112	--	105
6/16/2016	--	51	--	33	--	39	--	55	--	51
6/17/2016	--	63	38	40	--	45	--	55	29	35
6/18/2016	--	43	--	50	--	28	--	50	--	24
6/19/2016	--	22	--	23	--	20	--	26	--	18
6/20/2016	--	75	--	76	--	79	--	69	--	72
6/21/2016	--	62	--	69	--	77	--	67	--	79
6/22/2016	--	66	--	101	--	66	--	65	--	98
6/23/2016	--	76	51	58	--	71	--	55	58	67
6/24/2016	--	67	--	53	--	64	--	53	--	50
6/25/2016	--	59	--	49	--	53	--	47	--	44
6/26/2016	--	54	--	51	--	55	--	49	--	46
6/27/2016	--	55	--	52	--	47	--	48	--	50
6/28/2016	--	64	--	58	--	57	--	65	--	81
6/29/2016	--	84	65	73	--	80	--	74	70	92
6/30/2016	--	64	--	59	--	53	--	55	--	64
7/1/2016	--	41	--	44	--	40	--	42	--	49
7/2/2016	--	61	--	51	--	55	--	48	--	50
7/3/2016	--	51	--	37	--	38	--	33	--	54
7/4/2016	--	40	--	67	--	33	--	95	--	68
7/5/2016	--	62	80	89	--	50	--	85	73	85
7/6/2016	--	77	--	64	--	66	--	83	--	93

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
7/7/2016	--	61	--	39	--	40	--	40	--	56
7/8/2016	--	49	--	42	--	38	--	42	--	64
7/9/2016	--	60	--	63	--	52	--	49	--	50
7/10/2016	--	66	--	117	--	39	--	66	--	116
7/11/2016	--	48	48	54	--	60	--	76	48	54
7/12/2016	--	60	--	33	--	43	--	45	--	76
7/13/2016	--	66	--	51	--	55	--	45	--	50
7/14/2016	--	55	--	48	--	43	--	51	--	58
7/15/2016	--	67	--	59	--	59	--	57	--	70
7/16/2016	--	68	--	56	--	59	--	48	--	65
7/17/2016	--	75	61	68	--	65	--	72	53	68
7/18/2016	--	62	--	45	--	38	--	48	--	51
7/19/2016	--	47	--	52	--	45	--	58	--	47
7/20/2016	--	46	--	44	--	44	--	51	--	54
7/21/2016	--	50	--	39	--	38	--	34	--	48
7/22/2016	--	63	--	56	--	60	--	57	--	55
7/23/2016	--	195	129	144	--	203	--	137	111	147
7/24/2016	--	194	--	155	--	126	--	164	--	131
7/25/2016	--	49	--	40	--	42	--	37	--	37
7/26/2016	--	47	--	50	--	50	--	50	--	66
7/27/2016	--	43	--	46	--	37	--	49	--	46
7/28/2016	--	61	--	48	--	51	--	55	--	65
7/29/2016	--	69	92	87	--	66	--	54	82	79
7/30/2016	--	158	--	195	--	171	--	201	--	168
7/31/2016	--	33	--	27	--	31	--	23	--	31
8/1/2016	--	37	--	34	--	33	--	30	--	42
8/2/2016	--	35	--	44	--	35	--	38	--	43
8/3/2016	--	37	--	42	--	36	--	50	--	44
8/4/2016	--	40	39	36	--	39	--	38	48	50
8/5/2016	--	43	--	48	--	46	--	55	--	58
8/6/2016	--	47	--	39	--	40	--	37	--	44
8/7/2016	--	36	--	33	--	31	--	56	--	48
8/8/2016	--	84	--	62	--	94	--	74	--	75
8/9/2016	--	155	--	141	--	159	--	166	--	167
8/10/2016	--	--	43	40	--	40	--	44	38	44
8/11/2016	--	43	--	27	--	30	--	27	--	31
8/12/2016	--	46	--	27	--	34	--	31	--	26
8/13/2016	--	53	--	36	--	38	--	44	--	34
8/14/2016	--	49	--	34	--	33	--	32	--	40
8/15/2016	--	48	--	33	--	33	--	37	--	38
8/16/2016	--	51	38	35	--	47	--	45	39	39
8/17/2016	--	94	--	82	--	99	--	99	--	105
8/18/2016	--	55	--	63	--	50	--	86	--	60
8/19/2016	--	114	--	119	--	105	--	126	--	151
8/20/2016	--	89	--	84	--	89	--	82	--	93
8/21/2016	--	138	--	113	--	170	--	118	--	76
8/22/2016	--	42	58	66	--	33	--	75	57	69
8/23/2016	--	46	--	42	--	46	--	48	--	70
8/24/2016	--	58	--	46	--	60	--	49	--	56
8/25/2016	--	77	--	68	--	73	--	75	--	73
8/26/2016	--	53	--	42	--	44	--	40	--	46

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
8/27/2016	--	34	--	45	--	39	--	41	--	30
8/28/2016	--	41	24	23	--	30	--	21	27	25
8/29/2016	--	54	--	48	--	36	--	44	--	32
8/30/2016	--	62	--	55	--	47	--	52	--	60
8/31/2016	--	63	--	62	--	72	--	68	--	83
9/1/2016	--	52	--	53	--	52	--	49	--	95
9/2/2016	--	44	--	52	--	40	--	44	--	64
9/3/2016	--	97	275	119	--	174	--	130	--	97
9/4/2016	--	69	--	81	--	39	--	72	--	73
9/5/2016	--	33	--	44	--	28	--	52	--	43
9/6/2016	--	65	--	49	--	54	--	54	--	49
9/7/2016	--	52	--	47	--	49	--	46	--	41
9/8/2016	--	41	--	36	--	40	--	35	--	30
9/9/2016	--	51	37	33	--	38	--	37	33	32
9/10/2016	--	49	--	39	--	31	--	34	--	38
9/11/2016	--	31	--	56	--	27	--	53	--	42
9/12/2016	--	82	--	232	--	106	--	164	--	75
9/13/2016	--	180	--	160	--	179	--	82	--	93
9/14/2016	--	42	--	28	--	29	--	25	--	17
9/15/2016	--	48	36	33	--	32	--	28	27	24
9/16/2016	--	66	--	55	--	49	--	65	--	40
9/17/2016	--	49	--	48	--	37	--	43	--	39
9/18/2016	--	45	--	33	--	26	--	27	--	25
9/19/2016	--	129	--	99	--	110	--	141	--	104
9/20/2016	--	20	--	12	--	12	--	11	--	9
9/21/2016	--	19	10	9	--	10	--	7	8	6
9/22/2016	--	82	--	89	--	82	--	102	--	144
9/23/2016	--	71	--	52	--	50	--	41	--	54
9/24/2016	--	27	--	30	--	20	--	25	--	15
9/25/2016	--	30	--	37	--	30	--	21	--	12
9/26/2016	--	54	--	54	--	56	--	45	--	36
9/27/2016	--	39	40	40	--	46	--	33	35	36
9/28/2016	--	47	--	30	--	37	--	25	--	24
9/29/2016	--	53	--	28	--	36	--	49	--	48
9/30/2016	--	46	--	28	--	24	--	32	--	37
10/1/2016	--	33	--	24	--	27	--	28	--	26
10/2/2016	--	119	--	86	--	67	--	137	--	84
10/3/2016	--	55	79	95	--	57	--	76	--	60
10/4/2016	--	41	--	35	--	30	--	31	--	41
10/5/2016	--	51	--	--	--	33	--	39	29	30
10/6/2016	--	48	--	44	--	33	--	37	--	30
10/7/2016	--	62	--	33	--	28	--	26	--	29
10/8/2016	--	39	--	30	--	27	--	27	--	24
10/9/2016	--	40	32	30	--	31	--	32	26	23
10/10/2016	--	54	--	40	--	58	--	43	--	41
10/11/2016	--	56	--	37	--	37	--	43	--	30
10/12/2016	--	74	--	43	--	53	--	45	--	50
10/13/2016	--	78	--	50	--	47	--	44	--	45
10/14/2016	--	90	--	67	--	55	--	60	--	57
10/15/2016	--	54	38	38	--	43	--	39	34	36
10/16/2016	--	51	--	26	--	28	--	25	--	38

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
10/17/2016	--	44	--	44	--	20	--	41	--	38
10/18/2016	--	51	--	41	--	32	--	36	--	26
10/19/2016	--	59	--	43	--	35	--	28	--	21
10/20/2016	--	63	--	33	--	35	--	32	--	20
10/21/2016	--	76	48	45	--	44	--	38	31	30
10/22/2016	--	101	--	61	--	70	--	56	--	50
10/23/2016	--	45	--	29	--	38	--	30	--	34
10/24/2016	--	83	--	36	--	47	--	29	--	26
10/25/2016	--	29	--	21	--	19	--	17	--	10
10/26/2016	--	38	--	30	--	24	--	20	--	16
10/27/2016	--	51	29	27	--	31	--	35	17	13
10/28/2016	--	115	--	49	--	65	--	40	--	30
10/29/2016	--	64	--	39	--	38	--	33	--	23
10/30/2016	--	62	--	162	--	79	--	124	--	58
10/31/2016	--	48	--	23	--	23	--	28	--	16
11/1/2016	--	33	--	38	--	25	--	39	--	32
11/2/2016	--	46	36	30	--	23	--	20	33	10
11/3/2016	--	103	--	68	--	91	--	39	--	34
11/4/2016	--	133	--	107	--	82	--	103	--	68
11/5/2016	--	78	--	39	--	29	--	32	--	28
11/6/2016	--	69	--	27	--	28	--	24	--	22
11/7/2016	--	61	--	47	--	39	--	35	--	30
11/8/2016	--	54	33	33	--	30	--	25	24	22
11/9/2016	--	63	--	37	--	34	--	36	--	17
11/10/2016	--	61	--	46	--	39	--	73	--	21
11/11/2016	--	45	--	41	--	45	--	41	--	23
11/12/2016	--	40	--	38	--	30	--	28	--	37
11/13/2016	--	--	--	32	--	22	--	30	--	27
11/14/2016	--	--	39	35	--	32	--	37	--	17
11/15/2016	--	85	--	55	--	67	--	52	--	32
11/16/2016	--	136	--	105	--	128	--	101	76	57
11/17/2016	--	70	--	85	--	59	--	83	--	60
11/18/2016	--	67	--	35	--	29	--	31	--	16
11/19/2016	--	67	--	31	--	26	--	31	--	19
11/20/2016	--	98	37	36	--	51	--	37	30	32
11/21/2016	--	31	--	13	--	21	--	26	--	11
11/22/2016	--	28	--	20	--	19	--	15	--	12
11/23/2016	--	31	--	23	--	23	--	20	--	12
11/24/2016	--	21	--	20	--	26	--	16	--	9
11/25/2016	--	32	--	36	--	28	--	31	--	20
11/26/2016	--	92	88	98	--	53	--	135	65	91
11/27/2016	--	70	--	43	--	21	--	30	--	11
11/28/2016	--	31	--	39	--	39	--	30	--	39
11/29/2016	--	50	--	29	--	27	--	27	--	15
11/30/2016	--	58	--	31	--	33	--	19	--	11
12/1/2016	--	76	--	34	--	36	--	25	--	10
12/2/2016	--	50	39	47	--	49	--	51	20	24
12/3/2016	--	51	--	30	--	37	--	37	--	15
12/4/2016	--	55	--	15	--	24	--	12	--	14
12/5/2016	--	104	--	48	--	73	--	40	--	17
12/6/2016	--	93	--	58	--	57	--	54	--	45

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Table C-1. 2014-2016 Monitoring Data for Imperial County
Imperial County 2018 PM_{10} Plan

Date	PM_{10} Concentration (µg/m^3)									
	Calexico - Ethel		Brawley		El Centro		Westmorland		Niland	
	POC 1	POC 3	POC 1	POC 3	POC 2	POC 4	POC 1	POC 3	POC 1	POC 3
Station ID	60250005	60250005	60250007	60250007	60251003	60251003	60254003	60254003	60254004	60254004
12/7/2016	--	52	--	40	--	33	--	39	--	32
12/8/2016	--	54	38	35	--	38	--	27	18	15
12/9/2016	--	65	--	41	--	40	--	32	--	23
12/10/2016	--	87	--	46	--	45	--	38	--	36
12/11/2016	--	87	--	53	--	57	--	44	--	33
12/12/2016	--	76	--	42	--	56	--	33	--	34
12/13/2016	--	91	--	53	--	56	--	43	--	29
12/14/2016	--	69	42	41	--	46	--	36	24	21
12/15/2016	--	93	--	61	--	69	--	67	--	37
12/16/2016	--	238	--	232	--	207	--	198	--	278
12/17/2016	--	102	--	77	--	118	--	95	--	22
12/18/2016	--	25	--	21	--	14	--	14	--	16
12/19/2016	--	28	--	25	--	27	--	22	--	8
12/20/2016	--	38	38	27	--	27	--	25	19	18
12/21/2016	--	31	--	18	--	23	--	20	--	13
12/22/2016	--	13	--	2	--	5	--	2	--	1
12/23/2016	--	27	--	12	--	24	--	16	--	6
12/24/2016	--	14	--	11	--	15	--	14	--	12
12/25/2016	--	24	--	8	--	11	--	6	--	4
12/26/2016	--	15	15	12	--	10	--	8	--	4
12/27/2016	--	38	--	20	--	18	--	12	--	5
12/28/2016	--	34	--	28	--	21	--	19	12	8
12/29/2016	--	43	--	35	--	27	--	27	--	13
12/30/2016	--	44	--	27	--	25	--	20	--	18
12/31/2016	--	38	--	18	--	28	--	18	--	12

Notes:
Data obtained from United States Environmental Protection Agency Outdoor Air Quality Data. Available at: https://www.epa.gov/outdoor-air-quality-data/download-daily-data. Accessed: October 2017.

Abbreviations:
POC - parameter occurrence code

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Table C-2. 2014-2016 Monitoring Data Completeness
Imperial County 2018 PM_{10} Plan

Year	Monitoring Frequency	AQS Site ID	Name	POC	% Complete
2014	Continuous	60250007	Brawley-Main Street	3	99
2014	Continuous	60254004	Niland-English Road	3	96
2014	Intermittent	60250005	Calexico-Ethel Street	1	95
2014	Intermittent	60250007	Brawley-Main Street	1	86
2014	Intermittent	60251003	El Centro-9th Street	2	98
2014	Intermittent	60254003	Westmorland North	1	96
2014	Intermittent	60254004	Niland-English Road	1	93
2015	Continuous	60250007	Brawley-Main Street	3	98
2015	Continuous	60251003	El Centro-9th Street	4	91
2015	Continuous	60254003	Westmorland North	3	91
2015	Continuous	60254004	Niland-English Road	3	99
2015	Intermittent	60250005	Calexico-Ethel Street	1	98
2015	Intermittent	60250007	Brawley-Main Street	1	96
2015	Intermittent	60251003	El Centro-9th Street	2	98
2015	Intermittent	60254003	Westmorland North	1	93
2015	Intermittent	60254004	Niland-English Road	1	100
2016	Continuous	60250005	Calexico-Ethel Street	3	99
2016	Continuous	60250007	Brawley-Main Street	3	95
2016	Continuous	60251003	El Centro-9th Street	4	99
2016	Continuous	60254003	Westmorland North	3	99
2016	Continuous	60254004	Niland-English Road	3	100
2016	Intermittent	60250005	Calexico-Ethel Street	1	100
2016	Intermittent	60250007	Brawley-Main Street	1	100
2016	Intermittent	60254004	Niland-English Road	1	98

Notes:
1. Continuous monitoring refers to the collection of measurements once per day. Intermittent monitoring refers to the collection of measurements once every six days.
2. Data compiled from USEPA AMP600 certification reports.

Abbreviations:
AQS - Air Quality System
POC - parameter occurrence code
USEPA - United States Environmental Protection Agency

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Appendix D
2014-2016 Documented Exceptional Events for Imperial County

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Appendix D. 2014-2016 Documented Exceptional Events for Imperial County
Imperial County 2018 PM_{10} Plan

Monitoring Site	AQS No.	POC	Date	PM_{10} Concentration ($\mu g/m^3$)	Documentation Status	Event Description
Brawley	06-025-0007	3	01/31/2014	198	Submitted to CARB	Predominantly west-southwest winds with gusts as high as 38 mph.
Westmorland	06-025-4003	1	02/28/2014	294	Submitted to CARB	Predominantly south southwest with gusts as high as 41 mph.
Brawley	06-025-0007	3	03/17/2014	190	Submitted to CARB	Predominantly southwest winds with gusts as high as 31 mph.
Brawley	06-025-0007	3	03/26/2014	374	Submitted to CARB	Predominantly west winds with gusts as high as 43 mph.
Niland	06-025-4004	3	03/26/2014	279		
Brawley	06-025-0007	1	03/30/2014	220	Submitted to CARB	Predominantly west southwest winds with gusts as high as 36 mph.
Brawley	06-025-0007	3	04/01/2014	160		Predominantly west southwest winds with gusts as high as 34 mph.
Niland	06-025-4004	3	04/12/2014	167	Submitted to CARB	Predominantly west winds with gusts as high as 25 mph.
Brawley	06-025-0007	3	04/13/2014	166		
Brawley	06-025-0007	3	04/25/2014	184	Submitted to CARB	Predominantly west southwest winds with gusts as high as 42 mph.
Brawley	06-025-0007	3	04/26/2014	312		Predominantly west winds with gusts as high as 40 mph.
Brawley	06-025-0007	1	05/05/2014	269	Submitted to CARB	Predominantly west southwest winds with gusts as high as 40 mph.
Westmorland	06-025-4003	1	05/05/2014	375		Predominantly west southwest winds with gusts as high as 40 mph.
Brawley	06-025-0007	3	05/05/2014	222		Predominantly west southwest winds with gusts as high as 40 mph.
Brawley	06-025-0007	3	05/06/2014	438		Predominantly west winds with gusts as high as 51 mph.
Niland	06-025-4004	3	05/11/2014	172	Submitted to CARB	Predominantly west winds with gusts as high as 25 mph.
Brawley	06-025-0007	3	05/20/2014	250	Submitted to CARB	Predominantly west southwest winds with gusts as high as 38 mph.
Brawley	06-025-0007	3	06/26/2014	185	Submitted to CARB	Predominantly west southwest winds with gusts as high as 36 mph.
Westmorland	06-025-4003	1	07/16/2014	167	Submitted to CARB	Predominantly west southwest winds with gusts as high as 30 mph.
Niland	06-025-4004	3	08/18/2014	161	Submitted to CARB	Predominantly southeast winds with gusts as high as 41 mph.
Brawley	06-025-0007	3	09/27/2014	219	Submitted to CARB	Predominantly west southwest winds with gusts as high as 39 mph.
Niland	06-025-4004	3	10/31/2014	181	Submitted to CARB	Predominantly west southwest winds with gusts as high as 23 mph.
Brawley	06-025-0007	1	11/01/2014	471		Predominantly west southwest winds with gusts as high as 40 mph.
Westmorland	06-025-4003	1	11/01/2014	404		Predominantly west southwest winds with gusts as high as 40 mph.
Niland	06-025-4004	1	11/01/2014	173		Predominantly west southwest winds with gusts as high as 40 mph.
Niland	06-025-4004	3	11/01/2014	218		Predominantly west southwest winds with gusts as high as 40 mph.
Brawley	06-025-0007	3	11/16/2014	210	Submitted to CARB	Predominantly south southwest winds with gusts as high as 34 mph.
Niland	06-025-4004	3	11/16/2014	248		
Niland	06-025-4004	3	04/24/2015	168	Submitted to CARB	According to the weather briefing issued by the National Weather Service on April 24, 2015 unsettled weather occurred within the southeast desert region of California affecting Imperial County. As a result of the unsettled weather the NWS issued a "Wind Advisory" indicating that elevated winds were expected for April 24, 2015. West wind 10 to 20mph in the morning increasing to 20 to 30mph in the afternoon. Gusts up to 40mph in the afternoon. Affected areas include Southeast California including El Centro, Plaster City, Blythe, Desert Center, Joshua Tree National Park and additional locations along the Interstate 8 and 10 corridors.
Niland	06-025-4004	3	05/07/2015	210	Submitted to CARB	According to the National Weather Service Zone forecast and Wind Advisory, Sustained west southwest winds 25 to 30mph with strong gusts 40 to 45mph. Strong gusts were expected to create hazardous crosswinds and potentially reduce visibilities due to blowing dust. Affected areas include Southeast California including El Centro, Plaster City, Blythe, Desert Center, Joshua Tree National Park and additional locations along the Interstate 8 and 10 corridors.
Brawley	06-025-0007	1	05/18/2015	304	Submitted to CARB	According to the National Weather Service Zone forecast west winds 5 to 25mph throughout the day with evening gusts up to 30mph. Affected areas include Southeast California including Brawley, Calexico, El Centro, Glamis, Imperial and the Salton Sea.
Brawley	06-025-0007	3	05/21/2015	225	Submitted to CARB	According to the National Weather Service issued wind advisory west winds 15 to 25mph with gusts up to 40mph were expected in the afternoon. Affected areas included cities of Brawley, Calexico, El Centro, Glamis, Imperial and the Salton Sea
Niland	06-025-4004	3	05/21/2015	171		
Brawley	06-025-0007	3	05/22/2015	227		
Niland	06-025-4004	3	06/30/2015	183	Submitted to CARB	According to NOAA's National Climatic Centers an early-season monsoon pattern set up across the southwest U.S., bringing several days of enhanced mid-level moisture from the southeast. A disturbance moving through Baja on the 30th produced an active day of thunderstorms over southern California, reaching all the way to the coast with prolific lightning and rainfall for several areas. Lightning sparked a few small fires near Poway and La Mesa. The National Weather Service issued a weather briefing for the Arizona Desert area.

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Monitoring Site	AQS No.	POC	Date	PM_{10} Concentration ($\mu g/m^3$)	Documentation Status	Event Description
Niland	06-025-4004	3	07/08/2015	166	Submitted to CARB	According to NOAA's National Climatic Centers an unseasonable upper level low moving in from the Pacific helped trigger thunderstorms over eastern California and adjacent areas of western Nevada. Isolated severe weather and flash flooding occurred. The National Weather Service zone forecast indicated west winds 10 to 15mph becoming southwest 15 to 25mph in the afternoon with gusts up to 35mph
Brawley	06-025-0007	3	09/14/2015	168	Submitted to CARB	According to a High Wind Advisory issued for the Coachella Valley - a low pressure system from the Gulf of Alaska produced periods of strong and gusty west winds to the Coachella Valley and Riverside county mountains. Area west winds from 20 to 30mph with gusts to 45mphs were predicted. The area identified in the wind advisory included the San Diego County Deserts along the desert mountain slopes an into the adjacent desert areas which border the Imperial County Deserts.
Niland	06-025-4004	3	10/01/2015	171	Submitted to CARB	According to a High Wind Advisory issued for both Imperial County and the Coachella Valley - a low pressure system from the Gulf of Alaska produced periods of strong and gusty west winds to the Imperial and Coachella Valleys and Riverside county mountains. Area west winds from 20 to 30mph with gusts to 45mphs were predicted. The issued wind advisory identified Imperial County, including the cities of Brawley, Calexico, El Centro, Glamis, Imperial and the Salton Sea.
Westmorland	06-025-4003	3	10/04/2015	250	Submitted to CARB	According to zone forecast issued by the National Weather Service conditions were breezy with southwest winds 10 to 15mph becoming west 15 to 25 in the afternoon. Imperial County including Brawley, Calexico, El Centro, Glamis, Imperial and the Salton Sea
Brawley	06-025-0007	3	10/04/2015	166		
Westmorland	06-025-4003	1	11/02/2015	179	Submitted to CARB	The National Weather Service in Phoenix issued a wind advisory for west winds at 30 to 40mph with occasional gust around 50 affecting Imperial County including El Centro, Imperial and the Salton Sea
Niland	06-025-4004	3	11/25/2015	193	Submitted to CARB	The National Weather Service in Phoenix and San Diego synopsis indicated that a chilly Pacific weather system (low pressure system) would be moving into the desert southwest bringing cooler temperatures, breezy conditions, more cloud cover and a slight chance for light mountain showers. The low pressure system over the great basin and southwest states brought cooler weather and a few periods of mainly light showers through Friday with gusty west winds in the mountains and deserts.
Brawley	06-025-0007	3	11/25/2015	215		
Brawley	06-025-0007	1	12/14/2015	222	Submitted to CARB	The NWS issued high wind warnings for the San Diego mountain and desert areas while only issuing a Freeze alert for Imperial County. "Low pressure aloft will slowly move east today and result in a continued weakening of the winds," according to the weather service. "The low pressure system will leave behind a cold air mass which will result in areas of frost tonight in the valleys as temperatures fall to 30 to 35 degrees in many locations. Peak wind gusts recorded between Sunday evening and Monday morning were 59 mph in Borrego Springs; 55 mph in Boulevard and Ocotillo Wells; 50 mph in In-Koh-Pah. Gusts of less than 45 mph were noted in numerous other areas.
El Centro	06-025-1003	2	12/14/2015	165		
Westmorland	06-025-4003	1	12/14/2015	193		
Niland	06-025-4004	1	12/14/2015	250		
Westmorland	06-025-4003	3	12/14/2015	183		
Brawley	06-025-0007	3	12/14/2015	208		
El Centro	06-025-1003	4	12/14/2015	201		
Westmorland	06-025-4003	1	12/26/2015	165	Submitted to CARB	The NWS issued high wind warnings for the San Diego mountain and desert areas while only issuing a Freeze alert for Imperial County. "Low pressure aloft will slowly move east today and result in a continued weakening of the winds," according to the weather service. "The low pressure system will leave behind a cold air mass which will result in areas of frost tonight in the valleys as temperatures fall to 30 to 35 degrees in many locations. Peak wind gusts recorded between Sunday evening and Monday morning were 59 mph in Borrego Springs; 55 mph in Boulevard and Ocotillo Wells; 50 mph in In-Koh-Pah. Gusts of less than 45 mph were noted in numerous other areas.
Westmorland	06-025-4003	3	12/26/2015	198		
Brawley	06-025-0007	1	01/31/2016	218	Submitted to CARB	The NWS issued a Wind Advisory for a wide portion of southeast CA for warning of winds up to 35 mph and gusts up to 50 mph. Blowing dust was also expected.
Niland	06-025-4004	1	01/31/2016	225		
Brawley	06-025-0007	3	01/31/2016	236		
Niland	06-025-4004	3	01/31/2016	259		
Westmorland	06-025-4003	3	01/31/2016	344		
Brawley	06-025-0007	3	02/01/2016	207		
Brawley	06-025-0007	3	03/06/2016	237	Submitted to CARB	The NWS issued a Blowing Dust Advisory for southeast CA and the Yuma, Arizona area. West winds of 20 to 30 mph were expected with gusts up to 40 to 45 mph. Visibility was expected to drop below one mile.
Westmorland	06-025-4003	3	03/06/2016	220		
Brawley	06-025-0007	3	03/11/2016	178	Submitted to CARB	The NWS issued a Wind Advisory for southeast CA and western Arizona. Strong southwest winds of 30 mph with frequent gusts up to 45 mph were expected, along with occasional dense blowing dust.
Westmorland	06-025-4003	3	03/11/2016	179		

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Monitoring Site	AQS No.	POC	Date	PM_{10} Concentration ($\mu g/m^3$)	Documentation Status	Event Description
Brawley	06-025-0007	3	03/28/2016	334	Submitted to CARB	The NWS issued a Wind Advisory for southeast CA and western Arizona. Strong southwest winds of 30 mph with frequent gusts up to 45 mph were expected, along with occasional dense blowing dust.
Niland	06-025-4004	3	03/28/2016	333		
Westmorland	06-025-4003	3	03/28/2016	465		
El Centro	06-026-1003	4	03/28/2016	284		
Brawley	06-025-0007	3	04/14/2016	228	Submitted to CARB	According to the NWS San Diego office, a trough of low pressure moving inland across southern California generated west winds with gusts in excess of 60 mph across the mountains and deserts of San Diego County. A High Wind Warning was issued, advising of west to northwest winds up to 35 mph, with gusts up to 60 mph. Strong winds were expected along desert sloes west of Imperial County, with the potential of limited visibility below three miles due to blowing dust.
Westmorland	06-025-4003	3	04/14/2016	163		
Brawley	06-025-0007	3	04/22/2016	242	Submitted to CARB	West to southwest winds up to 30 mph with gusts over 35 mph. A Wind Advisory was issued along with warnings of possible blowing dust for portions of southeast California.
Westmorland	06-025-4003	3	04/22/2016	192		
Brawley	06-025-0007	1	04/24/2016	186	Submitted to CARB	Westerly winds over 30 mph with gusts up to 45 mph. The NWS issued a Wind Advisory for southeast California for winds 25-35 mph with gusts to 45 mph. Gusts up to 55 mph along with blowing dust and sand were expected along corridors like Interstate 8.
Brawley	06-025-0007	3	04/24/2016	218		
Westmorland	06-025-4003	3	04/24/2016	177		
Brawley	06-025-0007	3	04/25/2016	285		
Calexico	06-025-0005	3	04/25/2016	173		
Niland	06-025-4004	3	04/25/2016	225		
Westmorland	06-025-4003	3	04/25/2016	244		
Brawley	06-025-0007	3	05/05/2016	163	Submitted to CARB	The NWS issued a Blowing Dust Advisory for Imperial County with emphasis on the western portion. West winds of 25 to 30 mph were expected, with gusts up to 40 mph. Blowing dust was expected to limit visibility to one mile.
Niland	06-025-4004	3	05/05/2016	171		
Westmorland	06-025-4003	3	05/05/2016	227		
Niland	06-025-4004	3	05/15/2016	216	Submitted to CARB	A strong onshore flow brought gusty west winds over southern California. The NWS San Diego office issued a Wind Advisory for areas including the deserts of San Diego County west of Imperial County. West winds of 20 to 30 mph were expected with gusts up to 50 mph. Visibility was expected to be reduced due to blowing dust and sand.
Brawley	06-025-0007	3	05/20/2016	283	Submitted to CARB	A strong upper low moving inland over northern California created gusty winds over southeast California. The post frontal gradient over the southern California terrain brought strong downslope mountain waves to Imperial County. A Wind Advisory was issued May 20 for a wide area of southeast California including Imperial County. Southwest winds of 20 to 30 mph were expected, with gusts up to 40 mph. Dangerous cross-winds and dense patches of blowing dust.
Calexico	06-025-0005	3	05/20/2016	159		
Niland	06-025-4004	3	05/20/2016	309		
Westmorland	06-025-4003	3	05/20/2016	370		
Brawley	06-025-0007	3	05/21/2016	199		
Calexico	06-025-0005	3	05/21/2016	226		
El Centro	06-026-1003	4	05/21/2016	252		
Brawley	06-025-0007	3	05/25/2016	165	Submitted to CARB	West winds over 30 mph with gusts over 40 mph. Advisories were issued for wind and blowing dust in the mountains and deserts of southeastern California.
Calexico	06-025-0005	3	07/23/2016	195	Submitted to CARB	Southeast monsoonal winds with winds up to 20 mph.
El Centro	06-026-1003	4	07/23/2016	203		
Brawley	06-025-0007	3	07/24/2016	155		
Calexico	06-025-0005	3	07/24/2016	194		
Westmorland	06-025-4003	3	07/24/2016	164		
El Centro	06-026-1003	4	07/24/2016	162		
Brawley	06-025-0007	3	07/30/2016	195	Submitted to CARB	Southeast monsoonal winds up to 25 mph with gusts over 35 mph. The NWS issued a Dust Storm Warning for Imperial County and the eastern deserts of Riverside County.
Calexico	06-025-0005	3	07/30/2016	158		
Niland	06-025-4004	3	07/30/2016	206		
Westmorland	06-025-4003	3	07/30/2016	201		
El Centro	06-026-1003	4	07/30/2016	205		
Calexico	06-025-0005	3	08/09/2016	155	Submitted to CARB	Southern gulf surge monsoonal winds up to 25 mph. Possibility of suspended dust reducing visibility.
Niland	06-025-4004	3	08/09/2016	167		
Westmorland	06-025-4003	3	08/09/2016	166		
El Centro	06-026-1003	4	08/09/2016	159		

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Appendix D. 2014-2016 Documented Exceptional Events for Imperial County
Imperial County 2018 PM_{10} Plan

Monitoring Site	AQS No.	POC	Date	PM_{10} Concentration ($\mu g/m^3$)	Documentation Status	Event Description
Brawley	06-025-0007	3	08/19/2016	155	Submitted to CARB	Southern gulf surge monsoonal winds up to 25 mph. Possibility of suspended dust reducing visibility.
Westmorland	06-025-4003	3	08/19/2016	164		Southern gulf surge monsoonal winds up to 25 mph. Possibility of suspended dust reducing visibility.
El Centro	06-026-1003	4	08/21/2016	170		Monsoonal winds mostly from the southeast. The NWS issued a Blowing Dust Advisory for western Arizona.
Brawley	06-025-0007	1	09/03/2016	275	Submitted to CARB	Fall-like Pacific storm moved into the western states. West to southwest winds up to 25 mph forecasted.
Westmorland	06-025-4003	3	09/03/2016	202		
El Centro	06-026-1003	4	09/03/2016	174		
Brawley	06-025-0007	3	09/12/2016	232	Submitted to CARB	A weather disturbance moving through the region generated west to southwest up to 28 mph with gusts of 33 mph at El Centro NAF. Smoke Text Product identified blowing dust over portions of southern California and southern Arizona.
Westmorland	06-025-4003	3	09/12/2016	164		
Brawley	06-025-0007	3	09/13/2016	160		
Calexico	06-025-0005	3	09/13/2016	180		
El Centro	06-026-1003	4	09/13/2016	179		
Westmorland	06-025-4003	3	09/19/2016	176	Submitted to CARB	A weather system moving through the region generated west to southwest up over 25mph.
Brawley	06-025-0007	3	10/30/2016	162	Submitted to CARB	A vigorous trough dropped through southern California, generating southwest winds of 10 to 20 mph with gusts up to 30 mph.
Brawley	06-025-0007	3	12/16/2016	645	Submitted to CARB	A strong Pacific low pressure system and accompanying cold front moved through the region, generating gusty winds across southeast California and western Arizona. A Wind Advisory was issued for southeast California, with expected west to southwest winds of 20 to 35/40 mph and gusts exceeding 40/50 mph. Patches of blowing dust throughout the region were expected.
Calexico	06-025-0005	3	12/16/2016	238		
Niland	06-025-4004	3	12/16/2016	529		
Westmorland	06-025-4003	3	12/16/2016	733		
El Centro	06-026-1003	4	12/16/2016	207		

Notes:
Adjacent, color-blocked rows indicate multiple concentration measurements impacted by a singular exceptional event.

Abbreviations:
AQS - Air Quality System
CA - California
mph - miles per hour
NAF - Naval Air Facility
NOAA - National Oceanic and Atmospheric Administration
NWS - National Weather Service
PM_{10} - particulate matter less than 10 microns in aerodynamic diameter
POC - parameter occurrence code
$\mu g/m^3$ - micrograms per cubic meter
U.S. - United States

Appendix E
Best Available Control Measures Analysis for the 2018 Imperial County Redesignation Request and Maintenance Plan for PM_{10}

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BEST AVAILABLE CONTROL MEASURES ANALYSIS FOR THE 2018 IMPERIAL COUNTY REDESIGNATION REQUEST AND MAINTENANCE PLAN FOR PARTICULATE MATTER LESS THAN 10 MICRONS IN DIAMETER

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OCTOBER 2018

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Abbreviations and Acronyms

BACM	Best Available Control Measure
BACT	Best Available Control Technology
CAA	Clean Air Act
CARB	California Air Resources Board
CEMS	continuous emissions monitoring system
GE	General Electric
ICAPCD	Imperial County Air Pollution Control District
mph	miles per hour
MW	megawatts
NOx	nitrogen oxides
PM_{10}	Particulate Matter Less than 10 Microns in Diameter
SCR	selective catalytic reduction
SIP	State Implementation Plan
$\mu g/m_3$	micrograms per cubic meter
USG	United States Gypsum

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1. INTRODUCTION

1.1 PM_{10} State Implementation Plan

The *Imperial County 2018 Redesignation Request and Maintenance Plan for Particulate Matter Less than 10 Microns in Diameter (PM_{10})* ("Plan") compiles the data and discussion necessary to revise the previous State Implementation Plan submittal for PM_{10} and requests redesignation as attainment for the Imperial Valley Planning Area. This appendix provides an overview of the analysis that was conducted to determine that the control strategies currently implemented in Imperial County meet the Clean Air Act (CAA) requirement of controlling significant sources of PM_{10} to Best Available Control Measure (BACM) or Best Available Control Technology (BACT) standards. In particular, this appendix features a revision to Imperial County's previous PM_{10} significant source analysis and demonstrates that no new emission source categories qualify as significant. In addition, this appendix discusses the current major stationary sources of PM_{10} in Imperial County and how they are controlled to BACT-level stringency.

1.2 Background

CAA Section 189(b) requires areas designated as Serious nonattainment for PM_{10} to implement BACM/BACT for the control of PM_{10}. BACM/BACT is a label describing practices that allow for the maximum degree of emission reduction considering technical and economic feasibility and environmental impacts of the control. While the BACM/BACT requirement can also apply to sources of PM_{10} precursors, ambient PM_{10} in Imperial County is overwhelmingly primary PM_{10}, with little or no contribution from secondary aerosols. This observation is supported by a technical analysis performed by the California Air Resources Board (CARB) and included as Appendix A to this Plan. As a result, BACM/BACT for sources of PM_{10} precursors are not addressed under this Plan.

USEPA guidance for State Implementation Plans for Serious PM_{10} nonattainment areas[1] instructs that BACM standards are required for all source categories except those that "the State [can] demonstrate [do] not contribute significantly to nonattainment of the NAAQS." A source category is presumed to contribute significantly to a violation of the PM_{10} NAAQS if its PM_{10} impact exceeds 5 micrograms per cubic meter ($\mu g/m^3$). Analyses of the PM_{10} sources and controls in place in Imperial County have been conducted by the Imperial County Air Pollution Control District (ICAPCD or "District") in the past. This was first done in 2005 and resulted in the development of a set of fugitive dust rules, collectively known as Regulation VIII. That analysis had identified the following four sources as significant and requiring BACM: **windblown dust from open areas**, **entrained and windblown dust from unpaved roads**, **windblown dust from non-pasture agricultural lands**, and **tilling dust from agricultural operations.**

In 2008 and 2009, to support its *2009 Imperial County State Implementation Plan for Particulate Matter Less than 10 Microns in Aerodynamic Diameter* ("2009 PM_{10} SIP"),[2] the District revised its analysis of significant sources to reflect a 2005 base year inventory and 2006-2008 ambient data. That analysis identified only **entrained dust from unpaved roads** and **tilling dust from agricultural operations** as significant sources of PM_{10}. The USEPA disagreed with certain

[1] United States Environmental Protection Agency. 1994. *State Implementation Plans for Serious PM-10 Nonattainment Areas, and Attainment Date Waivers for PM-10 Nonattainment Areas Generally; Addendum to the General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990.* Federal Register. Vol. 59. No. 157. August 16, 1994. p. 41998.

[2] Imperial County Air Pollution Control District. 2009. 2009 Imperial County State Implementation Plan for Particulate Matter Less Than 10 Microns in Aerodynamic Diameter. August 11. Available at: http://www.co.imperial.ca.us/airpollution/attainment%20plans/final%20ic%202009%20pm10%20sip%20document.pdf. Accessed: July 2018.

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portions of that analysis, particularly the exclusion of certain high-wind exceedance days, and determined that **windblown dust from unpaved roads**, **windblown dust from open areas**, and **windblown dust from non-pasture agricultural lands** would also qualify as significant sources requiring BACM.[3] Ultimately, in 2010 the USEPA published a rule issuing limited approval and limited disapproval of Imperial County's Regulation VIII rules, citing certain BACM-related deficiencies in the rule set.[4]

In response to the limited approval/disapproval of the rules and related SIP submission, the District and the California Department of Parks and Recreation challenged the USEPA's decision in the U.S. Court of Appeals for the Ninth Circuit. Ultimately, the dispute was resolved through mediation and a Settlement Agreement (see Section 1.4.2 of the main text of the Plan for additional information). In 2013, the USEPA published a rule[5] finalizing approval of Imperial County's Regulation VIII rules, acknowledging that they satisfy BACM requirements for sources previously identified as significant for PM_{10}. Table 1-1 below presents a summary of these source categories and the most relevant Regulation VIII rule(s) that govern them.

Table 1-1. Source Categories Previously Identified as Significant for PM_{10} and Most Applicable Regulation VIII Rule(s)

Source Category	Applicable Regulation VIII Rule
Windblown Dust from Open Areas	Rule 800, Rule 804
Entrained Dust from Unpaved Roads	Rule 805
Windblown Dust from Unpaved Roads	Rule 805
Windblown Dust from Non-Pasture Agricultural Lands	Rule 806
Tilling Dust from Agricultural Operations	Rule 806

[3] United States Environmental Protection Agency. 2010. Technical Support Document for EPA's Notice of Proposed Rulemaking on Revisions to the California State Implementation Plan as Submitted by the State of California for the Imperial County Air Pollution Control District. EPA's Analysis of Imperial County Air Pollution Control District's Regulation VIII – Fugitive Dust Rules 800-806. February.

[4] United States Environmental Protection Agency. 2010. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Final rule.* Federal Register. Vol. 75. No. 130. July 8, 2010. p. 39366.

[5] United States Environmental Protection Agency. 2013. *Revisions to the California State Implementation Plan, Imperial County Air Pollution Control District; Final rule.* Federal Register. Vol. 78. No. 77. April 22, 2013. p. 23677.

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2. DETERMINATION OF SIGNIFICANT SOURCES OF PM_{10}

As discussed above, analyses have been conducted in the past to determine significant sources of PM_{10} in Imperial County. Those analyses were conducted using the most recent emission inventory and monitoring data available at that time. Since several years have passed since the most recent significant source analyses occurred, they are being revisited under this Plan using the most recent emission inventory and monitoring data available.

2.1 De Minimis Criterion

As a criterion for classification of PM_{10} sources into significant or *de minimis* categories, USEPA guidance states that "a source category….will be presumed to contribute significantly to a violation of the 24-hour NAAQS if its PM_{10} impact at the location of the expected violation would exceed 5 $\mu g/m^3$." [6] This language unambiguously implies that this test should be applied, for any violation, to every source category using information specific to the day of the violation. The implementation of the criterion for any specific violation requires a day-specific decomposition of the air quality impacts into fractional contributions from all relevant source categories (i.e., a day-specific emission inventory). This type of information can be difficult to obtain without comprehensive air dispersion modeling. Therefore, this analysis utilizes a more practical, alternative approach that involves evaluating the fractional contribution of sources in Imperial County's average annual daily emission inventory and then performing a sensitivity analysis to determine if variations in the inventory would alter the conclusions of the analysis.

From 2014 to 2016, Imperial County experienced 58 days where PM_{10} concentrations were greater than the 24-hour PM_{10} NAAQS. However, all of the exceedances on these days have been identified by the District as Exceptional Events and are currently going through USEPA's review process for affirmation. Therefore, the 5 $\mu g/m^3$ criterion was compared against a hypothetical "near-exceedance" concentration of 154 $\mu g/m^3$ to establish the fractional cut-off point (5 $\mu g/m^3$/154 $\mu g/m^3$ = 3.25%) above which Imperial County source categories would qualify as significant.

2.2 Average Annual Daily Emission Inventory Comparison

Table 2-1 presents the average annual daily PM_{10} emissions inventory for Imperial County for the attainment year, 2016. This table is organized by emission source category and features the percent contribution of each category. When compared against the established fractional cut-off point of 3.25%, three categories qualify as significant. These include **windblown dust from open areas – others** (which includes unpaved roads)**, windblown dust from non-pasture agricultural lands,** and **entrained dust from unpaved roads** (specifically city/county and canal roads). All three of these categories have been previously identified by the District as significant sources of PM_{10} and are currently controlled by rules approved by the USEPA as BACM for these source categories.[7] The following section presents a sensitivity analysis and demonstrates how variations in the inventory would not alter the conclusions of this analysis.

[6] United States Environmental Protection Agency. 1994. *State Implementation Plans for Serious PM-10 Nonattainment Areas, and Attainment Date Waivers for PM-10 Nonattainment Areas Generally; Addendum to the General Preamble for the Implementation of Title I of the Clean Air Act Amendments of 1990.* Federal Register. Vol. 59. No. 157. August 16, 1994. p. 41998.

[7] Windblown dust from open areas is regulated under ICAPCD Rule 804: Open Areas. Windblown dust from non-pasture agricultural lands is regulated under ICAPCD Rule 806: Conservation Management Practices. Entrained dust from unpaved roads is regulated under ICAPCD Rule 805: Paved and Unpaved Roadways.

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Table 2-1. Imperial County 2016 Average Annual Daily PM_{10} Emission Inventory

Inventory Category	PM_{10} Emissions[1] (tpd)	Percent of Total[2]
Electrical Utilities	0.09	0.03%
Cogeneration	0.00	0.00%
Manufacturing and Industrial	0.04	0.01%
Service and Commercial	0.07	0.03%
Fuel Combustion	0.00	0.00%
Industrial Processes		
Mineral Processes	3.67	1.29%
Food/Agriculture	0.31	0.11%
Residential Fuel Combustion	0.05	0.02%
Farming		
Tilling	4.87	1.71%
Harvest	0.99	0.35%
Cattle	2.62	0.92%
Construction[3]	3.02	1.06%
Paved Road Dust	1.16	0.41%
Entrained Unpaved Road Dust		
City/County	18.38	6.47%
Canal	30.74	10.82%
BLM/USFS	1.39	0.49%
Farm	1.37	0.48%
Fires	0.00	0.00%
Waste Burning	1.30	0.46%
Cooking	0.08	0.03%
On-Road Mobile	0.43	0.15%
Other Mobile	1.07	0.38%
Windblown Dust		
Open Areas - Urban	0.00	0.00%
Open Areas - Others	199.96	70.37%
Non-Pasture Agricultural Lands	10.77	3.79%
Pasture	1.79	0.63%
TOTAL:	**284.17**	**100.0%**

Notes:
[1] 2016 inventory data was queried from the California Air Resources Board's California Emissions Project Analysis Model, Version 1.05; however, some emissions have been recategorized to better align with past Imperial County significant source analyses.
[2] Highlighting indicates that the value exceeds the *de minimis* level for a near-exceedance day (3.25%; 5 µg/m^3 / 154 µg/m^3).

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3. SIGNIFICANT SOURCE SENSITIVITY ANALYSIS

As discussed previously, from 2014 to 2016 all measured exceedances of the 24-hour PM_{10} NAAQS in Imperial County were identified as Exceptional Events. These events were primarily caused by gusty westerly winds brought on by low pressure systems. A smaller fraction of the events can be attributed to monsoonal fronts passing through the region. For most of these events, one would expect that the fractional contribution of windblown dust to ambient PM_{10} levels to be greater compared to its average annual daily contribution. As a result, this sensitivity analysis focuses on the potential scenario of an exceedance occurring on a low-wind day, when the fractional contribution of windblown dust would be less than its daily average.

3.1 Low-Wind Day Emission Inventory Comparison

Table 3-1 presents the average annual daily PM_{10} emissions inventory for Imperial County for the attainment year, 2016; however, the percent contribution of each source category has been calculated for varying levels of windblown dust to assess how changes in the contribution of PM_{10} from windblown dust would affect the significance determination of other categories. It was found that if windblown dust were reduced to just 25% of its average annual daily contribution to the inventory, then one additional category, **tilling dust from agricultural operations**, would get added to the list of sources contributing more than 3.25% of the total emissions for that day. However, at 50% windblown dust, this category drops back below the fractional cut-off point, leaving only **entrained dust from unpaved roads** (specifically city/county and canal roads) as the only non-windblown dust source category above the cut-off point.

If the windblown dust category were completely excluded from the inventory (i.e., reduced to 0% contribution), several other source categories would rise above the 3.25% cut-off value. However, a review of the PM_{10} concentration data and collocated wind speed data from 2014 to 2016 shows that it's unlikely that this theoretical "no-wind" day would result in an exceedance of the 24-hour PM_{10} NAAQS. This scenario is further analyzed in the following section.

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Table 3-1. Imperial County 2016 Average Annual Daily PM_{10} Emission Inventory – Windblown Dust Sensitivity Analysis

Inventory Category	PM_{10} Emissions[1] (tpd)	Percent of Total When Windblown Dust Category Equals X% of its 2016 Inventory Value[2]				
		0%	25%	50%	75%	100%
Electrical Utilities	0.09	0.13%	0.07%	0.05%	0.04%	0.03%
Cogeneration	0.00	0.00%	0.00%	0.00%	0.00%	0.00%
Manufacturing and Industrial	0.04	0.06%	0.03%	0.02%	0.02%	0.01%
Service and Commercial	0.07	0.10%	0.06%	0.04%	0.03%	0.03%
Fuel Combustion	0.00	0.00%	0.00%	0.00%	0.00%	0.00%
Industrial Processes						
Mineral Processes	3.67	5.12%	2.94%	2.06%	1.59%	1.29%
Food/Agriculture	0.31	0.43%	0.25%	0.17%	0.13%	0.11%
Residential Fuel Combustion	0.05	0.06%	0.04%	0.03%	0.02%	0.02%
Farming						
Tilling	4.87	6.80%	3.90%	2.74%	2.11%	1.71%
Harvest	0.99	1.38%	0.79%	0.56%	0.43%	0.35%
Cattle	2.62	3.66%	2.10%	1.47%	1.13%	0.92%
Construction	3.02	4.21%	2.42%	1.70%	1.31%	1.06%
Paved Road Dust	1.16	1.62%	0.93%	0.65%	0.50%	0.41%
Entrained Unpaved Road Dust						
City/County	18.38	25.65%	14.73%	10.33%	7.96%	6.47%
Canal	30.74	42.90%	24.64%	17.28%	13.31%	10.82%
BLM/USFS	1.39	1.95%	1.12%	0.78%	0.60%	0.49%
Farm	1.37	1.91%	1.10%	0.77%	0.59%	0.48%
Fires	0.00	0.01%	0.00%	0.00%	0.00%	0.00%
Waste Burning	1.30	1.81%	1.04%	0.73%	0.56%	0.46%
Cooking	0.08	0.11%	0.06%	0.04%	0.03%	0.03%
On-Road Mobile	0.43	0.60%	0.35%	0.24%	0.19%	0.15%
Other Mobile	1.07	1.49%	0.85%	0.60%	0.46%	0.38%
Windblown Dust						
Open Areas - Urban	0.00	0.00%	0.00%	0.00%	0.00%	0.00%
Open Areas - Others	199.96	0.00%	40.06%	56.20%	64.91%	70.37%
Non-Pasture Agricultural Lands	10.77	0.00%	2.16%	3.03%	3.50%	3.79%
Pasture	1.79	0.00%	0.36%	0.50%	0.58%	0.63%
TOTAL:	**284.17**					

Notes:
[1] 2016 inventory data was queried from the California Air Resources Board's California Emissions Project Analysis Model, Version 1.05; however, some emissions have been recategorized to better align with past Imperial County significant source analyses.
[2] Highlighting indicates that the value exceeds the *de minimis* level for a near-exceedance day (3.25%; 5 $\mu g/m^3$ / 154 $\mu g/m^3$).

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3.2 Example "Low-Wind" Near-Exceedance Day

The 2014 to 2016 PM_{10} monitoring data for Imperial County were reviewed in conjunction with collocated wind speed data to see if there were any days in which a monitor measured a near exceedance on a low- or no-wind day. This analysis was done by creating a scatter plot for each year of data, with the x-axis representing measured 24-hour PM_{10} concentration values from the five Imperial County PM_{10} monitoring stations and the y-axis representing the average hourly wind speed measured each day at the collocated meteorological station (see Figures 3-1 through 3-3).[8] The vertical orange line represents a near-exceedance concentration of 154 $\mu g/m^3$. As discussed previously, all measurements above the standard during this period (colored orange in the plots below) have been identified as potential Exceptional Events and are being thoroughly evaluated through the USEPA's review process. Upon concurrence from the USEPA, these data points would be excluded from Imperial County's NAAQS determination.

Out of the three years of data, the 24-hour PM_{10} measurement at the El Centro monitoring station on January 15, 2016 (highlighted green in Figure 3-3) is the closest example of a low-wind near-exceedance day. On that day the average hourly wind speed at the collocated meteorological station was 4.28 miles per hour (mph), which was over 35% less than the next closest low-wind near-exceedance data point. However, a review of the hourly wind speed data from that day (as shown in Figure 3-4), shows that while the average hourly wind speed was relatively low, the day still exhibited periods of elevated wind speed and could not reasonably be categorized as a "no-wind" day. Seeing how this is the closest example to a low-wind near-exceedance scenario, this finding supports the conclusion that it's unlikely that a day with low winds and 0% windblown dust contributions would result in an exceedance of the 24-hour PM_{10} NAAQS at a monitor in Imperial County.

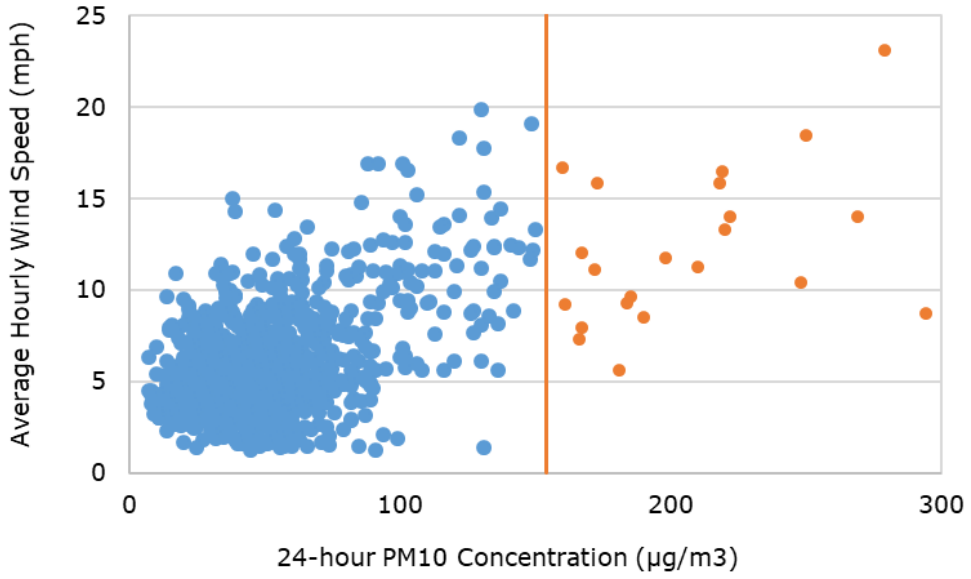

Figure 3-1. 24-hour PM_{10} Concentration vs. Wind Speed in Imperial County, 2014

[8] Except for the Brawley monitor, which does not have collocated wind speed data. For that monitor, wind speed data from the Imperial County Airport was used as a surrogate.

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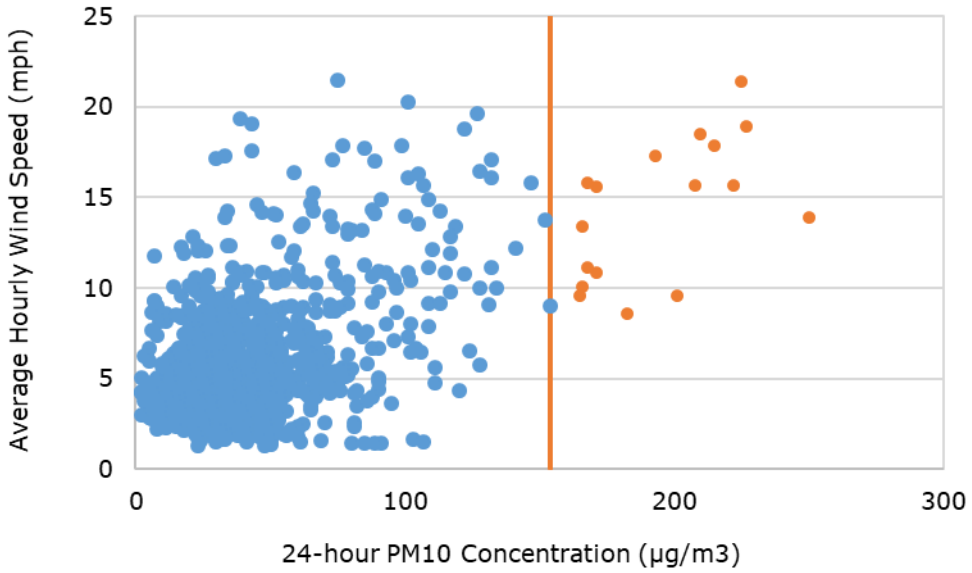

Figure 3-2. 24-hour PM_{10} Concentration vs. Wind Speed in Imperial County, 2015

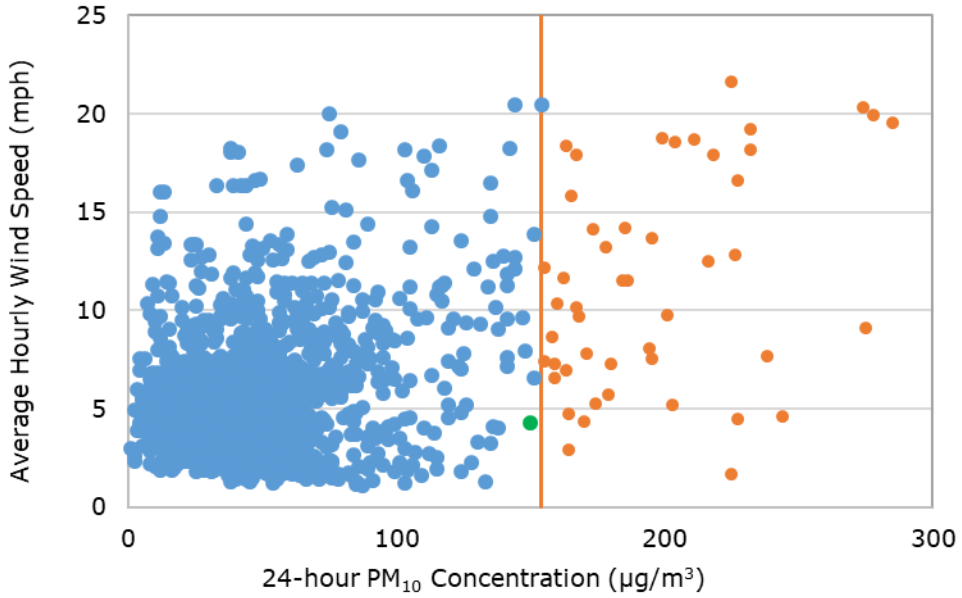

Figure 3-3. 24-hour PM_{10} Concentration vs. Wind Speed in Imperial County, 2016

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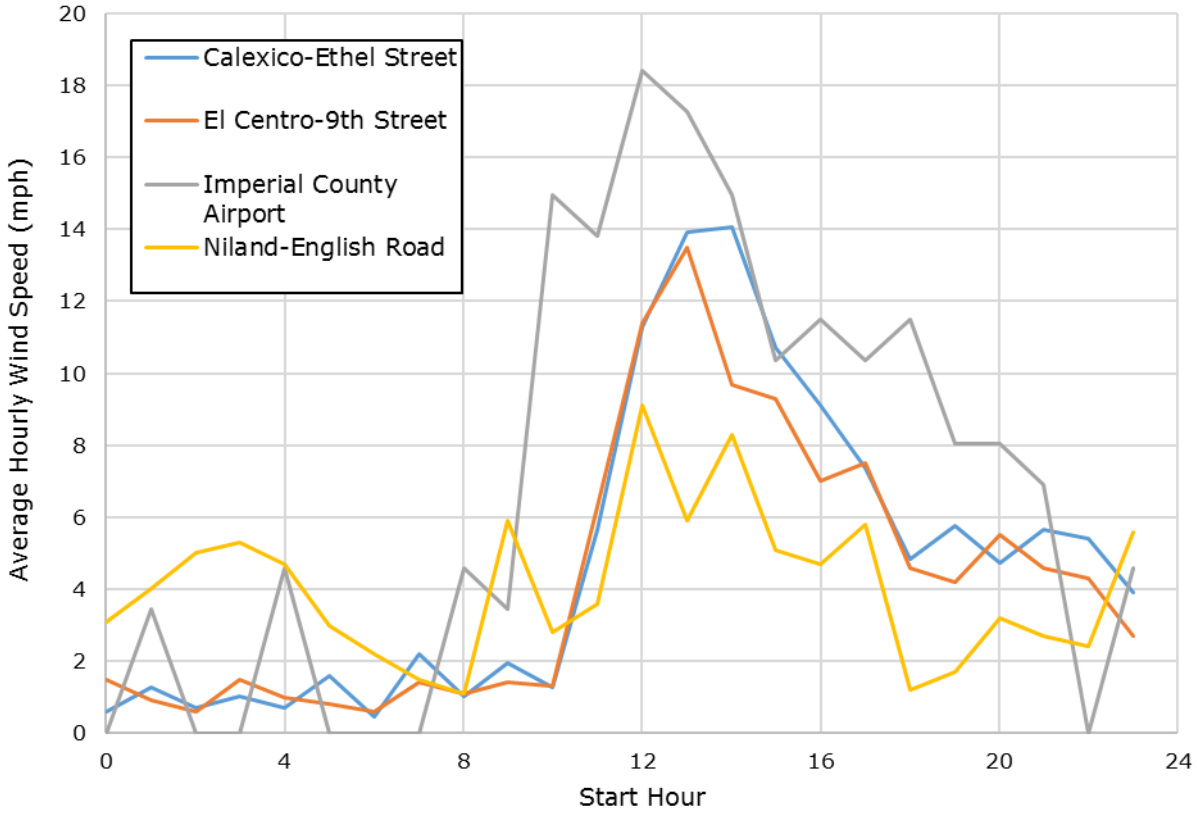

Figure 3-4. Average Hourly Wind Speed in Imperial County on January 15, 2016[9]

[9] The Westmorland data was omitted from this plot as there were only two hours of wind speed data available for this day.

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4. BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

For Serious PM_{10} nonattainment areas, CAA Section 189(b)(3) defines a major source as "any stationary source or group of stationary sources located within a contiguous area and under common control that emits, or has the potential to emit, at least 70 tons per year of PM_{10}." Imperial County currently has two facilities that qualify as major stationary sources of PM_{10}. These include the Imperial Irrigation District El Centro Generating Station and the United States Gypsum Plaster City facility. As described below, both facilities are controlled to BACT-level stringency.

4.1 Imperial Irrigation District El Centro Generating Station

The Imperial Irrigation District El Centro Generating Station features three main operational units (Units 2-4). Unit 2 is a General Electric (GE) Frame 7EA combined cycle unit (i.e., combustion and steam) capable of generating 115 megawatts (MW), of which the combustion turbine provides 83 MW. Unit 3 features two 48.0 MW Siemens SGT-800 combustion turbines and one condensing steam turbine. Unit 4 is a Riley Stoker Boiler rated at 74 MW.

Unit 2 was repowered with a gas turbine in 1993 and uses selective catalytic reduction (SCR) technology for the control of nitrogen oxides (NOx). The unit is allowed to burn No. 2 diesel as secondary fuel for 720 hours per year. In 2007, a new GEA CDX-080 cooling tower with drift eliminators rated at 0.0005% was installed at Unit 2, which at the time of installation satisfied BACT.

The two combustion turbines at Unit 3 operate solely on natural gas and are equipped with ultra-low NOx combustors and SCR. Unit 3 is equipped with a cooling tower with drift eliminators rated at 0.0005%, which at the time of installation satisfied BACT.

The Riley Boiler at Unit 4 commenced operation in 1968 and is a wall-fired type boiler with six Peabody burners (two rows of three). The boiler burns natural gas as the primary fuel, but is allowed to burn No. 6 fuel oil as secondary fuel. Over the years the Riley Boiler has been modified to meet various District rules. In 2000, an SCR system and a continuous emissions monitoring system (CEMS) were installed to meet NOx emission limits under ICAPCD Rule 400 (Fuel Burning Equipment – Oxides of Nitrogen). In 2013, a new SPX cooling tower with drift eliminators rated at 0.0005% was installed, which at the time satisfied BACT. At the same time, the permit was modified to incorporate ICAPCD rule 400.2 (Boilers, Process Heaters, and Steam Generators) NOx emissions limits.

4.2 United States Gypsum Plaster City Facility

The United States Gypsum (USG) Corporation manufactures gypsum wallboard and related products at its Plaster City facility, which has been in operation since the 1940s. Raw gypsum is mined at the Split Mountain quarry where it undergoes primary crushing and is stored. The ore is eventually transported via rail 20 miles to the Plaster City facility where wallboard and other gypsum products are manufactured. Over the past ten years, the Plaster City facility has undergone nearly a complete equipment modification upgrade. More energy efficient equipment has replaced older, less efficient equipment. Furthermore, each equipment modification has been subject to New Source Review permitting with increased emissions control requirements, including the installation of baghouses at transfer and crushing points. USG has various permitted combustion sources that are all fueled by natural gas, which meets BACT for PM_{10}. The mills have also been retrofitted with dust collectors limited to 0.01 grains per dry standard cubic feet, which also satisfies BACT.

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5. CONCLUSION

Concurrent with its submittal of the *Imperial County 2018 Redesignation Request and Maintenance Plan* for PM_{10}, the District evaluated its current control strategy to ensure that all significant sources of PM_{10} are being controlled to BACM/BACT standards. This appendix provides an overview of that analysis and demonstrates, using the 2016 attainment inventory and 2014 to 2016 monitoring data, that all source categories that that have the potential to contribute significantly to a violation of the PM_{10} NAAQS in Imperial County are controlled by rules that have been approved by the USEPA as BACM for those sources. Furthermore, this appendix demonstrates that current major sources of PM_{10} in Imperial County are controlled to BACT-level stringency. Therefore, no new control measures are being proposed with this Plan.

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Appendix F
Regulation VIII Fugitive Dust Rules

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RULE 800 GENERAL REQUIREMENTS FOR CONTROL OF FINE PARTICULATE MATTER (PM-10)

(Adopted 10/10/94; Revised 11/25/96; Revised 11/08/2005; Revised 10/16/2012)

A. General Description

The purpose of this regulation is to reduce the amount of fine Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from anthropogenic (man-made) Fugitive Dust (PM-10) sources generated from within Imperial County by requiring actions to prevent, reduce, or mitigate PM-10 emissions. The Rules contained within this Regulation have been developed pursuant to United States Environmental Protection Agency guidance for Serious PM10 Non Attainment Areas.

B. Applicability

The requirements of this rule shall apply to any Active Operation, and/or man-made or man-caused condition or practice capable of generating Fugitive Dust (PM-10) as specified in this Regulation except those determined exempt as defined in Part E of this Rule. The definitions, exemptions, requirements, administrative requirements recordkeeping requirements, and test methods set forth in this rule are applicable to all the rules under Regulation VIII (Fugitive Dust Requirements) of the Rules and Regulations of the Imperial County Air Pollution Control District.

C. Definitions

For the purpose of this Regulation, the following terms are defined:

C.1 ACTIVE OPERATION: Activities capable of generating Fugitive Dust (PM-10), including but not limited to, Earthmoving Activities, Construction activities, Unpaved Roads, Track-Out/Carry-Out, Bulk Material storage and transport, Unpaved Haul/Access Roads.

C.2 AGGREGATE MATERIALS: Consists of sand, Gravel, quarried stone and/or rock fragments that are typically used in Construction. Aggregates may be natural, artificial or recycled.

C.3 ANEMOMETRS: Are devices used to measure wind speed and direction in accordance with manufacturer's performance standards, maintenance and calibration criteria.

C.4 ANNUAL AVERAGE DAILY VEHICLE TRIPS: annual average 24-hour total of all vehicles counted on a road.

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C.5 APCD: The Imperial County Air Pollution Control District.

C.6 APCO: The Imperial County Air Pollution Control Officer.

C.7 AVERAGE VEHICLE TRIPS PER DAY: Means the average number of vehicles that cross a given point surface during a specific 24-hour period as determined by the most recent Institute of Transportation Engineers trip generation manual, tube counts, or observations.

C.8 BLM: The Bureau of Land Management.

C.9 BP: The United States Border Patrol.

C.10 BULK MATERIAL: Earth, rock, Silt, sediment, sand, Gravel, soil, fill, Aggregate, dirt, mud, debris, and other organic and/or inorganic material consisting of or containing Particulate Matter with five percent or greater Silt content. For the purpose of this Regulation, the Silt content level is assumed to be 5 percent or greater, unless the Person responsible for the Active Operation conducts the applicable laboratory tests and demonstrate that the Silt content is less than 5 percent. Active Operations seeking to determine if the Silt content is less than five percent are required to conduct the laboratory analysis in accordance with ASTM method C-136-a (Standard Test Method for Sieve analysis of Fine and Coarse Aggregates), or other equivalent test methods approved by EPA, ARB, and the APCD.

C.11 CANAL BANK: A rise of land on either side of an irrigation canal.

C.12 CHEMICAL STABILIZATION/SUPPRESSION: A means of Fugitive Dust (PM-10) control implemented to mitigate PM-10 emissions by applying petroleum resins, asphaltic emulsions, acrylics, adhesives, or any other materials approved for use by the California Air Resources Board (CARB), U.S. Environmental Protection Agency (U.S. EPA) and/or the APCO.

C.13 CONSTRUCTION: Any on-site mechanical activities preparatory to or related to the building, alteration, rehabilitation, or demolition of an improvement on real property, including, but not limited to, land clearing, excavation related to construction, land leveling, grading, cut and fill grading, and the erection or demolition of any structure. As used in Regulation VIII, a construction site may encompass several contiguous parcels, or may encompass only a portion of one parcel, depending on the relationship of the property boundaries to the actual construction activities.

C.14 DESIGNATED REPRESENTATIVE: The agent for a Person. The Designated Representative shall be responsible for and have the full authority to implement BACM on behalf of the Person.

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C.15 DISTURBED SURFACE AREA: An area in which naturally occurring soils, or soils or other materials placed thereon, have been physically moved, uncovered, destabilized, or otherwise modified by grading, land leveling, scraping, cut and fill activities, excavation, bush and timber clearing, or grubbing, and soils on which vehicle traffic and/or equipment operation has occurred. An area is considered to be disturbed until the activity that caused the disturbance has been completed, and the disturbed area meets the stabilized surface conditions specified in this rule, or the area has been paved or otherwise covered by a permanent structure.

C.16 DPR: The California Department of Parks and Recreation.

C.17 EARTHMOVING ACTIVITIES: The use of any equipment for an activity that may generate Fugitive Dust emissions, including, but not limited to, cutting and filling, grading, leveling, excavation, trenching, loading or unloading of Bulk Materials, demolishing, drilling, adding to or removing bulk materials from open storage piles, weed abatement through disking, and back filling.

C.18 FUGITIVE DUST: The Particulate Matter entrained in the ambient air which is caused from man-made and natural activities such as, but not limited to, movement of soil, vehicles, equipment, blasting, and wind. This excludes Particulate Matter emitted directly in the exhaust of motor vehicles or other fuel combustion devices, from portable brazing, soldering, or welding equipment, pile drivers, and stack emissions from stationary sources.

C.19 GRAVEL: Gravel travelways shall have a three (3) inch minimum depth Stabilized Surface. The travelway shall have a relative compaction of not less than 95% as determined by Test Method No. California 216 of State of California, Business and Transportation Agency Department of Transportation, and conforming to the following grading:

	¾" Maximum
Sieve Designation	Percent Passing
1"	100
¾"	90-100
#4	35-60
#30	10-30
#200	2-9

Reference: California Department of Transportation Standard Specification Section 26/class II Aggregate Base

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C.20 HAUL/ACCESS ROAD: Any on-site road used for commercial, industrial, institutional, and/or governmental traffic.

C.21 HAUL TRUCK: Any fully or partially open-bodied licensed motor vehicle used for transporting Bulk Material for industrial or commercial purposes.

C.22 IMPLEMENT OF HUSBANDRY: An unlicensed vehicle which is used exclusively in the conduct of Agricultural Operations. An Implement of Husbandry does not include a vehicle if its existing design is primarily for the transportation of persons or property on a highway, unless specifically designated as such by some other provision of the Vehicle Code of California.

C.23 NON-RESIDENTIAL AREA: Any unpaved vehicle and equipment traffic area operated at any commercial, manufacturing or government sites.

C.24 MODIFIED PAVED ROAD: Any Paved Road that is widened or improved so as to increase traffic capacity. This term does not include road maintenance, repair, chip seal, pavement or roadbed rehabilitation that does not affect roadway geometrics, or surface overlay work.

C.25 OFF-FIELD AGRICULTURAL SOURCE: Any Agricultural Source or activity at an Agricultural Source that falls into one or more of the following categories:

C.25.a Outdoor handling, storage and transport of Bulk Material;

C.25.b Paved Road;

C.25.c Unpaved Road; or

C.25.d Unpaved Traffic Area.

C.26 OFF-ROAD EVENT AND/OR COMPETITIONS: Means any of the following: any organized, sanctioned, or structured use, event or activity on public land in which two hundred and fifty (250) or more contestants compete and either or both of the following elements apply: (i) Participants register, enter, or complete an application for the event; (ii) A predetermined course or area is designated.

C.27 OFF- HIGHWAY VEHICLE(OHV): An off-highway vehicle is a motorized vehicle when operating off a highway, including a two-wheel, three-wheel or four-wheel vehicle, motorcycle, four-wheel drive vehicle, dune buggy, amphibious vehicle, ground effects or air cushion vehicle and any other means of land transportation deriving motive power from a source other than muscle or wind. "Highway" means the entire width between the

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boundary lines of every way publicly maintained by the federal government, a city, a town or a county if any part of the way is generally open to the use of the public for purposes of vehicular travel, excluding unpaved trails and paths specifically intended for recreational use.

C.28 ON-FIELD AGRICULTURAL SOURCE: Any Agricultural Source or activity at an Agricultural Source that is not an Off-Field Agricultural Source, including (but not limited to) the following:

C.28.a Activities conducted solely for the purpose of preparing land for the growing of crops or the raising of fowl or animals, such as brush or timber clearing, grubbing, scraping, ground excavation, land leveling, grading, turning under stalks, disking, or tilling;

C.28.b Drying or pre-cleaning of agricultural crop material on the field where it was harvested;

C.28.c Handling or storage of agricultural crop material that is baled, cubed, pelletized, or long-stemmed, on the field where it was harvested, and the handling of fowl or animal feed materials at sites where animals or fowl are raised;

C.28.d Disturbances of cultivated land as a result of fallowing, planting, fertilizing or harvesting.

C.29 OPEN AREA: Any of the following described in Subsection C.29.a through C.29.c of this rule. For the purpose of this rule, vacant portions of residential or commercial lots and contiguous parcels that are immediately adjacent to and owned and/or operated by the same individual or entity are considered one open area. An open area does not include any Unpaved Traffic Area as defined in this rule.

C.29.a An un-subdivided or undeveloped land whether or not it is adjoining a developed (or partially developed) residential, industrial, institutional, governmental, or commercial area.

C.29.b A subdivided residential, industrial, institutional, governmental, or commercial lot, which contains no approved or permitted building or structures of a temporary or permanent nature.

C.29.c A partially developed residential, industrial, institutional, governmental, or commercial lot and contiguous lots under common ownership.

C.30 PARTICULATE MATTER: Any material, except uncombined water, which exists in a finely divided form as a liquid or solid at 60 degrees F and one

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atmosphere pressure.

C.31 PAVED ROADS: An improved street, highway, alley, public way, that is covered by concrete, asphaltic concrete, or asphalt.

C.32 PERSON: Any individual, public or private corporation, partnership, association, firm, trust, estate, municipality, or any other legal entity whatsoever which is recognized by law as the subject of rights and duties, who is responsible for an Active Operation.

C.33 PM-10: Particulate Matter with an aerodynamic diameter smaller than or equal to a nominal 10 microns as measured by the applicable State and Federal reference test methods.

C.34 RECREATIONAL OFF-HIGHWAY VEHICLE (OHV) USE AREA: The entire area of a parcel of land, except for camping and approved buffer areas, that is managed for off-highway vehicle use through the development or designation of off-highway vehicle trails or areas.

C.35 RURAL: Areas not classified as urban constitute “rural.”

C.36 SILT: Any Aggregate Material with a particle size less than 75 micrometers in diameter as measured by a No. 200 sieve as defined in ASTM D-2487 and as tested by ASTM-C-136 or other equivalent test methods approved by EPA, ARB, and the APCD.

C.37 STABILIZED SURFACE: Any disturbed surface area or open bulk storage pile that is resistant to wind blown Fugitive Dust emissions. A surface is considered to be stabilized if it meets at least one of the following conditions specified in this Section and as determined by the test methods specified in Appendix B, Section A, B and D-G tests of this rule:

C.37.a A visible crust; or

C.37.b A threshold friction velocity (TFV) for disturbed surface areas corrected for non-erodible elements of 100 centimeters per second or greater; or

C.37.c A flat vegetative cover of at least 50 percent that is attached or rooted vegetation; or unattached vegetative debris lying on the surface with a predominant horizontal orientation that is not subject to movement by wind; or

C.37.d A standing vegetative cover of at least 30 percent that is attached or rooted vegetation with a predominant vertical orientation; or

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C.37.e A standing vegetative cover that is attached or rooted vegetative with a predominant vertical orientation that is at least 10 percent and where the TFV is at least 43 centimeters per second when corrected for non-erodible elements; or

C.37.f A surface that is greater than or equal to 10 percent of non-erodible elements such as rocks, stones, or hard-packed clumps of soil.

C.38 STABILIZED UNPAVED ROAD: Any Unpaved Road or unpaved vehicle/equipment traffic area surface which meets the definition of Stabilized Surface as determined by the test method in Appendix B, Section C of this rule, and where VDE is limited to 20% opacity.

C.39 TACTICAL TRAINING: Training conducted by the U.S. Department of Defense, the U.S. military services, or its allies for combat, combat support, combat service support, tactical or relief operations. Examples include but are not limited to munitions training.

C.40 TEMPORARY UNPAVED ROAD: Any Unpaved Road surface which is created to support a temporary or periodic activity and the use of such road surface is limited to vehicle access for a period of not more than six months during any consecutive three-year period.

C.41 THRESHOLD FRICTION VELOCITY (TFV): The corrected velocity necessary to initiate soil erosion as determined by the test method specified in Appendix B, Section D, of this rule. The lower TFV, the greater the propensity for fine particles to be lifted at relatively low wind speeds.

C.42 TRACK-OUT/CARRY-OUT: Any and all Bulk Materials that adhere to and agglomerate on the exterior surfaces of motor vehicles and/or equipment (including tires) that may then fall onto the pavement.

C.43 TRACK-OUT PREVENTION DEVICE: A Gravel pad, grizzly, wheel wash system, or a paved area, located at the point of intersection of an unpaved area and a Paved Road that prevents or controls Track-Out.

C.44 UNPAVED ROADS: Streets, alley ways, or roadways that are not covered by one of the following: concrete, asphaltic concrete, asphalt, or other similar materials specified by the U.S.EPA, CARB and/or the APCO.

C.45 UNPAVED TRAFFIC AREA: Any nonresidential area that is:

C.45.a Not covered by asphalt, recycled asphalt, asphaltic concrete, concrete, or concrete pavement, and

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C.45.b Used for fueling and servicing; shipping, receiving and transfer; or parking or storing equipment, haul trucks, vehicles, and any conveyances.

C.46 URBAN AREA: An area within an incorporated city boundary or within unincorporated areas completely surrounded by an incorporated city.

C.47 VDE: Visible dust emissions. Dust emissions that are visible to an observer.

C.48 VMT: Vehicle miles traveled.

C.49 WIND GUST: Is the maximum instantaneous wind speed as measured by an anemometer.

D. Compliance Schedule

D.1 Existing sources subject to this Regulation shall comply with its requirements no later than 90 days after its adoption date.

D.2 New sources subject to this Regulation shall comply with its requirements prior to initiation of activity.

D.3 BP and any person (including BLM and DPR) who owns or operates a Recreational OHV Use Area on public lands shall each comply with the following compliance schedule:

D.3.a Submit a draft dust control plan addressing all applicable portions of this Regulation including section F.5 and F.7 within three (3) months of the adoption date of this rule, to which the APCO shall respond within 60 days;

D.3.b Submit a final dust control plan addressing all APCO comments within two (2) months after receiving APCO's comments, which the APCO shall transmit to CARB and U.S. EPA for 45-day review and comment;

D.3.c If comments received from CARB or EPA, submit to them and APCO a revised final dust control plan addressing all comments within two (2) months after receiving comments.

D.3.d Implement all final dust control plan elements within six (6) months of submittal; and

D.3.e Submit an updated dust control plan every two calendar years

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by the procedures described in D.3.a to D.3.d. The updated plans shall be transmitted to the District no later than 90 days after the end of the calendar year and, in addition to information required of the initial plan, shall include a summary of actions taken to prevent or mitigate PM10 emissions during the previous two years.

E. Exemptions

The following activities are exempt from provisions of this Regulation:

E.1 Actions required by the Federal or State Endangered Species Act or any order issued by a court or governmental agency.

E.2 Off-Field Agricultural Sources necessary to minimize or respond to adverse effects on agricultural crops caused during freezing temperatures as declared by the National Weather Service.

E.3 Emergency maintenance of flood control channels and water spreading basins.

E.4 Any emergency operation activities performed to ensure public health and safety. Emergency activities lasting more than 30 days shall be subject to this Regulation, except where compliance would limit the effectiveness of the emergency activity performed to ensure public health and safety.

E.5 Blasting operations permitted by the California Division of Industrial Safety. Other activities performed in conjunction with blasting are not exempt from complying with the provisions of this rule.

E.6 The following military training activities conducted by the Department of Defense: (1) military Tactical Training, (2) maintenance, repair, and removal of targets and munitions associated with military Tactical Training, (3) open areas on active military ranges, including but not limited to designated impact areas, landing zones, and bivouac areas. However, unpaved roads, staging areas, parking lots, and other activities performed in conjunction with military Tactical Training are not exempt from complying with the provisions of this Regulation, as applicable.

F. General Requirements

F.1 Materials used for Chemical Stabilization of soils, including petroleum resins, asphaltic emulsions, acrylics, and adhesives shall not violate State Water Quality Control Board standards for use as a soil stabilizer. Materials accepted by the California Air Resources Board (ARB) and the

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United States Environmental Protection Agency (EPA), and which meet State water quality standards, shall be considered acceptable to the ICAPCD.

F.2 Any material prohibited for use as dust Suppressant by EPA, the ARB, or other applicable law, rule, or regulation is also prohibited under Regulation VIII.

F.3 Use of hygroscopic materials may be prohibited by the APCD in areas lacking sufficient atmospheric moisture of soil for such materials to effectively reduce Fugitive Dust emissions. The atmospheric moisture of soil is considered to be sufficient if it meets the application specifications of the hygroscopic product manufacturer. Use of such materials may be approved in conjunction with sufficient wetting of the controlled area.

F.4 Any use of dust Suppressants or gravel pads, and paving materials such as asphalt or concrete for paving, shall comply with other applicable District Rules.

F.5 Recreational OHV Use Area on Public lands Dust Control Plan Requirements

The BLM, DPR, or any other owner or operator of a Recreational OHV Use Area on public lands shall prepare a dust control plan to minimize PM-10 emissions. The dust control plan shall include at a minimum the following:

F.5.a A stipulation that all new authorizations for point and area stationary emission sources obtain all necessary permits and satisfy all applicable SIP provisions, including Regulation VIII specific control measures;

F.5.b A summary of:

F.5.b.1 The total miles of roads in the Recreational OHV Use Area on public lands that are paved, paved with unpaved shoulders, and unpaved roads with 50 or more average vehicle trips per day, including length and level of usage of each such road; the priority for control of road segments based on annual and episodic (e.g. event) usage; the plans for control of PM-10 emissions from these roads;

F.5.b.2 The location and extent (acreage and where feasible, estimate of number of vehicles) of open areas disturbed by legal and illegal Recreational Use,

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including maps such as those required by California Public Resources Code (PRC) section 5090.34; the priority for control of these open areas based on annual and episodic (e.g. event) usage; the plans for control of PM-10 emissions from these areas;

F.5.c Unpaved Roads and Unpaved Vehicle/Equipment Traffic Area. The dust control plan shall be implemented on all days that traffic exceeds, or is expected to exceed, the number of average daily vehicle trips per day as specified in sections F.5.c.1 and F.5.c.2 of this rule, except where measures are demonstrated by owner/operator to be prohibited by federal or state laws, regulations, or approved plans concerning wilderness preservation and species management and recovery.

F.5.c.1 On each day of an Off-Road Event and/or Competition that 50 average vehicle daily trips per day will occur on an unpaved road segment, the owner/operator shall limit VDE to 20% opacity and comply with the requirements of a stabilized unpaved road by application and/or re-application/maintenance of at least one of the following control measures:

F.5.c.1.1 Watering;
F.5.c.1.2 Uniform layer of washed gravel;
F.5.c.1.3 Paving;
F.5.c.1.4 Restrict access;
F.5.c.1.5 Restrict speed limit at or below 15 mph;
F.5.c.1.6 Chemical/organic dust suppressants;
F.5.c.1.7 Roadmix;
F.5.c.1.8 Any other method(s) that can be demonstrated that effectively limits VDE to 20% opacity and meets the conditions of a stabilized unpaved road.

F.5.c.2 On each day of an Off-Road Event and/or Competition that 50 average vehicle daily trips per day will occur on an unpaved surface area dedicated to any vehicle parking and Unpaved Traffic Area, the owner/operator shall limit VDE to 20% opacity and comply with the requirements of a stabilized unpaved road by application and/or re-application/maintenance of at least one of the following control measures:

F.5.c.2.1 Watering;
F.5.c.2.2 Uniform layer of washed gravel;

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F.5.c.2.3 Paving;
F.5.c.2.4 Restricted access below the limit;
F.5.c.2.5 Restrict speed limit at or below 15 mph;
F.5.c.2.6 Chemical/organic dust suppressants;
F.5.c.2.7 Roadmix;
F.5.c.2.8 Any other method(s) that can be demonstrated that effectively limits VDE to 20% opacity and meets the conditions of a stabilized unpaved road.

F.5.d The dust control plan must describe all PM-10 control measures that will be implemented, such as restricted use areas, stabilization of Unpaved Traffic Areas and current Recreation Area Management Plan (RAMP) measures, all applicable soil and habitat conservation requirements, and all monitoring and corrective actions taken to reduce PM10 emissions during Off-Road Events and/or Competitions on public land and include all those measures that are feasible and not prohibited by the laws, regulations and plans described in F.5.c;

F.5.e Use BLM-standard road design and drainage specifications when maintaining existing roads or authorizing road maintenance and new road construction;

F.5.f Include public educational information on reducing PM-10 emissions with agency (e.g., BLM and DPR) open area literature (e.g. identification of restricted areas and/or applicable speed limits) and on related information signs in heavily used areas; and

F.5.g The owner or operator of a recreational OHV use area on public lands shall not permit Off-Road Events and/or Competitions from June 15th to August 15th, unless a specific dust control plan is submitted to and approved by the ICAPCD. The dust control plan shall include specific fugitive dust control measures and demonstrate that all control measures, including the requirements of this rule, can be implemented and enforced.

F.6 Border Patrol (BP) Requirements

The BP shall prepare a dust control plan designed to minimize PM10 emissions from sources under the control of the BP. The dust control plan shall include the following fugitive dust control measures:

F.6.a A stipulation that all new authorizations for point and area stationary emission sources obtain all necessary permits and

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satisfy all applicable SIP provisions, including Regulation VIII specific control measures;

F.6.b Implement alternatives to tire-dragging that result in fewer PM10 emissions, unless BP demonstrates such alternatives to be inconsistent with the monitoring of immigration across the U.S.-Mexico border;

F.7 New Recreational OHV Use Area(s) on Public Land Requirements

Before a public agency (including BLM and DPR) designates a property as "New Recreational OHV Use Area" (hereafter referred to as "New Recreational OHV Use Area") for OHV recreation, the agency shall meet and confer with ICAPCD. A "New Recreational OHV Use Area" shall include areas physically undisturbed by OHV usage as of January 1, 2013. After development and approval of an agency's first Dust Control Plan under Section D.3 of this rule, "New Recreational OHV Use Area also includes areas not described in the previous public agency's dust control plan."

F.7.a ICAPCD shall review the public agency's draft General Plan, Specific Plan, or RAMP and/or related documents for consistency and compliance with the rules and requirements applicable to and/or implementing Imperial County's plan for attainment and/or maintenance of the 24-hour federal PM-10 standard. During the applicable public comment period, ICAPCD may provide comments on the applicable plan to the public agency related to consistency and compliance with such rules and requirements, and where applicable, describe additional measures necessary for consistency and compliance with such rules and requirements.

F.7.b For any New Recreational OHV Use Area(s) with PM-10 emissions of 70 tons per year or above, the public agency must demonstrate in a federal- and/or state-required environmental assessment that these emissions would not:

F.7.b.1 Cause or contribute to any new violations of any PM-10 NAAQS in the area.

F.7.b.2 Interfere with provisions in the applicable PM-10 SIP for maintenance of the PM-10 NAAQS.

F.7.b.3 Increase the frequency or severity of any existing violation of PM-10 NAAQS; or

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F.7.b.4 Delay timely attainment of the PM-10 NAAQS or any required interim emission reductions or other milestones in any area including, where applicable, emission levels specified in the applicable SIP for purposes of: (i) a demonstration of reasonable further progress; (ii) a demonstration of attainment; or (iii) a maintenance plan.

F.7.c The public agency shall not approve the applicable General Plan, Specific Plan, or RAMP unless and until it has incorporated ICAPCD's comments and recommended mitigation measures or explained why a comment or recommended mitigation measure does not apply or is infeasible. If the public agency does not accept a mitigation measure or comment, the public agency shall consult with ICAPCD to identify an alternative measure or way to address ICAPCD's concern. In any event, all New Recreational OHV Use Areas shall comply with Section F.5 above.

G. Administrative Requirements

G.1 Test Methods

G.1.a Determination of VDE Opacity

Opacity observations to determine compliance with VDE standards shall be conducted in accordance with the test procedures for "Visual Determination of Opacity" as described in Appendix A of this rule. Opacity observations for sources other than unpaved traffic areas (e.g., roads, parking areas) shall be conducted per Section B of Appendix A and shall require 12 readings at 15-second intervals.

G.1.b Determination of Stabilized Surface

Observations to determine compliance with the conditions specified for a stabilized surface, in any inactive disturbed surface area, whether at a work site that is under construction, at a work site that is temporarily or permanently inactive, or on an open area and vacant lot, shall be conducted in accordance with the test methods described in Appendix B of this rule. If a disturbed surface area passes any of the applicable Appendix B-Section A, B and D-G tests, then the surface shall be considered stabilized.

G.1.c Determination of Soil Moisture Content

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Soil moisture content shall be determined by using ASTM Method D2216-98 (Standard Test Method for Laboratory Determination of Water [Moisture] Content of Soil and Rock by Mass), or other equivalent test methods approved by the EPA, ARB, and the APCO.

G.1.d Determination of Silt Content for Bulk Materials

Silt content of a Bulk Material shall be determined by ASTM Method C136a (Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates), or other equivalent test methods approved by EPA, ARB, and the APCD.

G.1.e Determination of Silt Content for Unpaved Roads and Unpaved Vehicle/Equipment Traffic Areas

Silt Content for Unpaved Roads and Unpaved Traffic Areas shall be determined by using Section C of Appendix B of this Rule or other equivalent test methods approved by EPA, ARB, and the APCO.

G.1.f Determination of Threshold Friction Velocity (TFV)

TFV shall be determined by using Section D of Appendix B of this Rule or other equivalent test methods approved by EPA, ARB, and the APCO.

H. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application and compliance with this rule (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of treatment or control measure, extent of coverage, and date applied. For control measures which require multiple daily applications, recording the frequency of application will fulfill the recordkeeping requirements of this rule (i.e., water being applied three times a day and the date) Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

I. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII. Failure to comply with the provisions of an APCO approved dust control plan shall also constitute a violation of this Regulation. Regardless of whether an APCO approved dust control plan is being implemented or not, or

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whether a Person responsible for an Active Operation(s) is complying with an approved dust control plan, the Person is still subject to the requirements of Regulation VIII at all times.

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APPENDIX A
Visual Determination of Opacity

SECTION A Test Method For Unpaved Roads and Unpaved Traffic Areas
SECTION B Test Method For Time-Averaged Regulations

SECTION A TEST METHOD FOR UNPAVED ROADS AND UNPAVED TRAFFIC AREAS

A Opacity Test Method. The purpose of this test method is to estimate the percent opacity of Fugitive Dust plumes caused by vehicle movement on Unpaved Roads and Unpaved Traffic Areas. This method can only be conducted by an individual who has current certification as a qualified observer.

A.1 Step 1: Stand at least 16.5 feet from the fugitive dust source in order to provide a clear view of the emissions with the sun oriented in the 140° sector to the back. Following the above requirements, make opacity observations so that the line of vision is approximately perpendicular to the dust plume and wind direction. If multiple plumes are involved, do not include more than one plume in the line of sight at one time.

A.2 Step 2: Record the Fugitive Dust source location, source type, method of control used, if any, observer's name, certification data and affiliation, and a sketch of the observer's position relative to the Fugitive Dust source. Also, record the time, estimated distance to the Fugitive Dust source location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), observer's position to the Fugitive Dust source, and color of the plume and type of background on the visible emission observation form both when opacity readings are initiated and completed.

A.3 Step 3: Make opacity observations, to the extent possible, using a contrasting background that is perpendicular to the line of vision. Make opacity observations approximately 1 meter above the surface from which the plume is generated. Note that the observation is to be made at only one visual point upon generation of a plume, as opposed to visually tracking the entire length of a dust plume as it is created along a surface. Make two observations per vehicle, beginning with the first reading at zero seconds and the second reading at five seconds. The zero-second observation should begin immediately after a plume has been created above the surface involved. Do not look continuously at the plume but, instead, observe the plume briefly at zero seconds and then again at five seconds.

A.4 Step 4: Record the opacity observations to the nearest 5% on an observational record sheet. Each momentary observation recorded

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represents the average opacity of emissions for a 5-second period. While it is not required by the test method, EPA recommends that the observer estimate the size of the vehicles which generate dust plumes for which readings are taken (e.g. mid-size passenger car or heavy-duty truck.) and take the approximate speeds the vehicles are traveling when the readings are being taken.

A.5 Step 5: Repeat Step 3 (Section A.3. of this appendix) and Step 4 (Section A.4. of this appendix) until you have recorded a total of 12 consecutive opacity readings. This will occur once six vehicles have driven on the source in your line of observation for which you are able to take proper readings. The 12 consecutive readings must be taken within the same period of observation but must not exceed 1 hour. Observations immediately preceding and following interrupted observations can be considered consecutive.

A.6 Step 6: Average the 12 opacity readings together. If the average opacity reading equals 20% or lower, the source is in compliance with the opacity standard described in the applicable rule.

SECTION B TEST METHOD FOR VISUAL DETERMINATION OF OPACITY OF EMISSIONS FROM SOURCES FOR TIME-AVERAGED REGULATIONS

B Applicability. This method is applicable for the determination of the opacity of emissions from sources of visible emissions for time-averaged regulations. A time-averaged regulation is any regulation that requires averaging visible emission data to determine the opacity of visible emissions over a specific time period.

B.1 Principle. The opacity of emissions from sources of visible emissions is determined visually by a qualified observer who has received certification.

B.2 Procedures. A qualified observer who has been certified shall use the following procedures for visually determining the opacity of emissions.

B.2.a Position. Stand at a position at least 5 meters from the Fugitive Dust source n order to provide a clear view of the emissions with the sun oriented in the 140° sector to the back. Consistent as much as possible with maintaining the above requirements, make opacity observations from a position such that the line of sight is approximately perpendicular to the plume and wind direction. The observer may follow the Fugitive Dust plume generated by mobile earthmoving equipment, as long as the sun remains oriented in the 140° sector to the back. As much as possible, if multiple plumes are involved, do not include more than one plume in the line of sight at one time.

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B.2.b Field Records. Record the name of the site, Fugitive Dust source type (i.e., pile, material handling (i.e., transfer, loading, sorting)), method of control used, if any, observer's name, certification data and affiliation, and a sketch of the observer's position relative to the Fugitive Dust source. Also, record the time, estimated distance to the Fugitive Dust source location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds,) observer's position relative to the fugitive dust source, and color of the plume and type of the background on the visible emission observation form when opacity readings are initiated and completed.

B.2.c Observations. Make opacity observations, to the extent possible, using a contrasting background that is perpendicular to the line of sight. For storage piles, make opacity observations approximately 1 meter above the surface from which the plume is generated. For extraction operations and the loading of haul trucks in open-pit mines, make opacity observations approximately one meter above the rim of the pit. The initial observation should begin immediately after a plume has been created above the surface involved. Do not look continuously at the plume, but instead observe the plume momentarily at 15-second intervals. For Fugitive Dust from Earthmoving equipment, make opacity observations approximately 1 meter above the mechanical equipment generating the plume.

B.2.d Recording Observations. Record the opacity observations to the nearest 5% every 15 seconds on an observational record sheet. Each momentary observation recorded represents the average opacity of emissions for a 15-second period. If a multiple plume exists at the time of an observation, do not record an opacity reading. Mark an "x" for that reading. If the equipment generating the plume travels outside of the field of observation, resulting in the inability to maintain the orientation of the sun within the 140° sector or if the equipment ceases operating, mark an "x" for the 15 – second interval reading. Readings identified as "x" shall be considered interrupted readings.

B.2.e Data Reduction For Time-Averaged Regulations. For each set of 12 or 24 consecutive readings, calculate the appropriate average opacity. Sets must consist of consecutive observations, however, readings immediately preceding and following interrupted readings shall be deemed consecutive and in no case shall two sets overlap, resulting in multiple violations.

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APPENDIX B
Determination of Stabilization

SECTION A Test Methods for Determining Stabilization
SECTION B Visible Crust Determination
SECTION C Determination of Silt Content for Unpaved Roads and Unpaved Vehicle/Equipment Traffic Areas
SECTION D Determination of Threshold Friction Velocity
SECTION E Determination of Flat Vegetative Cover
SECTION F Determination of Standing Vegetative Cover
SECTION G Rock Test Method

SECTION A TEST METHODS FOR DETERMINING STABILIZATION

The test methods described in Section B through Section G of this appendix shall be used to determine whether an area has a Stabilized Surface. Should a disturbed area contain more than one type of disturbance, soil, vegetation, or other characteristics, which are visibly distinguishable, test each representative surface separately for stability, in an area that represents a random portion of the overall disturbed conditions of the site, according to the appropriate test methods in Section B through Section G of this appendix, and include or eliminate it from the total size assessment of disturbed surface area(s) depending upon test method results.

SECTION B VISIBLE CRUST DETERMINATION

B.1 Where a visible crust exists, drop a steel ball with a diameter of 15.9 millimeters (0.625 inches) and a mass ranging from 16-17 grams from a distance of 30 centimeters (one foot) directly above (at a 90° angle perpendicular to) the soil surface. If blowsand is present, clear the blowsand from the surfaces on which the visible crust test method is conducted. Blowsand is defined as thin deposits of loose uncombined grains covering less than 50% of a site which have not originated from the representative site surface being tested. If material covers a visible crust, which is not blowsand, apply the test method in Section D of this appendix to the loose material to determine whether the surface is stabilized.

B.2 A sufficient crust is defined under the following conditions: once a ball has been dropped according to section B.1 of this appendix, the ball does not sink into the surface, so that it is partially or fully surrounded by loose grains and, upon removing the ball, the surface upon which it fell has not been pulverized, so that loose grains are visible.

B.3 Drop the ball three times within a survey area that measures 1 foot by 1 foot and that represents a random portion of the overall disturbed conditions of the site. The survey area shall be considered to have passed the Visible Crust Determination Test if the results of at least two out of the three times that the ball

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was dropped, met the criteria in section B.2 of this appendix. Select at least two other survey areas that represent a random portion of the overall disturbed conditions of the site, and repeat this procedure. If the results meet the criteria of section B.2 of this appendix for all of the survey areas tested, then the site shall be considered to have passed the Visible Crust Determination Test and shall be considered sufficiently crusted.

B.4 At any given site, the existence of a sufficient crust covering one portion of the site may not represent the existence or protectiveness of a crust on another portion of the site. Repeat the visible crust test as often as necessary on each random portion of the overall conditions of the site for an accurate assessment.

SECTION C DETERMINATION OF SILT CONTENT FOR UNPAVED ROADS AND UNPAVED VEHICLE/EQUIPMENT TRAFFIC AREAS

The purpose of this test method is to estimate the silt content of the trafficked parts of Unpaved Roads and Unpaved vehicle/equipment Traffic Areas. The higher the Silt content, the more fine dust particles that are released when vehicles travel on Unpaved Roads and Unpaved vehicle/equipment Traffic Areas.

C.1 Equipment:

C.1.a A set of sieves with the following openings: 4 millimeters (mm), 2mm, 1mm, 0.5mm and 0.25 mm, a lid, and collector pan.
C.1.b A small whisk broom or paintbrush with stiff bristles and dustpan 1 ft. in width (the broom/brush should preferably have one, thin row of bristles no longer than 1.5 inches in length.)
C.1.c A spatula without holes.
C.1.d A small scale with half-ounce increments (e.g., postal/package scale.)
C.1.e A shallow, lightweight container (e.g., plastic storage container.)
C.1.f A sturdy cardboard box or other rigid object with a level surface.
C.1.g A basic calculator.
C.1.h Cloth gloves (optional for handling metal sieves on hot, sunny days.)
C.1.i Sealable plastic bags (if sending samples to a laboratory.)
C.1.j A pencil/pen and paper.

C.2 Step 1: Look for a routinely traveled surface, as evidenced by tire tracks. Only collect samples from surfaces that are not damp due to precipitation or dew. This statement is not meant to be a standard in itself for dampness where watering is being used as a control measure. It is only intended to ensure that surface testing is done in a representative manner. Use caution when taking samples to ensure personal safety with respect to passing vehicles. Gently press the edge of a dustpan (1 foot in width) into the surface four times to mark an area that is 1 square foot. Collect a sample of loose surface material into the dustpan, minimizing escape of dust particles. Use a spatula to lift heavier elements such as gravel. Only collect dirt/Gravel to an approximate depth of 3/8

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inch or 1 cm in the 1 square foot area. If you reach a hard, underlying subsurface that is <3/8 inch in depth, do not continue collecting the sample by digging into the hard surface. In other words, you are only collecting a surface sample of loose material down to 1 cm. In order to confirm that samples are collected to a 1cm depth, a wooden dowel or other similar narrow object at least one-foot in length can be laid horizontally across the survey area while a metric ruler is held perpendicular to the dowel. (Optional: At this point, you can choose to place the sample collected into a plastic bag or container and take it to an independent laboratory for silt content analysis. A reference to the procedure the laboratory is required to follow is at the end of this section.)

C.3 Step 2: Place a scale on a level surface. Place a lightweight container on the scale. Zero the scale with the weight of the empty container on it. Transfer the entire sample collected in the dustpan to the container, minimizing escape of dust particles. Weigh the sample and record its weight.

C.4 Step 3: Stack a set of sieves in order according to the size openings specified above, beginning with the largest size opening (4mm) at the top. Place a collector pan underneath the bottom (0.25mm) sieve.

C.5 Step 4: Carefully pour the sample into the sieve stack, minimizing escape of dust particles by slowly brushing material into the stack with a whiskbroom or brush. On windy days, use the trunk or door of a vehicle as a wind barrier. Cover the stack with a lid. Lift up the sieve stack and shake it vigorously up and down and sideways for at least 1 minute.

C.6 Step 5: Remove the lid from the stack and disassemble each sieve separately, beginning with the top sieve. As you remove each sieve, examine it to make sure that all of the material has been sifted to the finest sieve through which it can pass (e.g., material in each sieve (besides the top sieve that captures a range of larger elements) should look the same size.) If this is not the case, re-stack the sieves and collector pan, cover the stack with the lid, and shake it again for at least 1 minute. You only need to reassemble the sieve(s) that contain material, which require further sifting.

C.7 Step 6: After disassembling the sieves and collector pan, slowly sweep the material from the collector pan into the empty container originally used to collect and weigh the entire sample. Take care not to minimize escape of dust particles. You do not need to do anything with material captured in the sieves – only the collector pan. Weigh the container with the materials from the collector pan and record its weight.

C.8 Step 7: If the source is an unpaved road, multiply the resulting weight by 0.38. If the source is an Unpaved vehicle/equipment Traffic Area, multiply the resulting weight by 0.55. The resulting number is the estimated silt loading. Then, divide the total weight of the sample you recorded earlier in Step 2 (Section C.4) and

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multiply by 100 to estimate the percent Silt content.

C.9 Step 8: Select another two routinely traveled portions of the Unpaved Road or Unpaved vehicle/equipment Traffic Area and repeat this test method. Once you have calculated the silt loading and percent silt content of the 3 samples collected, average your results together.

C.10 Step 9: Examine Results. If the average silt loading is less than 0.33 oz/ft^2, the surface is STABLE. If the average silt loading is greater than or equal to 0.33 oz/ft^2, then proceed to examine the average percent Silt content. If the source is an Unpaved Road and the average percent Silt content is 6% or less, the surface is STABLE. If the source is an unpaved parking lot and the average percent Silt content is 8% or less, the surface is STABLE. If your field test results are within 2% of the standard (for example, 4%-8% Silt content on an Unpaved Road) it is recommended that you collect 3 additional samples from the source according to Step 1 (section C.2) and take them to an independent laboratory for Silt content analysis.

C.11 Independent Laboratory Analysis: You may choose to collect samples from the source, according to Step 1 (section C.2) and send them to an independent laboratory for Silt content analysis rather than conduct the sieve field procedure. If so, the test method the laboratory is required to use is: "Procedures For Laboratory Analysis for Surface/Bulk Dust Loading Samples," (Fifth Edition, Volume 1, Appendix C.2.3 "Silt Analysis," 1995,) AP-42, Office of Air Quality Planning & Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

SECTION D DETERMINATION OF THRESHOLD FRICTION VELOCITY (TFV)

For disturbed surface areas that are not crusted or vegetated, determine threshold friction velocity (TFV) according to the following sieving field procedure (based on a 1952 laboratory procedure published by W.S. Chepil).

D.1 Obtain and stack a set of sieves with the following openings: 4 millimeters (mm), 2 mm, 1 mm, 0.5 mm, and 0.25 mm or obtain and stack a set of standard/commonly available sieves. Place the sieves in order according to size openings, beginning with the largest size opening at the top. Place a collector pan underneath the bottom (0.25 mm) sieve. Collect a sample of loose surface material from an area at least 30 cm by 30 cm in size to a depth of approximately 1 cm using a brush and dustpan or other similar device. Only collect soil samples from dry surfaces (i.e. when the surface is not damp to the touch). Remove any rocks larger than 1 cm in diameter from the sample. Pour the sample into the top sieve (4 mm opening) and cover the sieve/collector pan unit with a lid. Minimize escape of particles into the air when transferring surface soil into the sieve/collector pan unit. Move the covered sieve/collector pan unit by hand using a broad, circular arm motion in the horizontal plane. Complete twenty

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circular arm movements, ten clockwise and ten counterclockwise, at a speed just necessary to achieve some relative horizontal motion between the sieves and the particles. Remove the lid from the sieve/collector pan unit and disassemble each sieve separately beginning with the largest sieve. As each sieve is removed, examine it for loose particles. If loose particles have not been sifted to the finest sieve through which they can pass, reassemble and cover the sieve/collector pan unit and gently rotate it an additional ten times. After disassembling the sieve/collector pan unit, slightly tilt and gently tap each sieve and the collector pan so that material aligns along one side. In doing so, minimize escape of particles into the air. Line up the sieves and collector pan in a row and visibly inspect the relative quantities of catch in order to determine which sieve (or whether the collector pan) contains the greatest volume of material. If a visual determination of relative volumes of catch among sieves is difficult, use a graduated cylinder to measure the volume. Estimate TFV for the sieve catch with the greatest volume using Table 1 of this appendix, which provides a correlation between sieve opening size and TFV.

Table 1. Determination of Threshold Friction Velocity (TFV)

Tyler Sieve No.	ASTM 11 Sieve No.	Opening (mm)	TFV (cm/s)
5	5	4	135
9	10	2	100
16	18	1	76
32	35	0.5	58
60	60	0.25	43
Collector Pan	---	---	30

D.2 Collect at least three soil samples which represent random portions of the overall conditions of the site, repeat the above TFV test method for each sample and average the resulting TFVs together to determine the TFV uncorrected for non erodible elements. Non-erodible elements are distinct elements, in the random portion of the overall conditions of the site, that are larger than 1 cm in diameter, remain firmly in place during a wind episode, and inhibit soil loss by consuming Section of the shear stress of the wind. Non-erodible elements include stones and bulk surface material but do not include flat or standing vegetation. For surfaces with non-erodible elements, determine corrections to the TFV by identifying the fraction of the survey area, as viewed from directly overhead, that is occupied by non-erodible elements using the following procedure. Select a survey area of 1 meter by 1 meter that represents a random portion of the overall conditions of the site. Where many non-erodible elements lie within the survey area, separate the non-erodible elements into groups according to size. For each group, calculate the overhead area for the non-erodible elements according to the following equations:

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Average Dimensions = (Average Length) x (Average Width)	Eq. 1
Overhead Area = (Average Dimensions) x (Number of Elements)	Eq. 2
Total Overhead Area = Overhead Area Of Group 1 + Overhead Area of Group 2 (etc)	Eq. 3
Total Frontal Area = Total Overhead Area/2	Eq. 4
Percent Cover of Non-Erodible Elements = (Total Frontal Area/Survey Area) x 100	Eq. 5

Note: Ensure consistent units of measurements (e.g., square meters or square inches when calculating percent cover).

Repeat this procedure on an additional two distinct survey areas that represent a random portion of the overall conditions of the site and average the results. Use Table 2 of this appendix to identify the correction factor for the percent cover of non-erodible elements. Multiply the TFV by the corresponding correction factor to calculate the TFV corrected for non-erodible elements.

Table 2. Correction Factors for Threshold Friction Velocity

Percent Cover of Non-Erodible Elements	Correction Factor
Greater than or equal to 10%	5
Greater than or equal to 5% and less than 10%	3
Less than 5% and greater than or equal to 1%	2
Less than 1%	None

SECTION E DETERMINATION OF FLAT VEGETATIVE COVER

Flat vegetation includes attached (rooted) vegetation or unattached vegetative debris lying on the surface with a predominant horizontal orientation that is not subject to movement by wind. Flat vegetation, which is dead but firmly attached, shall be considered equally protective as live vegetation. Stones or other aggregate larger than 1 centimeter in diameter shall be considered protective cover in the course of

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conduction the line transect test method. Where flat vegetation exists conduct the following line transect test method.

E.1 Line Transect Test Method. Stretch a 100 foot measuring tape across a survey area that represents a random portion of the overall conditions of the site. Firmly anchor both ends of the measuring tape into the surface using a tool such as a screwdriver, with the tape stretched taut and close to the soil surface. If vegetation exists in regular rows, place the tape diagonally (at approximately a 45° angle) away from a parallel or perpendicular position to the vegetated rows. Pinpoint an area the size of a 3/32 inch diameter brazing rod or wooden dowel centered above each 1 foot interval mark along one edge of the tape. Count the number of times that flat vegetation lies directly underneath the pinpointed area at 1 foot intervals. Consistently observe the underlying surface from a 90° angle directly above each pinpoint on one side of the tape. Do not count the underlying surface as vegetated if any portion of the pinpoint extends beyond the edge of the vegetation underneath in any direction. If clumps of vegetation or vegetative debris lie underneath the pinpointed area, count the surface as vegetated, unless bare soil is visible directly below the pinpointed area. When 100 observations have been made, add together the number of times a surface was counted as vegetated. This total represents the percent of flat vegetations cover (e.g., if 35 positive counts were made, then vegetation cover is 35%.) If the survey area that represents a random portion of the overall conditions of the site is too small for 100 observations, make as many observations as possible. Then multiply the count of vegetated surface areas by the appropriate conversion factor to obtain percent cover. For example, if vegetation was counted 20 times within a total of 50 observations, divide 20 by 50 and multiply by 100 to obtain a flat vegetation cover of 40%.

E.2 Conduct the line transect test method, as described in section E.1 of this appendix, an additional two times on areas that represent a random portion of the overall conditions of the site and average results.

SECTION F DETERMINATION OF STANDING VEGETATIVE COVER.

Standing vegetation includes vegetation that is attached (rooted) with a predominant vertical orientation. Standing vegetation, which is dead but firmly rooted, shall be considered equally protective as live vegetation. Conduct the following standing vegetation test method to determine if 30% cover or more exists. If the resulting percent cover is less than 30% but equal to or greater than 10%, then conduct the test in Section D; “Determination Of Threshold Friction Velocity (TFV,) of this appendix in order to determine if the site is stabilized, such that the standing vegetation cover is equal to or greater than 10%, where threshold friction velocity, corrected for non-erodible elements, is equal to or greater than 43cm/second.

F.1 For standing vegetation that consists of large, separate vegetative structures (e.g., shrubs and sagebrush,) select a survey area that represents a random

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portion of the overall conditions of the site that is the shape of a square with sides equal to at least 10 times the average height of the vegetative structures. For smaller standing vegetation, select a survey area of three feet by three feet.

F.2 Count the number of standing vegetative structures within the survey area. Count vegetation, which grows in clumps as a single unit. Where different types of vegetation exist and/or vegetation of different height and width exists, separate the vegetative structures with similar dimensions into groups. Count the number of vegetative structures in each group within the survey area. Select an individual structure within each group that represents the average height and width of the vegetation in the group. If the structure is dense (e.g., when looking at it vertically from base to top there is little or zero open air space within its perimeter,) calculate and record its frontal silhouette area, according to Equation 6 of this appendix. Also, use Equation 6 of this appendix to estimate the average height and width of the vegetation if the survey area is larger than nine square feet. Otherwise, use the procedure in section F.3 of this appendix to calculate the frontal silhouette area. Then calculate the percent cover of standing vegetation according to Equations 7, 8, and 9 of this appendix.

Frontal Silhouette Area = (Average Height) x (Average Width)	Eq. 6
Frontal Silhouette Area Of Group= (Frontal Silhouette Area Of Individual Vegetative Structure) x (Number Of Vegetation Structures Per Group)	Eq. 7
Total Frontal Silhouette Area = Frontal Silhouette Area Of Group 1 + Frontal Silhouette Area Of Group 2 (etc.)	Eq. 8
Percent Cover Of Standing Vegetation = (Total Frontal Silhouette Area/Survey Area) x 100	Eq. 9
Percent Open Space = [(Number Of Circled Gridlines Within The Outlined Area Counted That Are Not Covered By Vegetation/Total Number Of Gridline Intersections Within The Outlined Area) x 100]	Eq.10
Percent Vegetative Density = 100 – Percent Open Space	Eq. 11
Vegetative Density = Percent Vegetative Density/100	Eq. 12
Frontal Silhouette Area = [Max. Height x Max. Width] x [Vegetative Density/.04]o.5	Eq. 13

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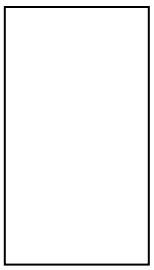
Note: Ensure consistent units of measurement (e.g., square meters or square inches when calculating percent cover.)

F.3 Vegetative Density Factor. Cut a single, representative piece of vegetation (or consolidated vegetative structure) to within 1cm of surface soil. Using a white paper grid or transparent grid over white paper, lay the vegetation flat on top of the grid (but do not apply pressure to flatten the structure.) Grid boxes of 1 inch or ½ inch squares are sufficient for most vegetation when conducting this procedure. Using a marker or pencil, outline the shape of the vegetation along its outer perimeter, according to Figure B, C, or D of this appendix, as appropriate. (Note: Figure C differs from Figure D primarily in that the width of vegetation in Figure C is narrow at its base and gradually broadens to its tallest height. In Figure D, the width of the vegetation generally becomes narrower from its midpoint to its tallest height.) Remove the vegetation, count and record the total number of gridline intersections within the outlined area, but do not count gridline intersections that connect with the outlined shape. There must be at least 10 gridline intersections within the outlined area and preferably more than 20, otherwise, use smaller grid boxes. Draw small circles (no greater than a 3/32 inch diameter) at each gridline intersection counted within the outlined area. Replace the vegetation on the grid within its outlined shape. From a distance of approximately 2 feet directly above the grid, observe each circled gridline intersection. Count and record the number of circled gridline intersections that are not covered by any piece of the vegetation. To calculate percent vegetative density, use Equations 10 and 11 of this appendix. If percent vegetative density is equal to or greater than 30, use an equation (one of the equations-Equations 16, 17, or 18 of this appendix) that matches the outline used to trace the vegetation (Figure B, C, or D) to calculate its frontal silhouette area. If percent vegetative density is less than 30, use Equations 12 and 13 of this appendix to calculate the frontal silhouette area.

Figure B. Cylinder



Frontal Silhouette Area = Maximum Height x Maximum Width Eq.16

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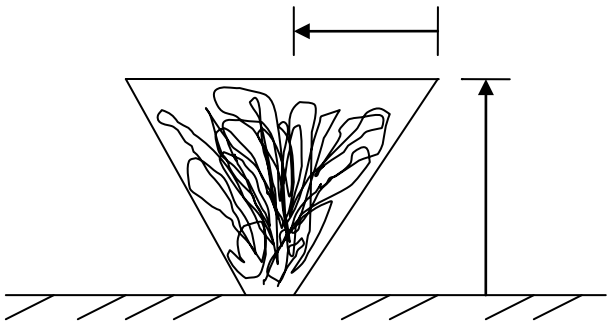
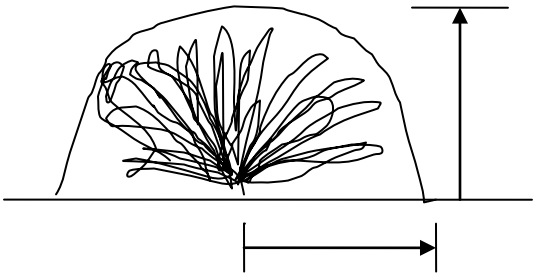
Figure C. Inverted Cone



Frontal Silhouette Area = Maximum Height x ½ Maximum Width Eq. 17

Figure D. Upper Sphere



Frontal Silhouette Area = (3.14 x Maximum Height x ½ Maximum Width)/2 Eq.18

SECTION G ROCK TEST METHOD

The Rock Test Method, which is similar to Section D, Test Methods For Stabilization-Determination Of Threshold Friction Velocity (TFV) of this appendix, examines the wind-resistance effects of rocks and other non-erodible elements on disturbed surfaces. Non-erodible elements are objects larger than 1 centimeter (cm) in diameter that remain firmly in place even on windy days. Typically, non-erodible elements include rocks, stones, glass fragments, and hardpacked clumps of soil lying on or embedded in the surface. Vegetation does not count as a non-erodible element in this method. The purpose of this test method is to estimate the percent cover of non-erodible elements on a given surface to see whether such elements take up enough space to offer protection against windblown dust. For simplification, the following test method refers to all non-erodible elements as 'rocks."

G.1 Select a 1 meter by 1 meter survey area that represents the general rock distribution on the surface. A 1 meter by 1 meter area is slightly greater than a 3 foot by 3 foot area. Mark-off the survey area by tracing a straight, visible line in the dirt along the edge of a measuring tape or by placing short ropes, yard sticks,

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or other straight objects in a square around the survey area.

G.2 Without moving any of the rocks or other elements, examine the survey area. Since rocks >3/8 inch (1cm) in diameter are of interest, measure the diameter of some of the smaller rocks to get a sense of which rocks need to be considered.

G.3 Mentally group the rocks >3/8 inch (1cm) diameter lying in the survey area into small, medium, and large size categories. Or, if the rocks are all approximately the same size, simply select a rock of average size and typical shape. Without removing any of the rocks from the ground, count the number of rocks in the survey area in each group and write down the resulting number.

G.4 Without removing rocks, select one or two average-size rocks in each group and measure the length and width. Use either metric units or standard units. Using a calculator, multiply the length times the width of the rocks to get the average dimensions of the rocks in each group. Write down the results for each rock group.

G.5 For each rock group, multiply the average dimensions (length times width) by the number of rocks counted in the group. Add the results from each rock group to get the total rock area within the survey area.

G.6 Divide the total rock area, calculated in section G.5 of this appendix, by two (to get frontal area.) Divide the resulting number by the size of the survey area (make sure the units of measurement match,) and multiply by 100 for percent rock cover. For example, the total rock area is 1,400 square centimeters divide 1,400 by 2 to get 700. Divide 700 by 10,000 (the survey area is 1 meter by 1 meter, which is 100 centimeters by 100 centimeters or 10,000 centimeters) and multiply by 100. The result is 7% rock cover. If rock measurements are made in inches, convert the survey area from meters to inches (1 inch = 2.54 centimeters.)

G.7 Select and mark-off two additional survey areas and repeat the procedures described in section G.1 through section G.6 of this appendix. Make sure the additional survey areas also represent the general rock distribution on the site. Average the percent cover results from all three survey areas to estimate the average percent of rock cover.

G.8 If the average rock cover is greater than or equal to 10%, the surface is stable. If the average rock cover is less than 10%, follow the procedures in section G.9 of this appendix.

G.9 If the average rock cover is less than 10%, the surface may or may not be stable. Follow the procedures in Section D.3 Determination Of Threshold Friction Velocity (TFV) of this rule and use the results from the rock test method as a correction (i.e., multiplication) factor. If the rock cover is at least 1%, such rock

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cover helps to limit windblown dust. However, depending on the soil's ability to release fine dust particles into the air, the percent rock cover may or may not be sufficient enough to stabilize the surface. It is also possible that the soil itself has a high enough TFV to be stable without even accounting for rock cover.

G.10 After completing the procedures described in Section G.9 of this appendix, use Table 2 of this appendix to identify the appropriate correction factor to the TFV, depending on the percent rock cover.

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RULE 801 CONSTRUCTION AND EARTHMOVING ACTIVITIES (Adopted 11/08/2005)

A. Purpose

The purpose of this rule is to reduce the amount of fine Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from Construction and other Earthmoving Activities by requiring actions to prevent, reduce, or mitigate PM-10 emissions.

B. Applicability

This rule applies to any Construction and other Earthmoving Activities, including, but not limited to, land clearing, excavation related to construction, land leveling, grading, cut and fill grading, erection or demolition of any structure, cutting and filling, trenching, loading or unloading of bulk materials, demolishing, drilling, adding to or removing bulk of materials from open storage piles, weed abatement through disking, back filling, travel on-site and travel on access roads to and from the site.

C. Definitions

The definitions of terms found in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM-10) shall apply to this rule.

D. Exemptions

In addition to the exemptions listed in Rule 800, Section E, the following exemptions are established for this rule:

D.1 Construction or demolition at existing single family residential dwellings.

D.2 The 20% opacity limit of Sections E.1.a and E.2.b shall not apply when Wind Gusts exceed 25 miles per hour, provided that at least one of the following control measures is implemented for each applicable Fugitive Dust source type:

D.2.a Cease dust generating activities for a period of one hour after Wind Gusts last exceed the threshold. If operations cease for the remainder of the day, stabilization measures must be implemented.

D.2.b Apply water or dust Suppressants once per hour.

D.2.c Apply water to maintain 12% soil moisture content.

D.2.d Construct fences 3-5 feet high with 50% or less porosity, and must

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be done in conjunction with another measure, as above.

E. Requirements

E.1 Construction sites and Earthmoving Activities:

E.1.a All Persons who own or operate a Construction site shall comply with the requirements of Section F.1 so as to limit VDE to 20% opacity and comply with the conditions for a Stabilized Surface when applicable.

E.1.b All Persons who perform any Earthmoving Activities shall comply with the requirements of Section F.1 so as to limit VDE to 20% opacity.

E.1.c All Persons who own or operate a Construction site of 10 acres or more in size for residential developments or 5 acres or more for non-residential developments shall develop a dust control plan. The dust control plan shall be made available to the APCD upon request. The dust control plan shall comply with the requirements of Section F.

E.1.d The owner or operator required to develop a dust control plan shall provide written notification to the APCD within 10 days prior to the commencement of any Construction activities via fax or mail. The requirement to develop a dust control plan shall apply to all such activities conducted for residential and non-residential (e.g., commercial, industrial, or institutional) purposes or conducted by any governmental entity. Regardless of whether a dust control plan is in place or not the owner or operator is still subject to comply with all requirements of the applicable rules under Regulation VIII at all times.

F. Best Available Control Measures for Fugitive Dust (PM-10)

F.1 Construction and Earthmoving Activities shall comply with the following requirements:

F.1.a Pre-Activity:

F.1.a.1 Pre-water site sufficient to limit VDE to 20% opacity, and

F.1.a.2 Phase work to minimize the amount of disturbed surface area at any one time.

F.1.b During Active Operations:

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F.1.b.1 Apply water or Chemical Stabilization as directed by product manufacturer to limit VDE to 20% opacity, or

F.1.b.2 Construct and maintain wind barriers sufficient to limit VDE to 20% opacity. If utilizing wind barriers, control measure F.1.b.1 above shall be implemented.

F.1.b.3 Apply water or Chemical Stabilization as directed by product manufacturer to unpaved haul/access roads and Unpaved Traffic Areas sufficient to limit VDE to 20% opacity and meet the conditions of a Stabilized Unpaved Road.

F.1.c Temporary Stabilization During Periods of Inactivity:

F.1.c.1 Restrict vehicular access to the area by fencing or signage; and

F.1.c.2 Apply water or Chemical Stabilization, as directed by product manufacturer, sufficient to comply with the conditions of a Stabilized Surface. If an area having 0.5 acres or more of disturbed surface area remains unused for seven or more days, the area must comply with the conditions for a Stabilized Surface area.

F.1.d Track Out/Carry Out of Bulk Materials at the site shall be mitigated in compliance with Rule 803.

F.1.e Unpaved Roads and Unpaved Traffic Areas at the site shall comply with Rule 805.

F.1.f Bulk Material handling operations at the site shall comply with Rule 802.

F.1.g Material transport of Bulk Material to, from, or around the site shall comply with Rule 802.

F.1.h Haul trucks transporting Bulk Material to, from, or around the site shall comply with Rule 802.

F.2 Dust Control Plan:

F.2.a Retain a copy of the dust control plan at the project site.

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F.2.b Comply with the requirements of the approved dust control plan.

F.2.c A dust control plan shall contain all of the following information:

1. Name, address, and phone number of the Person responsible for the preparation, submittal, and implementation of the dust control plan and responsible for the project site.

2. A plot plan which shows the type and location of each project.

3. The total area of land surface to be disturbed, estimated daily throughput volume of earthmoving in cubic yards, and total area in acres of the entire project site.

4. The expected start and completion dates of dust generating and soil disturbance activities to be performed on the site.

5. The actual and potential sources of Fugitive Dust emissions on the site and the location of Bulk Material handling and storage areas, Paved and Unpaved Roads, entrances and exits where Track Out/Carry Out may occur, and Unpaved Traffic Areas.

6. Dust Suppressants to be applied, including: product specifications; manufacturer's usage instructions (method, frequency, and intensity of application); type, number, and capacity of application equipment; and information on environmental impacts and approvals or certifications related to appropriate and safe use for ground application.

7. Specific surface treatment(s) and/or control measures utilized to control Track Out/Carry Out, and sedimentation where unpaved and/or access points join paved public access roads.

8. The dust control plan should describe all Fugitive Dust control measures to be implemented before, during, and after any dust generating activity.

G. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of

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treatment or control measure, extent of coverage, and date applied. For control measures which require multiple daily applications, recording the frequency of application will fulfill the recordkeeping requirements of this rule (i.e., water being applied three times a day and the date) Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

H. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII.

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RULE 802 BULK MATERIALS
(Adopted 11/08/2005)

A. Purpose

The purpose of this regulation is to reduce the amount of fine Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from outdoor handling, storage, and transport of Bulk Material by requiring actions to prevent, reduce, or mitigate PM-10 emissions.

B. Applicability

This rule applies to the outdoor handling, storage, and transport of Bulk Material, including, but not limited to, earth, rock, silt, sediment, sand, gravel, soil, fill, Aggregate Materials, dirt, mud, debris, and other organic and/or inorganic material consisting of or containing Particulate Matter with five percent or greater silt content.

C. Definitions

The definitions of terms found in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM-10) shall apply to this rule.

D. Exemptions

In addition to the exemptions listed in Rule 800, Section E, the following exemptions are established for this rule:

D.1 Outdoor storage, transport, or handling of Bulk Materials (including, but not limited to, organic or inorganic fertilizer, grains, seed, soil amendments, and feed) which would be damaged by wetting with water or by the application of Chemical Stabilization/Suppression, provided owners/operators demonstrate to the satisfaction of the APCO that none of the control measures required by this rule can be implemented to limit VDE to 20% opacity or provide a Stabilized Surface, as defined in Rule 800.

D.2 Outdoor storage or handling of any Bulk Material at a single site where no material is actively being added or removed at the end of the workday or overnight and where the total material stored is less than 100 cubic yards.

D.3 Transport of a Bulk Material in an outdoor area for a distance of twelve feet or less with the use of a chute or conveyor device.

D.4 Transport/hauling of Bulk Materials when conducted within the boundaries of a premises, are exempt from the requirements specified in Sections

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F.3.a and F.3.d.

E. Requirements

E.1 Bulk Material handling: no Person shall cause, suffer, allow or engage in any Bulk Material handling operation including, but not limited to stacking, loading, unloading, conveying and reclaiming of Bulk Material, for industrial or commercial purposes without complying with one or more of the requirements of Section F.1 so as to limit VDE to 20% opacity.

E.2 Bulk Material storage: no Person shall cause, suffer, allow or engage in any Bulk Material storage, for industrial or commercial purposes without complying with one or more of the requirements of Section F.2 so as to limit VDE to 20% opacity.

E.3 Material transport: no Person shall cause, suffer, allow or otherwise engage in the transportation of Bulk Materials for industrial or commercial purposes, without complying with all of the requirements of Section F.3 so as to limit VDE to 20% opacity.

E.4 Haul Trucks: no Person shall cause, suffer, allow or otherwise engage in the use or operation of any Haul Truck, for industrial or commercial purposes, of transporting or storing Bulk Material without complying with all of the requirements of Section F.3 so as to limit VDE to 20% opacity.

F. Best Available Control Measures for Fugitive Dust (PM-10)

F.1 BULK MATERIAL HANDLING/TRANSFER:

F.1.a Spray with water prior to handling and/or at points of transfer; or.

F.1.b Apply and maintain Chemical Stabilization, or

F.1.c Protect from wind erosion by sheltering or enclosing the operation and transfer line.

F.2 BULK MATERIAL STORAGE

F.2.a When storing Bulk Materials, comply with the conditions for a Stabilized Surface; or

F.2.b Cover Bulk Materials stored outdoors with tarps, plastic, or other suitable material and anchor in such a manner that prevents the cover from being removed by wind action, or

F.2.c Construct and maintain barriers with less than 50% porosity. If

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utilizing fences or wind barriers, apply water or chemical/organic stabilizers/suppressants, or

F.2.d Utilize a 3-side structure with a height at least equal to the height of the storage pile and with less than 50% porosity.

F.3 MATERIAL TRANSPORT/HAULING:

F.3.a Completely cover or enclose all Haul Truck loads of Bulk Material.

F.3.b Haul Trucks transporting loads of Aggregate Materials shall not be required to cover their loads if the load, where it contacts the side, front, and back of the cargo container area remains six inches from the upper area of the container area, and if the load does not extend, at its peak, above any part of the upper edge of the cargo container area (As defined in Section 23114 of the California Vehicle Code for both public and private roads).

F.3.c The cargo compartment(s) of all Haul Trucks are to be constructed and maintained so that no spillage and loss of Bulk Material can occur from holes or other openings in the cargo compartment's floor, side, and/or tailgate. Seals on any openings used to empty the load including, but not limited to, bottom-dump release gates and tailgates to be properly maintained to prevent the loss of Bulk Material from those areas.

F.3.d The cargo compartment of all Haul Trucks is to be cleaned and/or washed at delivery site after removal of Bulk Material.

G. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of treatment or control measure, extent of coverage, and date applied. For control measures which require multiple daily applications, recording the frequency of application will fulfill the recordkeeping requirements of this rule (i.e., water being applied three times a day and the date) Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

H. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII.

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RULE 803 CARRY-OUT AND TRACK-OUT
(Adopted 11/08/2005)

A. Purpose

The purpose of this regulation is to reduce the amount of fine Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from Track-Out and Carry-Out by requiring actions to prevent, reduce, or mitigate PM-10 emissions.

B. Applicability

This rule applies to all sites that are subject to Regulation VIII where Track-Out or Carry-Out has occurred or may occur on paved public roads or the paved shoulders of a paved public road.

C. Definitions

The definitions of terms found in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM-10) shall apply to this rule.

D. Exemptions:

In addition to the exemptions listed in Rule 800, Section E, the following exemptions are established for this rule:

D.1 Agricultural Operation Sites defined in and subject to Rule 806, Conservation Management Practices, are exempt from the requirements specified in Sections F.1.b and F.1.c.

D.2 Any operation site that operates no more than 10 days within a 90 days period at each location is exempt from the requirements specified in Sections F.1.b and F.1.c.

E. Requirements

E.1 Track Out/Carry Out: any Person who causes the deposition of Bulk Material by tracking out or carrying out onto a Paved Road surface shall comply with the requirements of Section F.1, as specified, to prevent or mitigate such deposition.

F. Best Available Control Measures for Fugitive Dust (PM-10)

F.1 TRACK OUT/CARRY OUT:

F.1.a Clean up any Bulk Material tracked out or carried out onto a Paved

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Road on the following time-schedule:

(1) Within urban areas, immediately, when Track-Out or Carry-Out extends a cumulative distance of 50 linear feet or more; and

(2) At the end of the workday, for all other Track-Out or Carry-Out.

F.1.b In addition to F.1.a, all sites with access to a Paved Road and with 150 or more Average Vehicle Trips per Day, or 20 or more Average Vehicle Trips per Day by vehicles with three or more axles shall install one or more Track-Out Prevention Devices or other APCO approved Track-Out control device or wash down system at access points where unpaved traffic surfaces adjoin Paved Roads; or

F.1.c In addition to F.1.a, all sites with access to a Paved Road and with 150 or more Average Vehicle Trips per Day, or 20 or more Average Vehicle Trips per Day by vehicles with three or more axles shall apply and maintain paving, Chemical Stabilization, or at least 3 inch depth of Gravel (using Gravel or other low Silt (<5%) content material), for a distance of 50 or more consecutive feet at access points where Unpaved Roads adjoin Paved Roads.

G. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of treatment or control measure, extent of coverage, and date applied. Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

H. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII.

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RULE 804 OPEN AREAS

(Adopted 11/08/2005; Revised 10/16/2012; 04/12/2016)

A. Purpose

The purpose of this regulation is to reduce the amount of fine Particulate Matter (PM_{10}) entrained in the ambient air as a result of emissions generated from Open Areas by requiring actions to prevent, reduce, or mitigate PM_{10} emissions.

B. Applicability

This rule shall apply to any open area having 0.5 acres or more within urban areas, or 3.0 acres or more within rural areas; and contains at least 1000 square feet of disturbed surface area.

C. Definitions

The definition of terms found in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM_{10}) shall apply to this rule.

D. Exemptions

In addition to the exemptions listed in Rule 800, Section E, the following exemptions are established for this rule:

D.1 Agricultural Operation Sites subject to Rule 806, Conservation Management Practices.

D.2 Recreational OHV Use Areas on public lands subject to Rule 800, General Requirements for Control of Fine Particulate Matter (PM_{10}).

E. Requirements

E.1 Open Areas: all Persons who own or otherwise have jurisdiction over an Open Area shall comply with one or more of the requirements of Section F.1 to comply with the conditions of a Stabilized Surface at all times and limit VDE to 20% opacity.

E.2 Vehicle use in Open Areas: within 30 days following initial discovery of evidence of trespass, a Person who owns or otherwise has jurisdiction over an Open Area shall prevent unauthorized vehicle access by posting "No Trespassing" signs or installing physical barriers such as fences, gates, posts, and/or appropriate barriers to effectively prevent access to the area.

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F. Best Available Control Measures for Fugitive Dust (PM_{10})

F.1 OPEN AREAS

Any Combination of BACM and Alternative BACM is permissible.

F.1.a Apply and maintain water or dust suppressant(s) to all unvegetated areas.

F.1.b Establish vegetation on all previously disturbed areas.

F.1.c Pave, apply and maintain Gravel, or apply and maintain Chemical Stabilizers/Suppressants

F.1.d Implement Alternative BACM, approved in accordance with subdivision G.

G. Alternative BACM Approval Process

G.1 The APCD may approve Alternative BACM if:

G.1a Both a technical evaluation submitted to the APCD and APCD-witnessed field test(s) (number and nature of tests determined by APCO) demonstrate that the proposed Alternative BACM achieves PM_{10} emissions reductions equivalent to BACM measures identified at F.1.a, F.1.b, and F.1.c available for the applicable operation and that the dust control method will achieve a STABALIZED SURFACE and meet the 20% opacity requirement; and,

G.2 After the APCD has accepted the Alternative BACM, the proposed Alternative BACM will be submitted to EPA for its approval.

H. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of treatment or control measure, extent of coverage, and date applied. For control measures which require multiple daily applications, recording the frequency of application will fulfill the recordkeeping requirements of this rule (i.e., water being applied three times a day and the date) Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

I. Violations

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Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII.

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RULE 805 PAVED AND UNPAVED ROADS
(Adopted 11/08/2005; Revised 10/16/2012)

A. Purpose

The purpose of this regulation is to reduce the amount of fine Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from new or existing public or private Paved or Unpaved Road, road construction project, or road modification project by requiring actions to prevent, reduce, or mitigate PM-10 emissions.

B. Applicability

This rule applies to any new or existing public or private Paved or Unpaved Road, road construction project, or road modification project.

C. Definitions

The definition of terms found in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM-10) shall apply to this rule.

D. Exemptions

In addition to the exemptions listed in Rule 800, Section E, the following exemptions are established for this Rule:

D.1 Paved and unpaved driveways serving one single family residential dwelling.

D.2 Agricultural Operation Sites subject to Rule 806, Conservation Management Practices.

D.3 Recreational OHV Use Areas on public lands subject to Rule 800, General Requirements for Control of Fine Particulate Matter (PM-10).

E. Requirements

E.1 Unpaved Haul/Access Roads: No Person shall cause, suffer or allow the operation, use, or maintenance of any unpaved Haul/Access Road without complying with one or more of the requirements of Section F.1 so as to limit VDE to 20% opacity.

E.2 Unpaved Roads: On any Unpaved Road segment with 50 or more Average Vehicle Trips per Day, the owner/operator shall limit VDE to 20% opacity, as determined by the test methods for “Visual Determination of Opacity” in Rule 800, Appendix A, and comply with the requirements of a

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Stabilized Unpaved Road by application and/or maintenance of at least one of the requirements of Section F.1.

E.3 The construction of any new Unpaved Road is prohibited within any area with a population of 500 or more unless the road meets the definition of a Temporary Unpaved Road. The Temporary Unpaved Road shall meet the definition of a Stabilized Unpaved Road as determined by the test methods in Rule 800, Appendix B, Section C, and where VDE is limited to 20% opacity.

E.4 Canal Roads: all Persons who cause, suffer or allow the operation, use or maintenance of any Canal Road with 20 or more Average Vehicle Trips per Day shall comply with one or more of the requirements of Section F.1 to comply with the requirements of a Stabilized Unpaved Road and limit VDE to 20% opacity, as determined by the test methods in Rule 800, Appendix A, and shall also comply with one or more of the requirements of Section F.2.

E.5 Unpaved Traffic Areas: All Persons who cause, suffer or allow the operation, use or maintenance of any Unpaved Traffic Area larger than one (1) acre and with 75 or more Average Vehicle Trips per Day shall comply with one or more of the requirements of Section F.3 and limit VDE to 20% opacity.

E.6 Paved Roads: any new or Modified Paved Roads shall comply with the requirements of section F.4.

E.7 Requirements for Existing Unpaved Public Roads in City and Rural Areas:

Each city or county agency with primary responsibility for any existing Unpaved Road shall take the following actions:

E.7.a By January 1, 2006 provide the APCD with a list of all Unpaved Roads under its jurisdiction in any city or Rural area(s), including data on length of, and Average Vehicle Trips per Day on, each Unpaved Road segment.

E.7.b By March 31, 2006 the County Public Works Department shall provide the APCD and comply with a compliance plan. The compliance plan shall include a compliance schedule indicating that during the period 2006 through 2015 a 10% per each fiscal year, beginning July 1 and ending June 30, of all Unpaved Roads subject to the requirements of this rule will comply with a 20% VDE and comply with the requirements of a Stabilized Unpaved Road (Treatment in excess of the annual requirement can be credited toward future year requirements). The plan shall identify the control

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measures implemented or that will be implemented at each Unpaved Road segment with 50 or more Average Vehicle Trips per Day. The plan shall clarify that the 10% stabilized each year differ from the roads previously stabilized so that 100% of roads are stabilized by 2015.

E.7.c By July 31 of each year, 2007 through 2016, the County Public Works Department shall submit to the APCD the total number of Unpaved Road miles which were mitigated during the previous fiscal year, a list of the specific mitigated roads, and the percentage of cumulative miles relative to the schedule provided pursuant to Section E.7.b. Once stabilized pursuant to Section E.7, Public Roads must comply with the requirements of a Stabilized Unpaved Road by application and/or maintenance of at least one of the requirements of Section F.1.

F. Best Available Control Measures for Fugitive Dust (PM-10)

F.1 UNPAVED ROADS, INCLUDING UNPAVED HAUL AND ACCESS ROADS:

F.1.a Pave.

F.1.b Apply Chemical Stabilization as directed by product manufacturer to control dust on Unpaved Roads.

F.1.c Apply and maintain Gravel, recrushed/recycled asphalt or other material of low Silt (<5%) content to a depth of three or more inches.

F.1.d Wetting. Apply water one or more times daily

F.1.e Permanent road closure

F.1.f Restrict unauthorized vehicle access.

F.1.g Any other method that effectively limits VDE to 20% opacity and meets the conditions of a Stabilized Unpaved Road.

F.2 CANAL ROADS:

F.2.a Stocking of Triploid Grass Carp in canals to reduce maintenance vehicle trips along Canal Banks to mechanically remove aquatic weeds.

F.2.b Installation of remote control delivery gates to eliminate manual

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gate operation by maintenance personnel in vehicles along Canal Banks.

F.2.c Implement Silt removal program to delay grading of spoil piles deposited on Canal Bank after cleaning operations until the next cleaning operation to eliminate vehicle access to Canal Bank.

F.2.d Permanent road closure.

F.2.e Conversion of open canals to pipeline.

F.2.f Lining canals to eliminate maintenance for Silt/weed control.

F.2.g Canal Bank surface maintenance.

F.3 UNPAVED TRAFFIC AREAS:

F.3.a Pave.

F.3.b Apply Chemical Stabilization as directed by product manufacturer to control dust on Unpaved Roads.

F.3.c Apply and maintain Gravel, recrushed/recycled asphalt or other material of low silt (<5%) content to a depth of three or more inches.

F.3.d Wetting. Apply water one or more times daily.

F.4 NEW OR MODIFIED PAVED ROADS

Any Person having jurisdiction over, or ownership of, public or private Paved Roads shall construct, or require to be constructed, all new or Modified Paved Roads in conformance with the Imperial County Public Works Department guidelines for width of shoulders and median shoulders as specified below:

F.4.a New arterial roads or streets or modifications to existing arterial roads or streets shall be constructed with paved shoulders that meet following widths:

Annual Average Daily Vehicle Trips	Minimum Paved or Stabilized Shoulder Width in Feet
1-2000	2
Greater than 2000	6

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F.4.b New or modified collector roads or streets or local roads or streets shall be constructed with paved shoulders that meet following widths:

Annual Average Daily Vehicle Trips	Minimum Paved or Stabilized Shoulder Width in Feet
1-2000	2
Greater than 2000	4

F.4.c A curbing adjacent to and contiguous with the travel lane or paved shoulder or a road may be constructed, in lieu of meeting the paved shoulder width standard listed in Sections F.4.a and F.4.b. Any road paving projects constructing curbing in County road right of ways shall be approved by the Director of Public Works Department prior to construction.

F.4.d Intersections, auxiliary entry lanes, and auxiliary exit lanes may be constructed adjacent to and contiguous with the roadway, in lieu of meeting the paved shoulder width standard in Sections F.4.a and F.4.b.

F.4.e New Paved Road construction or modifications to an existing Paved Road that are required to comply with California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) determinations regarding environmental, cultural, archeological, historical, or other considerations addressed in such documents, are exempt from the paved shoulder width requirements specified in Section F.4.a.

F.4.f Whenever any Paved Road which has projected Annual Average Daily Vehicle Trips of 500 or more is constructed, or modified with medians, the medians shall be constructed with paved shoulders having a minimum width of four feet adjacent to the traffic lanes unless:

F.4.f.1 The medians of roads having speed limits set at or below 45 miles per hour are constructed with curbing; or

F.4.f.2 The medians are landscaped and maintained with grass or other vegetative ground cover to comply with the definition of Stabilized Surface.

F.4.g In lieu of complying with the paving or vegetation requirements a Person may apply oils or other Chemical Stabilizers/Suppressants to the required width of shoulder and median areas as specified in

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Sections F.4.a and F.4.b. The material shall be reapplied and maintained to limit VDE to 20% opacity and fulfill conditions for a Stabilized Surface.

G. Record of Control Implementation

Any Person subject to the requirements of this rule shall compile and retain records that provide evidence of control measure application (i.e., receipts and/or purchase records). Such Person shall describe, in the records, the type of treatment or control measure, extent of coverage, and date applied. For control measures which require multiple daily applications, recording the frequency of application will fulfill the recordkeeping requirements of this rule (i.e., water being applied three times a day and the date) Records shall be maintained and be readily accessible for two years after the date of each entry and shall be provided to the APCD upon request.

H. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII.

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RULE 806 CONSERVATION MANAGEMENT PRACTICES
(Adopted 11/08/2005; Revised 10/16/2012)

A. Purpose

The purpose of this regulation is to reduce the amount of coarse Particulate Matter (PM-10) entrained in the ambient air as a result of emissions generated from Agricultural Operation Sites by requiring Conservation Management Practices to prevent, reduce, or mitigate PM-10 emissions.

B. Applicability

This rule applies to Agricultural Operation Sites located within Imperial County. Effective on and after January 1, 2013, an owner/operator shall implement the applicable CMPs selected for each Agricultural Operation Site. The provisions of this rule adopted on November 8, 2005 shall remain in effect until January 1, 2013 at which time the amendments adopted on October 16, 2012 shall take effect.

C. Definitions

In addition to the definitions of terms in Rule 800 (General Requirements for Control of Fine Particulate Matter (PM-10), the following definitions shall govern the implementation of this rule:

C.1 AGRICULTURAL OPERATIONS: The growing and harvesting of crops for the primary purpose of earning a living.

C.2 AGRICULTURAL OPERATION SITE: One or more agricultural parcels that meet the following:

C.2.a Are under the same or common ownership or operation, or which are owned or operated by entities which are under common control; and

C.2.b Are located on one or more contiguous or adjacent properties wholly within Imperial County.

C.3 AGRICULTURAL PARCEL: A portion of real property used by an owner or operator for carrying out a specific agricultural operation. Roads, vehicle/equipment traffic areas, and facilities, on or adjacent to the cropland are part of the agricultural parcel.

C.4 ALTERNATIVE TILLING: Till alternative rows for weed management, reducing approximately 50% of field activity related to tilling, in addition to stabilizing soil surface and reducing soil compaction.

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C.5 APPLICATION EFFICIENCIES: Use more efficient application equipment so as to reduce a minimum of one ground operation. Examples include: compact or low volume spray equipment; aerial applications; micro-heads or infrared spot sprayers; electrostatic sprayers. Reduces soil compaction, passes and chemical usage.

C.6 BALING/LARGE BALES: Reduce a minimum of one pass through the field per acre by using large balers to harvest crops.

C.7 BED/ROW SIZE OR SPACING: Reduce a minimum of one tillage operation by Increasing or decreasing the size of the planting bed area (can be done for field and permanent crops) or adjusting spacing. Spacing adjustments reduce the number of passes and soil disturbance by increasing plant density/canopy through reduction of row width to contain PM within the canopy.

C.8 BULK MATERIALS CONTROL: Minimize visible dust emissions from bulk materials by using dust suppressant or water to form a stabilized surface, or using a tarp to fully cover the pile or truckbed, or using a wind barrier or 3-sided structure to reduce entrainment of fugitive dust.

C.9 CHEMIGATION/FERTIGATION: Reduce a minimum of one ground operation by applying chemicals through an irrigation system. This reduces the need to travel in the field for application purposes, thus reducing operations and soil disturbance while increasing the efficiency of the application.

C.10 CHIPS/MULCHES, ORGANIC MATERIALS, POLYMERS, ROAD OIL & SAND: Application of any nontoxic chemical or organic dust suppressant that meets all specification required by any federal, state, or local water agency and is not prohibited for use by any applicable regulations. Chips/Mulches and organic materials should meet the specifications in the mulches definition below. Polymers, road oil and sand should create a stabilized surface during high traffic times such as harvest.

C.11 COMBINED OPERATION: Combine equipment to perform several operations during one pass, thereby reducing a minimum of one tillage operation. Examples include: use of one-pass till equipment in ground preparation or crop tillage; and cultivation and fertilization of a field crop in a single pass. Other benefits are reduction of soil compaction and time to prepare fields, both of which can be precursors to additional tillage requirements. If a combined operation is accomplished through equipment change/technological improvement, that action is considered one CMP, and either Equipment Changes/Technological Improvements CMP or Combined Operations CMP may be selected in a CMP Plan, but not both.

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C.12 CONSERVATION IRRIGATION: Reduce a minimum of one tillage operation related to weeding by conserving the amount of water used by using either drip, sprinkler, or buried/underground line irrigation. Conserving water reduces weed population, which in turn reduces the need for tillage and reduces soil compaction.

C.13 CONSERVATION MANAGEMENT PRACTICE (CMP): An activity or procedure that prevents, reduces, or mitigates PM-10 normally emitted by, or associated with, an agricultural activity.

C.14 CONSERVATION MANAGEMENT PRACTICES PLAN (CMP PLAN): A document prepared by the owner or operator of an Agricultural Operation site that lists the selected CMPs for implementation. The CMP Plan also contains, but is not limited to, contact information for the owner or operator, a description of the Agricultural Operation Site and locations of Agricultural Parcels, and other information describing the extent and duration of CMP implementation.

C.15 CONSERVATION TILLAGE (e.g.: no tillage, minimum tillage): A tillage system that reduces a minimum of three tillage operations. This system reduces soil and water loss by reducing the number of passes and by leaving crop residue on the field after harvest as well as managing the residue so that it remains intact during the planting season. It reduces the number of passes and amount of soil disturbance. It improves soil because it retains plant residue and increases organic matter.

C.16 COVER CROPS: Establish cover crops that maintain a minimum of 60 percent ground cover, as determined by the Line Transect Test Method. Native or volunteer vegetation that meets the minimum ground cover requirement is acceptable.

C.17 CROP RESIDUE MANAGEMENT: Maintain crop residue from previous crops until tilling for the next crop. Crop residues must maintain a minimum of 60 percent ground cover as determined by Line Transect Test Method. Implements such as undercuters or sweeps can maintain crop residues without burying or destroying residues.

C.18 CROPLAND - OTHER: This CMP category includes CMPs to reduce windblown emissions.

C.19 CROSS WIND STRIPCROPING: Establish crops in parallel strips across the prevailing wind erosion direction and arranged so that strips susceptible to wind erosion are alternated with strips having a protective cover that is resistant to wind erosion. The strips with the protective cover should be at least as wide as the strips susceptible to wind erosion.

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C.20 EQUIPMENT CHANGES/TECHNOLOGICAL IMPROVEMENTS: Reduce a minimum of one tillage operation by modifying equipment or making technological improvements. Examples include flame cultivation or equipment that combines discing, chiseling and ring rolling. If an equipment change/technological improvement is made in order to combine operations, that action is considered one CMP; either Equipment Changes/Technological Improvements CMP or Combined Operations CMP may be selected in the CMP plan, but not both.

C.21 FALLOW LAND: Temporary or permanent removal from production. Eliminates entire operation/passes or reduces activities.

C.22 FIELD WINDBREAKS: Plant or maintain a single or multiple row of trees or shrubs adjacent to windward edge of the field as close to perpendicular as practical with the direction of erosive winds. Windbreaks such as trees or shrubs should be established at a right angle to the prevailing wind direction. Sites downwind of the windbreak are considered protected if they fall within an area that is less than or equal to 10 times the height of the windbreak. The windbreak should have a porosity of 50 %.

C.23 GRAVEL: Placing a layer of Gravel at least 3 inches in depth to minimize dust generated from vehicle movement and to dislodge any excess debris which can become entrained. Gravel should conform to the grading defined in Rule 800.

C.24 GREEN CHOP: Reduce a minimum of one ground operation by harvesting a forage crop without allowing it to dry in the field. This practice reduces soil disturbance and soil compaction.

C.25 GRINDING/CHIPPING/SHREDDING: Grinding pruning's and orchard removals instead of burning; incorporate to soil. Reduces PM from burning crop residues.

C.26 GROUND OPERATION: An agricultural operation that is not a tillage operation that involves equipment passing across the field, such as a chemical spray application. A pass through the field may be a subset of a ground operation.

C.27 HAND HARVESTING: Reduce a minimum of one ground operation by harvesting a crop by hand. It reduces soil disturbance due to machinery passes.

C.28 INTEGRATED PEST MANAGEMENT: Reduce a minimum of one ground operation by using a combination of techniques including organic, conventional and biological farming concepts to suppress pest problems.

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It creates beneficial insect habitat that reduces the use of herbicides/pesticides thereby reducing number of passes for spraying. It also reduces soil compaction and the need for additional tillage. If integrated pest management CMP uses the same practices described in the Organic Practices CMP, this action is considered one CMP, and either Integrated Pest Management CMP or Organic Practices CMP may be selected in a CMP plan, but not both.

C.29 IRRIGATION POWER UNITS: Use cleaner burning engines, electric motors (CMP only applicable if engines are cleaner than otherwise required by current local, state and federal requirements).

C.30 MULCHING: Reducing PM10 emissions and wind erosion and preserving soil moisture by uniformly applying a protective layer of plant residue or other material to a soil surface prior to disturbing the site to reduce soil movement. Mulching material shall be evenly applied, and if necessary, anchored to the soil. Mulch should achieve a minimum 70% cover, and a minimum of 2 inch height above the surface. Inorganic material used for mulching should consist of pieces of .75 to 2 inches in diameter.

C.31 NIGHT FARMING: Operate at night when moisture levels are higher and winds are lighter. It decreases the concentration of PM emissions during daytime and the increased ambient humidity reduces PM emissions during the night. Night farming should take place between sundown and sunrise.

C.32 NIGHT HARVESTING: Implementing harvesting practices at night when moisture levels are higher and winds are lighter. It reduces PM by operating when ambient air is moist, thereby reducing PM emissions. Night harvesting should take place between sundown and sunrise.

C.33 NO BURNING: Switching to a crop/system that would not require waste burning. It reduces emissions associated with burning.

C.34 NON TILLAGE/CHEMICAL TILLAGE: Reduce a minimum of one tillage operation by, for example, using a flail mower or low volume sprayers. It reduces soil compaction and stabilizes soil.

C.35 ORGANIC PRACTICES: Reduce a minimum of one ground or tillage operation by using biological control methods or non-chemical control methods. Examples include: organic certification, biological controls, mulches and humus. If an organic practice CMP uses the same practice as described in the integrated pest management CMP, this action is considered one CMP, and either Organic Practices CMP or Integrated Pest Management CMP may be selected in a CMP plan, but not both.

C.36 PAVING: To pave currently Unpaved Roads.

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C.37 PERMANENT CROPS: Having an established permanent crop that is not replanted annually.

C.38 PRECISION FARMING (GPS): Reduce a minimum of one pass through the field per acre by using satellite navigation to calculate position in the field, therefore manage/treat the selective area. It reduces overlap and allows operations to occur during inclement weather conditions and at night thereby generating less PM.

C.39 PRE-HARVEST SOIL PREPARATION: Applying a water or stabilizing material to soil prior to harvest to form a visible crust. It reduces PM emissions at harvest.

C.40 REDUCED PRUNING: Reduce a minimum of one ground operation by reducing the frequency of pruning (e.g. one time per year, or every other year).

C.41 RESTRICTED ACCESS: To restrict or eliminate public access to unpaved private roads with signs or physical obstructions. At each access point, install signs or physical barriers such as gates, fencing, posts, signs, shrubs, trees that block or effectively control access to the area. It reduces vehicle traffic and thus reduces associated fugitive dust.

C.42 RIDGE ROUGHNESS: Establish stabilized ridges by normal tillage and planting equipment as close to perpendicular as practical with the direction of erosive winds (not appropriate for unstable soils such as sands or loamy sands). After establishment, ridges shall be maintained through those periods when wind erosion is expected to occur, or until growing crops provide enough cover to protect the soil from wind erosion. Ridge spacing should be no greater than 4 times the ridge height.

C.43 ROAD MIX: A mixture of tank bottoms from crude oil storage tanks, material from crude oil spills, or other crude-oil-containing soil mixed with aggregates and soils, that are used as a base cover materials for roads, parking lots, berms, tank and well locations, or similar applications.

C.44 SHED PACKING: Reducing a minimum of one pass through the field per acre by packing commodities in a covered or closed area, rather than field-pack. It reduces field traffic, thereby reducing PM emissions.

C.45 SHUTTLE SYSTEM/LARGE CARRIER: Reduce a minimum of one pass through the field per acre by hauling multiple or larger trailers/bins per trip.

C.46 SOIL AMENDMENTS: Organic or chemical materials uniformly applied to the soil for improvement (e.g: gypsum, lime, polyacrylamide).

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C.47 SPEED LIMITS: Control speed limits to 15 mph on unpaved roads through worker behavior modifications, signage, or any other necessary means.

C.48 SULFUR REDUCTION OR ELIMINATION: Reduce a minimum of one ground operation by reducing or eliminating sulfur dusting, an organic chemical used to control disease in crop, ornamental and home and gardens.

C.49 SURFACE ROUGHENING: Produce and maintain stable clods or aggregates on the land surface by bedding, rough disking, or tillage that leaves the surface covered by stable clods. Soil clods prevent wind erosion because they resist the forces of the wind and because they shelter other erodible materials. This CMP should be implemented consistent with NRCS Code 609 – Surface Roughening.

C.50 TILLAGE OPERATION: An agricultural operation that mechanically manipulates the soil for the enhancement of crop production. Examples include discing, weeding, or bedding. A pass through the field may be a subset of a tillage operation.

C.51 TRACK-OUT CONTROL: Minimize any and all material that adheres to and agglomerates on all vehicle and equipment from unpaved roads and falls onto a paved public road or the paved shoulder of a paved public road. Install one of the following devices: a grizzly, a gravel pad or a wheelwash system at all intersections of unpaved roads and public roads.

C.52 TRANSGENIC CROPS: Use of GMO or Transgenic crops such as “herbicide-ready” to reduce a minimum of one tillage operation. It reduces the need for tillage or cultivation operations, as well as reduces soil disturbance. It can also reduce the number of chemical applications.

C.53 WATER APPLICATION: Application of water to unpaved roads and traffic areas to create a visibly moist surface.

C.54 WIND BARRIER: Reduce wind erosion by planting or maintaining perennial or annual plants established in rows or narrow strips interspersed throughout a crop field as close to perpendicular as practical with the direction of erosive winds. To be effective, the selected plant(s) must create a stand at least three feet tall, with a porosity of 50%.

D. Requirements for Agricultural Operation Sites:

D.1 All Persons who own or operate an Agricultural Operation Site of forty (40) acres or more in size shall implement in each Agricultural Parcel at least one of the Conservation Management Practices from each of D.1.a through D.1.f. unless they implement the Conservation Tillage CMP. On

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acres implementing the Conservation Tillage CMP, persons do not need to select additional measures for D.1.a, D.1.b or D.1.e, but do need to implement at least one CMP each from D.1.c, D.1.d and D.1.f. Persons may choose the same CMP for D.1.c and D.1.d since they apply to different land, but must choose a unique and individual CMP for each of D.1.a, D.1.b, D.1.e and D.1.f (unless using Conservation Tillage CMP) since they apply to the same land.

D.1.a Land preparation and cultivation, CMPs in Section E.1;

D.1.b Harvest activities, CMPs in section E.2;

D.1.c Unpaved Roads, CMPs in Section E.3;

D.1.d Unpaved Traffic Areas, CMPs in Section E.4;

D.1.e Cropland-Other CMPs, in Section E.5; and

D.1.f Windblown Dust Control CMPs in Section E.6.

D.2 Agricultural unpaved roads with greater than fifty (50) or more vehicle daily trips (VDT), or twenty (20) or more VDT with three (3) or more axle vehicles, must meet the stabilization and opacity requirements in Section E.3.

D.3 Agricultural unpaved equipment or traffic areas with fifty (50) or more VDT, or twenty (20) or more VDT with 3 or more axle vehicles, must meet the stabilization and opacity requirements in Section E.4.

D.4 The owner or operator of an Agricultural Operation Site may implement more than one Conservation Management Practices for one or more of the categories.

D.5 The owner or operator of an Agricultural Operation Site shall ensure that the implementation of each selected Conservation Management Practices does not violate any other local, state, or federal law.

D.6 The owner or operator of an Agricultural Operation Site may develop alternative CMPs. The owner or operator shall submit to the APCD a technical evaluation of the alternative CMPs, demonstrating that the alternative CMP achieves PM-10 emission reductions that are at least equivalent to the most effective CMPs available for the applicable operation (e.g., by eliminated equivalent passes or operations). The APCD will review the technical evaluation, and the alternative CMP must receive approval by the APCD before being included in the CMP Plan.

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D.7 The owner or operator shall prepare a CMP Plan for each Agricultural Operation Site. The CMP Plan shall be made available to the APCD upon request. The CMP Plan shall be provided to the APCD within 72 hours of notice to the owner or operator.

E. Conservation Management Practices for Fugitive Dust (PM-10)

E.1 The owner or operator of an Agricultural Operation Site shall implement at least one of the following CMPs in each Agricultural Parcel to reduce PM10 emissions from land preparation and cultivation (CMP Category D.1.a). If the owner or operator selects “Fallow Land” as its CMP, the owner/operator must comply with section E.6 of this rule.

E.1.a Alternative Tilling,
E.1.b Bed/Row Size Spacing,
E.1.c Chemigation/Fertigation,
E.1.d Combined Operations,
E.1.e Conservation Irrigation,
E.1.f Cover Crops,
E.1.g Equipment Changes/Technological Improvements,
E.1.h Fallow Land,
E.1.i Integrated Pest Control,
E.1.j Mulching,
E.1.k Night Farming,
E.1.l Non Tillage /Chemical Tillage,
E.1.m Organic Pesticides,
E.1.n Precision Farming (GPS), or
E.1.o Transgenic Crops

E.2 The owner or operator of an Agricultural Operation Site shall implement at least one of the following CMPs in each Agricultural Parcel to reduce PM10 emissions from harvest activities (CMP Category D.1.b). If the owner or operator selects “Fallow Land” as its CMP, the owner/operator must comply with Section E.6 of this rule.

E.2.a Baling /Large Bales
E.2.b Combined Operations
E.2.c Equipment Changes/Technological Improvements
E.2.d Green Chop
E.2.e Hand Harvesting
E.2.f Fallow Land
E.2.g Night Harvesting
E.2.h No Burning
E.2.i Pre-Harvesting Soil Preparation
E.2.j Shed Packing
E.2.k Shuttle System/Large Carrier

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E.3 The owner or operator of an Agricultural Operation Site shall implement at least one of the following CMPs for each unpaved road (CMP Category D.1.c) to reduce PM10 emissions at all times:

E.3.a Chips/Mulches, Organic Materials, polymers, road oil and sand,
E.3.b Gravel
E.3.c Paving,
E.3.d Restricted access
E.3.e Speed limit
E.3.f Track-out control
E.3.g Water Application
E.3.h Field windbreak

On each day that high traffic accounts for 50 or more vehicle daily trips (VDT), or 20 or more VDT with 3 or more axles, on an unpaved road segment, the owner/operator of an Agricultural Operation Site shall comply with the requirements of a stabilized unpaved road and limit VDE to 20% opacity by implementing or maintaining one or more of the following CMPs:

E.3.i Pave.
E.3.j Apply Chemical Stabilization as directed by product manufacturer to control dust on Unpaved Roads.
E.3.k Apply and maintain Gravel, recrushed/recycled asphalt or other material of low Silt (<5%) content to a depth of three or more inches.
E.3.l Water Application.
E.3.m Permanent road closure.
E.3.n Restrict unauthorized vehicle access.

E.4 The owner or operator of an agricultural operation site shall implement at least one of the following CMPs for each unpaved traffic area (CMP Category D.1.d) to reduce PM10 emissions at all times:

E.4.a Chips/Mulches, Organic Materials, Polymers, Road Oil and Sand,
E.4.b Gravel
E.4.c Paving
E.4.d Restricted Access
E.4.e Speed Limit
E.4.f Track-Out Control
E.4.g Water Application
E.4.h Field windbreak

On each day that high traffic accounts for 50 or more vehicle daily trips (VDT), or 20 or more VDT with 3 or more axles, on an Unpaved Traffic

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Area larger than one (1) acre, the owner/operator of an Agricultural Operation Site shall comply with the requirements of a stabilized unpaved road and limit VDE to 20% opacity by implementing or maintaining one or more of the following CMPs:

E.4.i Pave.
E.4.j Apply Chemical Stabilization as directed by product manufacturer to control dust on Unpaved Roads.
E.4.k Apply and maintain Gravel, recrushed/recycled asphalt or other material of low Silt (<5%) content to a depth of three or more inches.
E.4.l Water Application.

E.5 The owner or operator of an Agricultural Operation Site shall implement at least one of the following CMPs in each Agricultural Parcel to reduce PM10 emissions from cropland-others (Category D.1.e). If the owner or operator selects “Fallow Land” as its CMP, the owner/operator must comply with Section E.6 of this rule.

E.5.a Alternate Tilling
E.5.b Application Efficiencies
E.5.c Bailing/Large Bales
E.5.d Bulk Materials Control
E.5.e Chemigation/Fertigation
E.5.f Conservation Irrigation
E.5.g Fallow Land
E.5.h Grinding/Chipping/Shredding
E.5.i Integrated Pest Management
E.5.j Irrigation Power Units
E.5.k Mulching
E.5.l Night Farming
E.5.m No Burning
E.5.n Non Tillage/Chemical Tillage
E.5.o Organic Practices
E.5.p Permanent Crops
E.5.q Reduced Pruning
E.5.r Soil Amendments
E.5.s Soil Incorporation
E.5.t Sulfur: Reduction or Elimination of Dusting
E.5.u Surface Roughening
E.5.v Transgenic Crops
E.5.w Wind Barrier

E.6 For windblown dust control (CMP Category D.1.f), the owner or operator of an agricultural operation site shall implement E.6.1. In addition to following E.6.1, if the owner or operator of an Agricultural Operation Site

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has fields that are in between crops or more permanently fallow, the owner or operator shall implement at least one of the CMPs in E.6.2.

E.6.1 When preparing a field for planting, minimize the time that newly tilled soil is smooth and dry by leaving the field surface with large clods for as long as possible and bedding and planting the field as soon as possible once it no longer has large clods.

E.6.2 For fields that are in between crops or are permanently fallow, the owner shall implement at least one of the CMPs below:

E.6.2a Cover Crop
E.6.2b Conservation Tillage
E.6.2c Crop Residue Management
E.6.2d Cross Wind Stripcropping
E.6.2e Field Windbreaks
E.6.2f Ridge Roughness
E.6.2g Surface Roughening
E.6.2h Wind Barrier

F. CMP Plan Preparation

An owner or operator shall prepare a CMP Plan for each Agricultural Operation Site. An owner or operator must maintain a CMP Plan that corresponds to the current crops being grown in the field and the corresponding CMPs for those crops. Each CMP Plan shall include, but is not limited to, the following information:

F.1 The name, business address, and telephone number of the owner or operator responsible for the preparation and implementation of the CMP Plan.

F.2 The signature of the owner or operator and the date that the CPM Plan was signed.

F.3 The location of the Agricultural Operation Site: cross roads; canal and gate number.

F.4 The crop grown at each location covered by the CMP Plan, total acreage for each crop, the length (miles) of unpaved roads, and the total area (acres or square feet) of the unpaved equipment and traffic areas to be covered by the CMP Plan

F.5 The CMPs being implemented for each crop, unpaved road, unpaved equipment and traffic area, and windblown dust control. The CMPs implemented should be described to verify that implementation is

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consistent with the CMP definitions in this rule.

F.6 Other relevant information as determined by the APCD.

G. Violations

Failure to comply with any provisions of this rule shall constitute a violation of Regulation VIII. Failure to comply with the provisions of a CMP Plan shall also constitute a violation of Regulation VIII.

H. Record of Control Implementation

Any Person subject to the requirements of this rule shall maintain a copy of the CMP Plan and any supporting documentation necessary to confirm implementation of the CMPs. An owner or operator implementing alterative CMPs shall maintain a copy of technical evaluation for alternative CMPs and documentation of APCD approval of alternative CMPs. Records shall be maintained for two years after the date of each entry and shall be provided to the APCD upon request.

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Appendix G
Emission Inventory Documentation

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Appendix G. Emissions Inventory Documentation for the Imperial County PM_{10} Nonattainment Area Maintenance Plan

Emissions inventories are one of the fundamental building blocks in the development of a State Implementation Plan (SIP or Plan). In simple terms, an emissions inventory is a systematic listing of the sources of air pollution along with the amount of pollution emitted from each source or category over a given time period. This document describes the emissions inventory included in the Plan for the Imperial County PM_{10} Nonattainment Area.

The California Air Resources Board (CARB) and Imperial County Air Pollution Control District (District) have developed a comprehensive, accurate, and current emissions inventory consistent with the requirements set forth in Section 182(a)(1) of the federal Clean Air Act. CARB and District staff conducted a thorough review of the inventory to ensure that the emission estimates reflect accurate emission reports for point sources, and that estimates for mobile and areawide sources are based on the most recent models and methodologies.

CARB also reviewed the growth profiles for point and areawide source categories and updated them as necessary to ensure that the emission projections are based on data that reflect historical trends, current conditions, and recent economic and demographic forecasts. Growth forecasts for most point and areawide sources were developed either by CARB or by the Southern California Association of Governments (SCAG) and provided to CARB through the South Coast Air Quality Management District. SCAG is the metropolitan planning organization representing Imperial County, along with five other counties in Southern California.

Emissions Inventory Overview

Emissions inventories are estimates of the amount and type of pollutants emitted into the atmosphere by industrial facilities, mobile sources, and areawide sources such as consumer products and paint. They are fundamental components of an air quality plan, and serve critical functions such as:

1) the primary input to air quality modeling used in attainment demonstrations;
2) the emissions data used for developing control strategies; and
3) a means to track progress in meeting emission reduction commitments.

The United States Environmental Protection Agency (U.S. EPA) regulations require that the emissions inventory for a PM_{10} SIP contain emissions data for directly emitted PM_{10} and its precursors: oxides of nitrogen (NOx), sulfur oxides (SOx), volatile organic compounds (VOC), and ammonia (NH_3). The inventory included in this plan substitutes VOC with reactive organic gases (ROG), which in general represent a slightly broader group of compounds than those in U.S. EPA's list of VOCs. Although precursor emissions are included in this Plan, elevated PM_{10} concentrations in Imperial County are dominated by primary PM_{10} emissions from wind-blown dust rather than by

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secondarily formed PM_{10}. The precursor contribution analysis in Appendix A demonstrates that secondary formation is negligible compared with directly emitted PM_{10}.

Agency Responsibilities

CARB and District staff worked jointly to develop the emissions inventory for Imperial County. The District worked closely with operators of major stationary facilities in their jurisdiction to develop the point source emission estimates. CARB staff developed the emission inventory for mobile sources, both on-road and off-road. The District and CARB shared responsibility for developing estimates for the nonpoint (areawide) sources such as paved road dust and agricultural burning. CARB worked with several State and local agencies such as the Department of Transportation (Caltrans), the Department of Motor Vehicles (DMV), the Department of Pesticide Regulation (DPR), and the California Energy Commission (CEC) to assemble activity information necessary to develop the mobile and areawide source emission estimates.

Inventory Base Year

The base year inventory forms the basis for all future year projections and also establishes the emission levels against which progress in emission reductions will be measured. U.S. EPA regulations establish that the base year inventory should be preferably consistent with the triennial reporting schedule required under the Air Emissions Reporting Requirements (AERR) rule. However, U.S. EPA allows a different year to be selected if justified by the state. CARB worked with the local air districts to determine the base year that should be used across the State. Since the South Coast Air Quality Management District typically aligns their base year inventory with the data collection period for their Multiple Air Toxics Exposure Study, which was last conducted in 2012, CARB selected 2012 as the base year to maintain consistency across the various plans being developed in the State. A 2016 inventory was forecasted from this 2012 base year inventory. This coincides with the Plan's attainment year of 2016.

Forecasted Inventories

In addition to a base year inventory, U.S. EPA regulations also require future year inventory projections for specific years. Forecasted inventories are a projection of the base year inventory that reflects expected growth trends for each source category and emission reductions due to adopted control measures. CARB develops emission forecasts by applying growth and control profiles to the base year inventory.

Growth profiles for point and areawide sources are derived from surrogates such as economic activity, fuel usage, population, housing units, etc., that best reflect the expected growth trends for each specific source category. Growth projections were obtained primarily from government entities with expertise in developing forecasts for specific sectors, or in some cases, from econometric models. Control profiles, which account for emission reductions resulting from adopted rules and regulations, are

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derived from data provided by the regulatory agencies responsible for the affected emission categories.

Projections for mobile source emissions are generated by models that predict activity rates and vehicle fleet turnover by vehicle model year. As with stationary sources, the mobile source models include control algorithms that account for all adopted regulatory actions. This Plan includes forecasted emissions inventories for 2018-2030, which encompasses the maintenance period.

Temporal Resolution

Planning inventories typically include annual as well as seasonal (summer and winter) emission estimates. Annual emission inventories represent the total emissions over an entire year (tons per year), or the daily emissions produced on an average day (tons per day). Seasonal inventories account for temporal activity variations throughout the year, as determined by category-specific temporal profiles. The emission inventory used in the Plan is an annual inventory.

Quality Assurance and Quality Control

CARB has established a quality assurance and quality control (QA/QC) process involving CARB and District staff to ensure the integrity and accuracy of the emissions inventories used in the development of air quality plans. QA/QC occurs at the various stages of SIP emission inventory development. Base year emissions are assembled and maintained in the California Emission Inventory Development and Reporting System (CEIDARS). CARB inventory staff works with District staff, who are responsible for developing and reporting point source emission estimates, to verify these data are accurate. The locations of point sources, including stacks, are checked to ensure they are valid. Areawide source emission estimates are reviewed by CARB and District staff before their inclusion in the emission inventory. Additionally, CEIDARS is designed with automatic system checks to prevent errors such as double counting of emission sources. The system also makes various reports available to assist staff in their efforts to identify and reconcile anomalous emissions.

Future year emissions are estimated using the California Emission Projection Analysis Model (CEPAM), 2016 SIP Baseline Emission Projections, Version 1.05. Growth and control factors are reviewed for each category and year along with the resulting emission projections. Year to year trends are compared to similar and past datasets to ensure general consistency. Emissions for specific categories are checked to confirm they reflect the anticipated effects of applicable control measures. Mobile categories are verified with mobile source staff for consistency with the on-road and off-road emission models.

A summary of the information supporting the Imperial PM_{10} Nonattainment Area Maintenance Plan emissions inventory is presented in the sections below.

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Point Sources

The inventory reflects actual emissions from industrial point sources reported to the District by the facility operators through calendar year 2012, in accordance with the requirements set forth in U.S. EPA's AERR rule. The data elements in the 2012 baseline inventory are consistent with the data elements required by the AERR rule. Estimation methods include source testing, direct measurement by continuous emissions monitoring systems, or engineering calculations. The point source categories that occur in the PM_{10} nonattainment area are listed below in Table 1.

Table 1
Point Source Categories

Source Category	Subcategory
Fuel Combustion	Electrical Utilities
	Cogeneration
	Manufacturing and Industrial
	Food and Agricultural Processing
	Service and Commercial
	Other (I.C. Reciprocating Engines)
Waste Disposal	Sewage Treatment
	Landfills
	Other
Cleaning and Surface Coatings	Laundering
	Degreasing
	Coatings and Thinners
	Adhesives and Sealants
Petroleum Production and Marketing	Petroleum Refining
	Petroleum Marketing
	Other (Petroleum Production & Marketing)
Industrial Processes	Food and Agriculture
	Mineral Processes

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The point source inventory includes emissions from stationary area sources, which are categories such as internal combustion engines and gasoline dispensing facilities that are not inventoried individually, but are estimated as a group and reported as an aggregated total. Estimates for the following categories were developed by CARB:

Stationary Nonagricultural Diesel Engines

This category includes emissions from backup and prime generators and pumps, air compressors, and other miscellaneous stationary diesel engines that are widely used throughout the industrial, service, institutional, and commercial sectors. The emission estimates, including emission forecasts, are based on a 2003 CARB methodology derived from the OFFROAD model. Additional information on this methodology is available at:
https://www.arb.ca.gov/ei/areasrc/FULLPDF/FULL1-2.pdf

Agricultural Diesel Irrigation Pumps

This category includes emissions from the operation of diesel-fueled stationary and mobile agricultural irrigation pumps. The emission estimates are based on a 2003 CARB methodology using statewide population and include replacements due to the Carl Moyer Program. Emissions are grown based on projected acreage for irrigated farmland. Additional information on this category is available at:
https://www.arb.ca.gov/ei/areasrc/arbfuelcombagric.htm

Waste Disposal, Composting Facilities

This category includes emissions from composting facilities that process organic materials via an open windrow composting or aerated static pile processes. The emission estimates are based on a 2015 CARB methodology using facility specific emissions testing or an emission factor derived from testing at composting facilities. No growth is assumed for future years. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/index2.htm

Laundering

This category includes emissions from perchloroethylene (perc) dry cleaning establishments. The emission estimates are based on a 2002 CARB methodology that used nationwide perc consumption rates allocated to the county level based on population and an emission factor of 10.125 pounds per gallon used. Emissions were grown from the original estimates to 2012 using human population growth trends from SCAG. Additional information on this methodology is available at:
https://www.arb.ca.gov/ei/areasrc/onehtm/one3-1.htm

Degreasing

This category includes emissions from solvents in degreasing operations in the manufacturing and maintenance industries. The emissions estimates are based on a 2000 CARB methodology using survey and industry data, activity factors, emission factors and a user's fraction. Growth for this category is based on CARB/REMI industry-

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specific economic output. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/arbcleandegreas.htm

Coatings and Thinners

This category includes emissions from coatings and related process solvents. Auto refinishing emissions estimates are based on a 1990 CARB methodology using production data and a composite emission factor derived from surveys. Growth is based on projected vehicle miles traveled (VMT) provided by SCAG. Estimates for industrial coatings emissions are based on a 1990 CARB methodology using production and survey data, and emission factors derived from surveys. Estimates for thinning and cleaning solvents are based on a 1991 CARB methodology, census data and a default emission factor developed by CARB. Growth for these categories is projected using CARB/REMI industry-specific economic output and employment. Additional information on these methodologies is available at: https://www.arb.ca.gov/ei/areasrc/arbcleancoatreproc.htm

Adhesives and Sealants

This category includes emissions from solvent-based and water-based solvents contained in adhesives and sealants. Emissions are estimated based on a 1990 CARB methodology using production data and default emission factors. Growth for this category is based on CARB/REMI industry-specific economic output. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/arbcleanadhseal.htm

Gasoline Dispensing Facilities

CARB staff developed an updated methodology to estimate emissions from fuel transfer and storage operations at gasoline dispensing facilities (GDFs). The methodology addresses emissions from underground storage tanks, vapor displacement during vehicle refueling, customer spillage, and hose permeation. The updated methodology uses emission factors developed by CARB staff that reflect more current in-use test data and also accounts for the emission reduction benefits of onboard refueling vapor recovery (ORVR) systems. The emission estimates are based on the 2012 statewide gasoline sales data from the California Board of Equalization that were apportioned to the county level using fuel consumption estimates from CARB's on-road mobile sources model (EMFAC). Additional information on this category is available at: https://www.arb.ca.gov/ei/areasrc/arbpetprodmarkpm.htm

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Areawide Sources

Areawide sources are categories such as consumer products, unpaved road dust, fireplaces, and prescribed burning for which emissions occur over a wide geographic area. Emissions for these categories are estimated by both CARB and the local air districts using various models and methodologies. The areawide sources are listed below in Table 2.

Table 2
Areawide Sources

Source Category	Subcategory
Solvent Evaporation	Consumer Products
	Architectural Coatings and Related Solvents
	Pesticides/Fertilizers
	Asphalt Paving and Roofing
Miscellaneous Processes	Residential Fuel Combustion
	Farming Operations
	Construction And Demolition
	Paved Road Dust
	Unpaved Road Dust
	Fugitive Windblown Dust
	Fires
	Managed Burning and Disposal
	Cooking
	Other (Miscellaneous Processes)

A summary of the areawide methodologies is presented below:

Ammonia Emissions from Publicly Owned Treatment Works, Landfills, Composting, Fertilizer Application, Domestic Activity, Native Animals, and Native Soils

CARB staff updated the ammonia emissions inventory methodology for publicly owned treatment works, landfills, composting, fertilizer application, domestic activity, native animals, and native soils. Revisions for these categories consist primarily of updated activity data for the 2008 calendar year. Emission factors were revised only for fertilizer application.

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Ammonia Emissions, Miscellaneous Sources

Ammonia emissions from miscellaneous domestic processes (human respiration and perspiration, smoking, pets, untreated human waste, etc.) were grown from a 2005 CARB estimate using DOF population projections. Ammonia emissions for other categories such as residential wood combustion, livestock husbandry, managed burning, and on-road motor vehicles, were estimated as part of the methodologies for those specific area source categories.

Consumer Products

The consumer products category reflects the four most recent surveys conducted by CARB staff for the years 2003, 2006, 2008, and 2010. Together these surveys collected updated product information and ingredient information for approximately 350 product categories. Based on the survey data, CARB staff determined the total product sales and total VOC emissions for the various product categories. The growth trend for most consumer product subcategories is based on the latest SCAG human population growth projections, except for aerosol coatings. Staff determined that a no-growth profile would be more appropriate for aerosol coatings based on survey data that show relatively flat sales of these products over the last decade. Additional information on CARB's consumer products surveys is available at: https://www.arb.ca.gov/consprod/survey/survey.htm.

Architectural Coatings

The architectural coatings category reflects emission estimates based on a comprehensive CARB survey for the 2004 calendar year. The emission estimates include benefits of the 2000 and 2007 CARB Suggested Control Measures. These emissions are grown based on SCAG projections for number of households. Additional information about CARB's architectural coatings program is available at: https://www.arb.ca.gov/coatings/arch/arch.htm

Pesticides

DPR develops month-specific emission estimates for agricultural and structural pesticides. Each calendar year, DPR updates the inventory based on the Pesticide Use Report, which provides updated information from 1990 to the most current data year available. The inventory includes estimates through the 2014 calendar year. For agricultural categories, emission forecasts for years 2015 and beyond are based on the average of the most recent five years. Growth for agricultural pesticides is based on CARB projections of harvested acreage provided by the U.S. Department of Agriculture (USDA). Growth for structural pesticides is based on CARB projections of housing expenditures.

Asphalt Paving/Roofing

Asphalt paving emissions for 2012 were estimated using a District methodology, and asphalt roofing emissions were grown from a 2005 estimate. Emissions are estimated based on tons of asphalt applied and a default emission factor for each type of asphalt

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operation. The growth profile for both categories is based on construction employment from the CARB/REMI forecasting model. Additional information on the District's methodology is available at: https://www.arb.ca.gov/ei/areasrc/distsolevapasphpav.htm

Residential Wood Combustion

CARB staff updated the methodology to reflect 2005 fuel use, and more recent emission factors and calculation approaches. The emission estimates reflect emission factors from U.S. EPA's National Emission Inventory. No growth is assumed for future years. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/arbmiscprocresfuelcom.htm

Farming Operations

CARB staff updated the inventory based on CARB methodologies for Agricultural Land Preparation and Agricultural Harvest Operations to reflect 2012 harvested crop acreage from the USDA's National Agricultural Statistics Service (NASS). NASS data are based on reports compiled by County Agricultural Commissioner staff. Emissions reflect crop and operation specific emission factors. Temporal profiles were updated based on crop specific activity profiles. In addition, the inventory reflects the emission reductions from District Rule 806. Growth is based on projected harvested acreage. The methodologies are available at: https://www.arb.ca.gov/ei/areasrc/arbmiscprocfarmops.htm

CARB staff updated the Livestock Husbandry methodology to reflect livestock population data based on the USDA's 2007 Census of Agriculture, and ammonia emission factors for dairy support cattle. A seasonal adjustment was added to account for the suppression of dust emissions in months in which rainfall occurs. Animal populations and emission factors for feedlots and dairies were updated for 2012 based on District data and California specific testing. CARB projects growth for feedlot cattle based on county livestock report data. Based on an analysis of livestock population trends, no growth is assumed for other livestock categories. In addition, the inventory reflects emission reductions from District Rules 420 and 217.
Additional information on CARB's methodology is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscproclivestock.htm

Additional information on the District's update is available here:
https://www.arb.ca.gov/ei/areasrc/districtmeth/imperial/2016mar16_dairyfeedlotops.pdf

Construction and Demolition

Emission estimates for building construction and road construction were grown from CARB estimates developed in 2002 and 1997, respectively. The growth profile for both categories is based on construction employment from the CARB/REMI forecasting model. In addition, the inventory reflects emission reductions from District Rules 801, 802 and 805. Additional information on this methodology is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscprocconstdem.htm

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Paved Road Dust

Paved road dust emissions for 2012 were estimated using an CARB methodology consistent with the current U.S. EPA method (AP-42). The emission estimates are based on VMT provided by SCAG, California-specific silt loading values, VMT distribution (travel fractions) for various paved road categories, and an Imperial County specific rain adjustment. Emissions were grown using VMT projections from SCAG. The inventory also reflects the emission reductions from District Rules 803 and 805. Additional information is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscprocpaverddst.htm

Unpaved Road Dust – Farm Roads

Emissions for unpaved farm roads were updated based on CARB's methodology and 2012 harvested crop acreage from NASS. Emissions reflect crop specific VMT factors and an emission factor based on California test data conducted by the University of California, Davis (UC Davis), and the Desert Research Institute (DRI). Temporal profiles were updated based on crop specific activity profiles. Growth for this category is based on harvested acreage. In addition, the inventory reflects the emission reductions from District Rule 806. The methodology is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscprocunpaverddst.htm

Unpaved Nonfarm Road Dust

Emissions from unpaved nonfarm roads were estimated from 2008 unpaved road data collected from the California Statewide Local Streets and Roads Needs Assessment, Caltrans, and local agencies. Dust emissions were calculated using an emission factor derived from tests conducted by UC Davis and DRI. In addition, a rainfall adjustment factor was applied. Staff assumed no growth for this category based on the assumption that existing unpaved roads tend to get paved as vehicle traffic on them increases, which counteracts any additional emissions from new unpaved roads. The inventory also reflects the emission reductions from District Rule 805. Additional information on this methodology is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscprocunpaverddst.htm

Fugitive Windblown Dust from Open Areas and Non-pasture Agriculture Lands

The District provided estimates of windblown fugitive dust derived from a model developed by ENVIRON Inc. under a contract with the District. The model assesses emission characteristics, hourly emission factors and hourly meteorological data for each land parcel within the modeling domain, and applies correction terms based on vegetative cover, as well as non-climatic corrections for agricultural lands. Based on these inputs, the model was used to estimate fugitive windblown dust emission from open areas and non-pasture agriculture lands in the Imperial County PM_{10} Nonattainment Area. Growth for agricultural lands is based on projected acreage from the California Department of Conservation's Farmland Mapping and Monitoring Program (FMMP). No growth is assumed for non-agricultural lands. The inventory also reflects the emission reductions from District Rules 804 and 806. Additional information

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about CARB's methodology is available at:
https://www.arb.ca.gov/ei/areasrc/arbmiscprocfugwbdst.htm

Windblown Dust from Unpaved Roads

Emissions for this source category were estimated based on a 1997 CARB methodology reflecting unpaved road mileage and local parameters that affect wind erosion. The estimates assume no growth. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/arbmiscprocfugwbdst.htm

Fires

Emissions from structural and automobile fires were estimated based on a 1999 CARB methodology using the number of fires and the associated emission factors. Estimates for structural fires are calculated using the amount of the structure that is burned, the amount and content of the material burned, and emission factors derived from test data. Estimates for automobile fires are calculated using the weight of the car and components and composite emission factors derived from AP-42 emission factors. No growth is assumed for this category. Additional information on this methodology is available at: https://www.arb.ca.gov/ei/areasrc/arbmiscprocfires.htm

Managed Burning & Disposal

CARB updated the emissions inventory to reflect burn data reported by District staff for 2012. Emissions are calculated using crop specific emission factors and fuel loadings. Temporal profiles reflect monthly burn activity. Growth for agricultural burning is based on projected harvested acreage. No growth is assumed for burning associated with weed abatement. CARB's methodology for managed burning is available at:
https://www.arb.ca.gov/ei/areasrc/distmiscprocwstburndis.htm
Additional background information is available here:
https://www.arb.ca.gov/ei/see/see.htm

Commercial Cooking

Commercial cooking emissions were grown from a 2005 estimate. The emissions estimates were developed from the number of restaurants, the number and types of cooking equipment, the food type, and default emission factors. The growth profile reflects the latest population projections provided by SCAG.

Point and Areawide Source Emissions Forecasting

Emission forecasts (2013 and subsequent years) are based on growth profiles that in many cases incorporate historical trends up to the base year or beyond. The growth surrogates used to forecast the emissions from these categories are presented below in Table 3.

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Table 3
Growth Surrogates for Point and Areawide Sources

Source Category	Subcategory	Growth Surrogate
Fuel Combustion	Electric Utilities	SoCAL Gas Company (SCG) 2014 report
	Cogeneration	ARB/REMI industry-specific economic output
	Manufacturing and Industrial Area Source/Natural Gas	SCG 2014 report
	Manufacturing and Industrial Others	ARB/REMI industry-specific economic output
	Food and Agricultural Processing Ag Irrigation I. C. Engines	Modeled estimate
	Food and Agricultural Processing Point Sources	ARB/REMI industry-specific economic output
	Service and Commercial Natural Gas	SCG 2014 Report
	Service and Commercial Other Fuels	ARB/REMI industry-specific employment
	Other, Diesel	ARB EMFAC model for fuel consumption
	Other Fuels	ARB/REMI industry specific economic output/employment
Waste Disposal	Sewage Treatment	SCAG population
	Landfills	SCAG population
	Other (Composting)	No growth
Laundering	Dry Cleaning	SCAG population
Degreasing	All	ARB/REMI industry-specific economic output
Coatings & Thinners	Auto Refinishing	SCAG Vehicle Miles Traveled (VMT)
	Others	ARB/REMI industry specific economic output/employment
Adhesives & Sealants	All	ARB/REMI industry-specific economic output
Petroleum Refining	All	ARB EMFAC model fuel consumption
Petroleum Marketing	All	ARB EMFAC model fuel consumption
Petroleum Production & Marketing	All	ARB/REMI industry-specific economic output
Food & Agriculture	All	ARB/REMI industry specific economic output

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Table 3
Growth Surrogates for Point and Areawide Sources

Source Category	Subcategory	Growth Surrogate
Mineral Processes	All	ARB/REMI industry-specific economic output/employment
Other Industrial Processes	Electrical Power Generation	SCG 2014 report
	Others	ARB/REMI industry-specific economic output
Consumer Products	Consumer Products	SCAG population
	Aerosol Coatings	No growth
Architectural Coatings and Related Process Solvents	All	SCAG households
Pesticides/Fertilizers	Agricultural Pesticides	Harvested acreage
	Structural Pesticides	ARB housing expenditure
Asphalt Paving/Roofing	All	ARB/REMI industry-specific employment
Residential Fuel Combustion	Natural Gas	SCG 2014 report
	Woodstoves & Fireplaces - Wood	No growth
	Water Heating	SCAG households
	Cooking	SCAG households
	Other	SCAG households
Farming Operations	Tilling & Harvest Operations	Harvested acreage
	Livestock / Feedlot Cattle	County livestock report data/ARB
	Livestock / Others	No growth
Construction & Demolition	All	ARB/REMI industry-specific employment
Paved Road Dust	All	SCAG VMT
Unpaved Road Dust	Farm Roads	Harvested acreage
	Others	No growth
Fugitive Windblown Dust	Agricultural & Pasture Lands	ARB FMMP data
	Others	No growth
Fires	All	No growth
Managed Burning & Disposal	Agricultural Burning, Prunings & Field Crops	Harvested acreage
	Weed Abatement	No growth
Cooking	All	SCAG population
Other (Miscellaneous Processes)	All	SCAG population

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Stationary Source Control Profiles

The emissions inventory reflects emission reductions from point and areawide sources subject to District rules and CARB regulations. The rules and regulations reflected in the inventory are listed below in Table 4.

Table 4
District and ARB Stationary and Areawide Source Control Rules and Regulations Included in the Inventory

Agency	Rule/Reg No.	Rule Title	Source Categories Impacted
District	217	Large Confined Animal Facilities (LCAF) Permits Required	Livestock Husbandry
District	420	Beef Feedlots	Livestock Operations
District	801	Construction and Earthmoving Activities	Construction and Demolition
District	802	Bulk Materials	Point Sources
District	803	Carry-Out and Track-Out	Paved Roads
District	804	Open Areas	Windblown Dust
District	805	Paved and Unpaved Roads	Paved and Unpaved Non-farm Roads
District	806	Conservation Management Practices	Tilling and Harvesting Operations, Windblown Dust, Unpaved Farm Roads Unpaved Traffic Areas
CARB	AC_SCM2007	Architectural Coatings 2007 SCM	Architectural coatings
CARB	ARCH_SCM	Architectural Coatings 2000 SCM	Architectural coatings
CARB	ARB_R003	Consumer Product Regulations & Amendments	Consumer products
CARB	ARB_R003_A	Consumer Product Regulations & Amendments	Consumer products
CARB	ARB_R007	Aerosol Coating Regulation	Consumer products / Aerosol coatings
CARB	GDF_HOSREG	Gasoline Dispensing Facilities - Hose Permeation	Petroleum marketing
CARB	ORVR	Fueling emissions from ORVR vehicles	Petroleum marketing

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Mobile Sources

CARB uses the EMFAC model to assess emissions from on-road vehicles. Off-road mobile source emissions are estimated using a new modular approach for different source categories. On-road and off-road models account for the effects of various adopted regulations, technology types, and seasonal conditions on emissions.

On-Road Mobile Sources

Emissions from on-road mobile sources, which include passenger vehicles, buses, and trucks, were estimated using outputs from CARB's EMFAC2014 model. The on-road emissions were calculated by applying EMFAC2014 emission factors to the transportation activity data provided by SCAG from their 2016 adopted Regional Transportation Plan/Sustainable Communities Strategy (2016 RTP/SCS).

EMFAC2014 includes data on California's car and truck fleets and travel activity. Light-duty motor vehicle fleet age, vehicle type, and vehicle population were updated based on 2012 DMV data. The model also reflects the emissions benefits of CARB's recent rulemakings such as the Pavley Standards and Advanced Clean Cars Program, and includes the emissions benefits of CARB's Truck and Bus Rule and previously adopted rules for other on-road diesel fleets.

EMFAC2014 utilizes a socio-econometric regression modeling approach to forecast new vehicle sales and to estimate future fleet mix. Light-duty passenger vehicle population includes 2012 DMV registration data along with updates to mileage accrual using Smog Check data. Updates to heavy-duty trucks include model year specific emission factors based on new test data, and population estimates using DMV data for in-state trucks and International Registration Plan (IRP) data for out-of-state trucks.

Additional information and documentation on the EMFAC2014 model is available at: https://www.arb.ca.gov/msei/categories.htm#emfac2014

Off-Road Mobile Sources

Emissions from off-road sources were estimated using a suite of category-specific models or, where a new model was not available, the OFFROAD2007 model. Many of the newer models were developed to support recent regulations, including in-use off-road equipment, ocean-going vessels and others. The sections below summarize the updates made to specific off-road categories.

Cargo Handling Equipment (CHE)

The emissions inventory for the Cargo Handling Equipment category has been updated to reflect new information on equipment population, activity, recessionary impacts on growth, and engine load. The new information includes regulatory reporting data which provide an accounting of all the cargo handling equipment in the State including their

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model year, horsepower and activity. Background and supporting documents for the Cargo Handling Equipment Regulation are available here:
https://www.arb.ca.gov/ports/cargo/cheamd2011.htm

Pleasure Craft and Recreational Vehicles

A new model was developed in 2011 to estimate emissions from pleasure craft and recreational vehicles. In both cases, population, activity, and emission factors were re-assessed using new surveys, registration information, and emissions testing. Additional information is available at:
https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

In-Use Off-Road Equipment

CARB developed this model in 2010 to support the analysis for amendments to the In-Use Off-Road Diesel Fueled Fleets Regulation. Staff updated the underlying activity forecast to reflect more recent economic forecast data, which suggests a slower rate of recovery through 2024 than previously anticipated. Additional information is available at:
https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

Locomotives

In 2016, CARB updated California's Class I and Class II line-haul locomotive model. The new model provides the following updates: age and model year distribution based on 2011 and 2014 rail company data, activity based on FAF data, fuel growth based on Board of Equalization historical rail data, and new locomotive populations, survival rates, and Tier distributions. To estimate emissions, CARB used duty cycle, fuel consumption and activity data reported by the rail lines in 2011. These results were combined with the Class III locomotive emissions inventory from previous SIPS, that were incorporated in the 2006 locomotive inventory, to create an overall California line-haul locomotive emissions inventory for the SIP. More information may be found at https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

Transport Refrigeration Units (TRU)

This model reflects updates to activity, population, growth and turn-over data, and emission factors developed to support the 2011 amendments to the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units. Additional information is available at:
https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

Fuel Storage and Handling

Emissions for fuel storage and handling were estimated using the OFFROAD2007 model. Additional information is available at:
https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

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Diesel Agricultural Equipment

The inventory for agricultural diesel equipment (such as tractors, harvesters, combines, sprayers and others) was revised based on a 2008 survey of thousands of farmers, custom operators, and first processors. The survey data, along with information from the 2007 USDA Farm Census, was used to revise almost every aspect of the agricultural inventory, including population, activity, age distribution, fuel use, and allocation. This updated inventory replaces general information on farm equipment in the United States with one specific to California farms and practices. The updated inventory was compared against other available data sources such as Board of Equalization fuel reports, USDA tractor populations and age, and Eastern Research Group tractor ages and activity, to ensure the results were reasonable and compared well against outside data sources. Agricultural growth rates through 2050 were developed through a contract with URS Corp and UC Davis. Additional information is available at: https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

Military Aircraft

Baseline emission estimates were developed for the El Centro Naval Air Facility by El Centro staff based on actual operational data and were submitted by the District.

Mobile Source Forecasting

Table 5 summarizes the data and methods used to forecast future-year mobile source emissions by broad source category groupings.

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Table 5
Growth Surrogates for Mobile Sources

Category	***Growth Methodology***
On-Road Sources	
All	*Match total VMT projections provided by SCAG*
Off-Road Gasoline Fueled Equipment	
Lawn & Garden	*Household growth projection*
Off-Road Equipment	Employment growth projection
Recreational Boats	Housing starts (short-term) and human population growth (long-term)
Recreational Vehicles	Housing starts (short-term) and human population growth (long-term)
Off-Road Diesel-Fueled Equipment	
Construction and Mining	California construction employment data from U.S. Bureau of Labor Statistics
Farm Equipment	2011 study of forecasted growth by URS Corp.
Industrial Equipment	California construction employment data from Bureau of Labor Statistics
Trains (line haul)	Freight Analysis Framework (FAF) 2015 growth projections and historical Bureau of Transportation Statistics locomotive fuel trends (1990-2013 data)
Transport Refrigeration Units	Projection of historical Truck/Trailer TRU sales from ACT Research, adjusted for recession.
Off-Road Equipment (Other Fuels)	
Military Aircraft	The growth for military aircraft are based on estimates from El Centro Naval Air Facility staff that facilitate the fielding of new weapons systems, potentially expanding operations that accommodate all activities necessary to continue the national security mission.

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Condensable Particulate Matter

Background

Condensable particulate matter (PM) is "material that is vapor phase at stack conditions, but which condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack."[1] Condensable PM is a component of primary PM, which is the sum of condensable and filterable PM. Filterable PM comprises "particles that are directly emitted by a source as a solid or liquid [aerosol] at stack or release conditions."[2] All condensable PM is assumed to be smaller than 2.5 microns (µm) in diameter; therefore, PM_{10} primary encompasses condensable PM and filterable PM less than 10µm, while $PM_{2.5}$ primary encompasses condensable PM and filterable PM less than 2.5µm. Consequently, the condensable PM value within PM_{10} primary and $PM_{2.5}$ primary are the same.

The AERR requires states to report annual emissions of filterable and condensable components of PM_{10} and $PM_{2.5}$, "as applicable," for large sources every inventory year and for all sources every third inventory year, beginning with 2011.[3] Subsequent emissions inventory guidance[4] from the U.S. EPA clarifies the meaning of the phrase "as applicable" by providing a list of source types "for which condensable PM is expected by the AERR." These source types are stationary point and nonpoint combustion sources that are expected to generate condensable PM and include, for instance, commercial cooking, fuel combustion at electric generating utilities, industrial processes like cement or chemical manufacturing, and flares or incinerators associated with waste disposal. The District reports condensable PM from stationary and area sources using the methodology outlined below.

Mobile sources emit PM in both filterable and condensable form; however, the AERR does not require states to report filterable and condensable PM separately for mobile sources. Emissions from mobile sources are reported in the emissions inventory in Appendix G as primary PM, e.g. the sum of filterable and condensable PM.

Methodology

For future emissions inventory cycles, the District intends to gather condensable PM data for stationary and area sources directly as part of routine data collection. In all previous inventories, however, the District has collected data on primary PM only, containing both filterable and condensable components without distinguishing between the two. Consequently, to be able to report emissions of the condensable component of PM_{10} separately as required by the AERR, the District must use conversion factors to convert primary PM to condensable PM.

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[1] 40 CFR §51.50
[2] Ibid.
[3] 40 CFR §51.15(a)(1) and §51.30(b)(1)
[4] U.S. EPA. *Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations*. May 2017. https://www.epa.gov/sites/production/files/2017-07/documents/ei_guidance_may_2017_final_rev.pdf

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U.S. EPA has published an augmentation tool[5] which contains conversion factors for each source classification code (SCC) to convert filterable PM_{10} (PM10FIL) to condensable PM (PMCON). In this form, these conversion factors ($CF_{PM10FIL \rightarrow PMCON}$) are not useful because the District does not directly collect PM10FIL data. But, the following formula adjusts U.S. EPA's existing conversion factors to obtain new conversion factors for each SCC that convert from primary PM_{10} (PM10PRI)—data which the District does collect—to condensable PM ($CF_{PM10PRI \rightarrow PMCON}$):

$$CF_{PM10PRI \rightarrow PMCON} = \frac{CF_{\mathrm{PM10FIL \rightarrow PMCON}}}{(1 + CF_{\mathrm{PM10FIL \rightarrow PMCON}})}$$

The formula was derived as follows:

$$PM10PRI = PM10FIL + PMCON$$

and

$$PMCON = PM10FIL\,(CF_{\mathrm{PM10FIL \rightarrow PMCON}})$$

and

$$PMCON = PM10PRI(CF_{\mathrm{PM10PRI \rightarrow PMCON}})$$

$$\therefore \quad PM10PRI = PM10FIL + PM10FIL\,(CF_{\mathrm{PM10FIL \rightarrow PMCON}})$$
$$= PM10FIL(1 + CF_{\mathrm{PM10FIL \rightarrow PMCON}})$$

and

$$CF_{\mathrm{PM10PRI \rightarrow PMCON}} = \frac{PMCON}{PM10PRI} = \frac{PMCON}{PM10FIL(1 + CF_{\mathrm{PM10FIL \rightarrow PMCON}})}$$
$$= \frac{PM10FIL\,(CF_{\mathrm{PM10FIL \rightarrow PMCON}})}{PM10FIL(1 + CF_{\mathrm{PM10FIL \rightarrow PMCON}})} = \frac{CF_{\mathrm{PM10FIL \rightarrow PMCON}}}{(1 + CF_{\mathrm{PM10FIL \rightarrow PMCON}})}$$

To ensure that the calculated condensable PM values are smaller than the District-reported $PM_{2.5}$ values, a 1:1 ratio between PM_{10} and $PM_{2.5}$ is assumed, and the derived conversion factors are applied to convert primary $PM_{2.5}$ (PM25PRI) to condensable PM using the same method. That is, $CF_{PM10PRI \rightarrow PMCON} = CF_{PM25PRI \rightarrow PMCON}$ where $CF_{PM25PRI \rightarrow PMCON}$ represents the conversion factors that convert from primary $PM_{2.5}$—again, data the District does collect—to condensable PM. The resulting calculated condensable PM value is then the PMCON portion of both PM2.5PRI and PM10PRI since the condensable PM value within primary $PM_{2.5}$ are one and the same as the condensable PM value within primary PM_{10}.

[5] U.S. EPA. *PM Augmentation*. Air Emissions Inventories. May 20, 2016. https://www.epa.gov/air-emissions-inventories/pm-augmentation

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Appendix H
PM_{10} and PM_{10} Precursor Emission Inventories

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Table H-1a. PM_{10} Emissions by Major Source Category in Imperial County, 2016-2030
Imperial County PM_{10} Plan

Source Category	PM_{10} (tons/day)														
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Stationary Sources															
Fuel Combustion	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Electric Utilities	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*
Cogeneration	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Manufacturing and Industrial	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Food and Agricultural Processing	*0.01*	*0.01*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Service and Commercial	*0.07*	*0.07*	*0.07*	*0.07*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.07*	*0.08*	*0.08*
Other (Fuel Combustion)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Waste Disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Landfills	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Waste Disposal)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cleaning and Surface Coatings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laundering	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Degreasing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Coatings and Related Process Solvents	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Adhesives and Sealants	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Production and Marketing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Refining	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Marketing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Petroleum Production and Marketing)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Industrial Processes	3.99	4.14	4.27	4.41	4.56	4.69	4.83	4.96	5.10	5.25	5.39	5.54	5.69	5.85	6.01
Food and Agriculture	*0.30*	*0.31*	*0.31*	*0.32*	*0.32*	*0.33*	*0.33*	*0.34*	*0.34*	*0.35*	*0.35*	*0.36*	*0.36*	*0.37*	*0.37*
Mineral Processes	*3.67*	*3.81*	*3.95*	*4.08*	*4.22*	*4.35*	*4.48*	*4.61*	*4.75*	*4.89*	*5.03*	*5.17*	*5.32*	*5.47*	*5.62*
Metal Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Industrial Processes)	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Total Stationary Sources	**4.19**	**4.33**	**4.47**	**4.61**	**4.76**	**4.90**	**5.04**	**5.17**	**5.31**	**5.46**	**5.60**	**5.75**	**5.90**	**6.06**	**6.22**
Areawide Sources															
Solvent Evaporation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumer Products	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Architectural Coatings and Related Process Solv	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pesticides/Fertilizers	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Asphalt Paving/Roofing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Miscellaneous Processes	278.48	278.58	278.69	278.69	278.75	278.81	277.30	277.28	277.33	277.39	277.39	277.45	277.51	277.57	277.64
Residential Fuel Combustion	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*
Farming Operations	*8.48*	*8.42*	*8.37*	*8.31*	*8.25*	*8.22*	*8.20*	*8.17*	*8.14*	*8.11*	*8.09*	*8.06*	*8.03*	*8.00*	*7.98*
Construction and Demolition	*3.02*	*3.16*	*3.29*	*3.40*	*3.51*	*3.59*	*3.66*	*3.71*	*3.76*	*3.82*	*3.90*	*3.98*	*4.06*	*4.14*	*4.22*
Paved Road Dust	*1.16*	*1.20*	*1.27*	*1.24*	*1.28*	*1.30*	*1.38*	*1.35*	*1.39*	*1.43*	*1.40*	*1.42*	*1.45*	*1.47*	*1.50*
Unpaved Road Dust	*51.88*	*51.87*	*51.85*	*51.84*	*51.83*	*51.82*	*50.22*	*50.21*	*50.20*	*50.20*	*50.19*	*50.18*	*50.18*	*50.17*	*50.16*
Fugitive Windblown Dust	*212.52*	*212.51*	*212.51*	*212.50*	*212.50*	*212.49*	*212.49*	*212.48*	*212.48*	*212.47*	*212.47*	*212.46*	*212.46*	*212.45*	*212.45*
Fires	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Managed Burning and Disposal	*1.30*	*1.28*	*1.27*	*1.26*	*1.25*	*1.24*	*1.23*	*1.23*	*1.22*	*1.22*	*1.21*	*1.20*	*1.20*	*1.19*	*1.19*
Cooking	*0.08*	*0.08*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*
Other (Miscellaneous Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Areawide Sources	**278.48**	**278.58**	**278.69**	**278.69**	**278.75**	**278.81**	**277.30**	**277.28**	**277.33**	**277.39**	**277.39**	**277.45**	**277.51**	**277.57**	**277.64**
Mobile Sources															
On-Road Vehicles	0.43	0.43	0.44	0.43	0.44	0.44	0.46	0.45	0.46	0.48	0.47	0.48	0.49	0.50	0.51
Off-Road Vehicles	1.07	1.06	1.05	1.05	1.04	1.04	1.04	1.55	1.55	1.55	1.56	1.57	1.57	1.58	1.59
Total Mobile Sources	**1.50**	**1.49**	**1.49**	**1.47**	**1.48**	**1.48**	**1.50**	**1.99**	**2.01**	**2.03**	**2.03**	**2.04**	**2.06**	**2.08**	**2.09**
Total for Imperial County	**284.17**	**284.40**	**284.65**	**284.77**	**284.99**	**285.19**	**283.84**	**284.44**	**284.66**	**284.88**	**285.02**	**285.24**	**285.48**	**285.71**	**285.96**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
Totals may not add up due to rounding.

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Table H-1b. Condensable/Filterable PM_{10} Emissions by Major Source Category in Imperial County, 2016

Imperial County PM_{10} Plan

Source Category	PM_{10} Emissions (tons/day)		
	Total	**Condensable**	**Filterable**
Stationary Sources			
Fuel Combustion	0.199	0.028	0.171
Electric Utilities	*0.091*	*0.025*	*0.066*
Cogeneration	*0.002*	*0.001*	*0.001*
Manufacturing and Industrial	*0.029*	*0.000*	*0.028*
Food and Agricultural Processing	*0.005*	*0.001*	*0.004*
Service and Commercial	*0.072*	*0.000*	*0.071*
Other (Fuel Combustion)	*0.000*	*0.000*	*0.000*
Waste Disposal	0.000	0.000	0.000
Sewage Treatment	*0.000*	*0.000*	*0.000*
Landfills	*0.000*	*0.000*	*0.000*
Other (Waste Disposal)	*0.000*	*0.000*	*0.000*
Cleaning and Surface Coatings	0.000	0.000	0.000
Laundering	*0.000*	*0.000*	*0.000*
Degreasing	*0.000*	*0.000*	*0.000*
Coatings and Related Process Solvents	*0.000*	*0.000*	*0.000*
Adhesives and Sealants	*0.000*	*0.000*	*0.000*
Petroleum Production and Marketing	0.000	0.000	0.000
Petroleum Refining	*0.000*	*0.000*	*0.000*
Petroleum Marketing	*0.000*	*0.000*	*0.000*
Other (Petroleum Production and Marketing)	*0.000*	*0.000*	*0.000*
Industrial Processes	3.989	0.010	3.980
Food and Agriculture	*0.305*	*0.003*	*0.301*
Mineral Processes	*3.672*	*0.006*	*3.666*
Metal Processes	*0.000*	*0.000*	*0.000*
Other (Industrial Processes)	*0.013*	*0.000*	*0.013*
Total Stationary Sources	**4.188**	**0.038**	**4.150**
Areawide Sources			
Solvent Evaporation	0.000	0.000	0.000
Consumer Products	*0.000*	*0.000*	*0.000*
Architectural Coatings and Related Process Solvents	*0.000*	*0.000*	*0.000*
Pesticides/Fertilizers	*0.000*	*0.000*	*0.000*
Asphalt Paving/Roofing	*0.000*	*0.000*	*0.000*
Miscellaneous Processes	278.479	0.080	278.400
Residential Fuel Combustion	*0.046*	*0.000*	*0.046*
Farming Operations	*8.481*	*0.000*	*8.481*
Construction and Demolition	*3.017*	*0.000*	*3.017*
Paved Road Dust	*1.158*	*0.000*	*1.158*
Unpaved Road Dust	*51.881*	*0.000*	*51.881*
Fugitive Windblown Dust	*212.515*	*0.000*	*212.515*
Fires	*0.004*	*0.000*	*0.004*
Managed Burning and Disposal	*1.297*	*0.000*	*1.297*
Cooking	*0.080*	*0.080*	*0.000*
Other (Miscellaneous Processes)	*0.000*	*0.000*	*0.000*
Total Areawide Sources	**278.479**	**0.080**	**278.400**
Mobile Sources			
On-Road Vehicles	0.433	--	--
Off-Road Vehicles	1.066	--	--
Total Mobile Sources	**1.499**	**--**	**--**
Total for Imperial County	**284.167**	**--**	**--**

Notes:

Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.

"--" indicates that the portion of condensable/filterable PM is unknown/unmeasurable.

The condensable portion of each inventory category was calculated using an individual, source-specific conversion factor applied to the reported PM emissions value. The filterable portion was then calculated as the difference between the PM emissions value and its condensable portion.

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Table H-1c. Condensable/Filterable PM_{10} Emissions by Major Source Category in Imperial County, 2030
Imperial County PM_{10} Plan

Source Category	PM_{10} Emissions (tons/day)		
	Total	**Condensable**	**Filterable**
Stationary Sources			
Fuel Combustion	0.212	0.031	0.181
Electric Utilities	*0.099*	*0.027*	*0.071*
Cogeneration	*0.002*	*0.001*	*0.001*
Manufacturing and Industrial	*0.032*	*0.001*	*0.032*
Food and Agricultural Processing	*0.003*	*0.001*	*0.002*
Service and Commercial	*0.075*	*0.000*	*0.075*
Other (Fuel Combustion)	*0.000*	*0.000*	*0.000*
Waste Disposal	0.000	0.000	0.000
Sewage Treatment	*0.000*	*0.000*	*0.000*
Landfills	*0.000*	*0.000*	*0.000*
Other (Waste Disposal)	*0.000*	*0.000*	*0.000*
Cleaning and Surface Coatings	0.000	0.000	0.000
Laundering	*0.000*	*0.000*	*0.000*
Degreasing	*0.000*	*0.000*	*0.000*
Coatings and Related Process Solvents	*0.000*	*0.000*	*0.000*
Adhesives and Sealants	*0.000*	*0.000*	*0.000*
Petroleum Production and Marketing	0.000	0.000	0.000
Petroleum Refining	*0.000*	*0.000*	*0.000*
Petroleum Marketing	*0.000*	*0.000*	*0.000*
Other (Petroleum Production and Marketing)	*0.000*	*0.000*	*0.000*
Industrial Processes	6.009	0.012	5.996
Food and Agriculture	*0.371*	*0.004*	*0.367*
Mineral Processes	*5.623*	*0.008*	*5.615*
Metal Processes	*0.000*	*0.000*	*0.000*
Other (Industrial Processes)	*0.015*	*0.000*	*0.015*
Total Stationary Sources	**6.221**	**0.043**	**6.178**
Areawide Sources			
Solvent Evaporation	0.000	0.000	0.000
Consumer Products	*0.000*	*0.000*	*0.000*
Architectural Coatings and Related Process Solvents	*0.000*	*0.000*	*0.000*
Pesticides/Fertilizers	*0.000*	*0.000*	*0.000*
Asphalt Paving/Roofing	*0.000*	*0.000*	*0.000*
Miscellaneous Processes	277.642	0.100	277.542
Residential Fuel Combustion	*0.046*	*0.000*	*0.046*
Farming Operations	*7.977*	*0.000*	*7.977*
Construction and Demolition	*4.221*	*0.000*	*4.221*
Paved Road Dust	*1.497*	*0.000*	*1.497*
Unpaved Road Dust	*50.164*	*0.000*	*50.164*
Fugitive Windblown Dust	*212.447*	*0.000*	*212.447*
Fires	*0.004*	*0.000*	*0.004*
Managed Burning and Disposal	*1.186*	*0.000*	*1.186*
Cooking	*0.100*	*0.100*	*0.000*
Other (Miscellaneous Processes)	*0.000*	*0.000*	*0.000*
Total Areawide Sources	**277.642**	**0.100**	**277.542**
Mobile Sources			
On-Road Vehicles	0.507	--	--
Off-Road Vehicles	1.588	--	--
Total Mobile Sources	**2.094**	**--**	**--**
Total for Imperial County	**285.957**	**--**	**--**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
"--" indicates that the portion of condensable/filterable PM is unknown/unmeasurable.
The condensable portion of each inventory category was calculated using an individual, source-specific conversion factor applied to the reported PM emissions value. The filterable portion was then calculated as the difference between the PM emissions value and its condensable portion.

Table H-2. ROG Emissions by Major Source Category in Imperial County, 2016-2030
Imperial County PM_{10} Plan

Source Category	ROG (tons/day)														
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Stationary Sources															
Fuel Combustion	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Electric Utilities	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Cogeneration	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Manufacturing and Industrial	*0.02*	*0.02*	*0.02*	*0.02*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Food and Agricultural Processing	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Service and Commercial	*0.02*	*0.02*	*0.02*	*0.02*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Other (Fuel Combustion)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Waste Disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Landfills	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Waste Disposal)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cleaning and Surface Coatings	0.59	0.59	0.60	0.60	0.61	0.63	0.64	0.65	0.67	0.69	0.70	0.72	0.74	0.76	0.78
Laundering	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Degreasing	*0.30*	*0.30*	*0.30*	*0.30*	*0.31*	*0.31*	*0.32*	*0.33*	*0.33*	*0.34*	*0.35*	*0.36*	*0.38*	*0.39*	*0.40*
Coatings and Related Process Solvents	*0.19*	*0.20*	*0.20*	*0.20*	*0.21*	*0.21*	*0.22*	*0.22*	*0.22*	*0.23*	*0.23*	*0.24*	*0.24*	*0.25*	*0.25*
Adhesives and Sealants	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.10*	*0.10*	*0.10*	*0.11*	*0.11*	*0.11*	*0.12*	*0.12*
Petroleum Production and Marketing	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.56	0.55	0.55
Petroleum Refining	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Marketing	*0.67*	*0.66*	*0.65*	*0.64*	*0.63*	*0.62*	*0.61*	*0.60*	*0.59*	*0.58*	*0.57*	*0.56*	*0.55*	*0.55*	*0.54*
Other (Petroleum Production and Marketing)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Industrial Processes	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Food and Agriculture	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Mineral Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*
Metal Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Industrial Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Stationary Sources	**1.36**	**1.36**	**1.36**	**1.35**	**1.35**	**1.36**	**1.36**	**1.36**	**1.37**	**1.38**	**1.38**	**1.39**	**1.41**	**1.42**	**1.44**
Areawide Sources															
Solvent Evaporation	3.50	3.54	3.59	3.63	3.67	3.69	3.71	3.72	3.74	3.75	3.77	3.78	3.80	3.82	3.83
Consumer Products	*1.10*	*1.14*	*1.17*	*1.20*	*1.24*	*1.25*	*1.26*	*1.28*	*1.29*	*1.30*	*1.31*	*1.33*	*1.34*	*1.35*	*1.36*
Architectural Coatings and Related Process Solv	*0.47*	*0.49*	*0.51*	*0.53*	*0.55*	*0.56*	*0.57*	*0.58*	*0.59*	*0.60*	*0.61*	*0.62*	*0.62*	*0.63*	*0.64*
Pesticides/Fertilizers	*1.79*	*1.78*	*1.76*	*1.74*	*1.72*	*1.72*	*1.71*	*1.70*	*1.69*	*1.68*	*1.67*	*1.66*	*1.66*	*1.65*	*1.64*
Asphalt Paving/Roofing	*0.14*	*0.14*	*0.15*	*0.15*	*0.16*	*0.16*	*0.16*	*0.17*	*0.17*	*0.17*	*0.18*	*0.18*	*0.18*	*0.19*	*0.19*
Miscellaneous Processes	3.48	3.47	3.47	3.46	3.45	3.45	3.44	3.44	3.43	3.43	3.42	3.42	3.42	3.41	3.41
Residential Fuel Combustion	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Farming Operations	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*	*2.53*
Construction and Demolition	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Paved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Unpaved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fugitive Windblown Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fires	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Managed Burning and Disposal	*0.90*	*0.89*	*0.88*	*0.88*	*0.87*	*0.86*	*0.86*	*0.85*	*0.85*	*0.84*	*0.84*	*0.84*	*0.83*	*0.83*	*0.82*
Cooking	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Other (Miscellaneous Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Areawide Sources	**6.98**	**7.02**	**7.05**	**7.09**	**7.12**	**7.14**	**7.15**	**7.16**	**7.17**	**7.18**	**7.19**	**7.21**	**7.22**	**7.23**	**7.24**
Mobile Sources															
On-Road Vehicles	2.78	2.63	2.60	2.37	2.28	2.18	2.19	2.02	2.00	1.99	1.87	1.85	1.83	1.80	1.77
Off-Road Vehicles	4.13	4.08	4.03	3.97	3.93	3.89	3.87	4.08	4.08	4.08	4.07	4.06	4.05	4.05	4.06
Total Mobile Sources	**6.92**	**6.71**	**6.63**	**6.34**	**6.21**	**6.07**	**6.06**	**6.10**	**6.08**	**6.06**	**5.94**	**5.91**	**5.88**	**5.85**	**5.83**
Total for Imperial County	**15.26**	**15.09**	**15.04**	**14.77**	**14.68**	**14.56**	**14.57**	**14.62**	**14.62**	**14.62**	**14.51**	**14.51**	**14.50**	**14.50**	**14.51**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
Totals may not add up due to rounding.

EEC ORIGINAL PKG

Table H-3. NO_X Emissions by Major Source Category in Imperial County, 2016-2030
Imperial County PM_{10} Plan

Source Category	NO_X (tons/day)														
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Stationary Sources															
Fuel Combustion	1.63	1.62	1.61	1.60	1.71	1.71	1.71	1.70	1.69	1.69	1.68	1.67	1.66	1.66	1.66
Electric Utilities	*0.37*	*0.36*	*0.36*	*0.36*	*0.36*	*0.37*	*0.38*	*0.39*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*
Cogeneration	*0.02*	*0.02*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Manufacturing and Industrial	*0.44*	*0.44*	*0.44*	*0.43*	*0.48*	*0.47*	*0.46*	*0.46*	*0.45*	*0.45*	*0.45*	*0.44*	*0.44*	*0.43*	*0.43*
Food and Agricultural Processing	*0.11*	*0.10*	*0.10*	*0.09*	*0.09*	*0.09*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.07*	*0.07*	*0.07*	*0.07*
Service and Commercial	*0.69*	*0.69*	*0.69*	*0.68*	*0.76*	*0.75*	*0.75*	*0.74*	*0.73*	*0.73*	*0.73*	*0.72*	*0.72*	*0.72*	*0.73*
Other (Fuel Combustion)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Waste Disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Landfills	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Waste Disposal)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cleaning and Surface Coatings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laundering	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Degreasing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Coatings and Related Process Solvents	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Adhesives and Sealants	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Production and Marketing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Refining	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Marketing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Petroleum Production and Marketing)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Industrial Processes	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11
Food and Agriculture	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Mineral Processes	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.06*
Metal Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Industrial Processes)	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Total Stationary Sources	**1.71**	**1.69**	**1.69**	**1.68**	**1.80**	**1.80**	**1.80**	**1.79**	**1.79**	**1.78**	**1.78**	**1.77**	**1.76**	**1.76**	**1.77**
Areawide Sources															
Solvent Evaporation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumer Products	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Architectural Coatings and Related Process Solv	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pesticides/Fertilizers	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Asphalt Paving/Roofing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Miscellaneous Processes	0.52	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.49	0.49	0.49	0.49
Residential Fuel Combustion	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*
Farming Operations	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Construction and Demolition	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Paved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Unpaved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fugitive Windblown Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fires	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Managed Burning and Disposal	*0.44*	*0.43*	*0.43*	*0.43*	*0.42*	*0.42*	*0.42*	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	*0.40*	*0.40*	*0.40*
Cooking	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Miscellaneous Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Areawide Sources	**0.52**	**0.52**	**0.52**	**0.51**	**0.51**	**0.51**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.49**	**0.49**	**0.49**	**0.49**
Mobile Sources															
On-Road Vehicles	7.42	6.93	6.58	5.80	5.66	5.20	4.89	3.53	3.46	3.41	3.28	3.25	3.23	3.23	3.24
Off-Road Vehicles	7.49	7.25	6.94	6.65	6.39	6.13	5.84	7.67	7.45	7.22	7.00	6.80	6.62	6.44	6.27
Total Mobile Sources	**14.91**	**14.18**	**13.52**	**12.45**	**12.06**	**11.33**	**10.73**	**11.20**	**10.91**	**10.63**	**10.29**	**10.05**	**9.84**	**9.67**	**9.51**
Total for Imperial County	**17.14**	**16.40**	**15.72**	**14.65**	**14.36**	**13.63**	**13.03**	**13.49**	**13.20**	**12.91**	**12.56**	**12.31**	**12.10**	**11.92**	**11.77**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
Totals may not add up due to rounding.

EEC ORIGINAL PKG

Table H-4. SO_X Emissions by Major Source Category in Imperial County, 2016-2030
Imperial County PM_{10} Plan

Source Category	SO_X (tons/day)														
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Stationary Sources															
Fuel Combustion	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electric Utilities	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cogeneration	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Manufacturing and Industrial	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Food and Agricultural Processing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Service and Commercial	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Fuel Combustion)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Waste Disposal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Landfills	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Waste Disposal)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cleaning and Surface Coatings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laundering	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Degreasing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Coatings and Related Process Solvents	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Adhesives and Sealants	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Production and Marketing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Refining	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Marketing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Petroleum Production and Marketing)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food and Agriculture	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Mineral Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Metal Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Industrial Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Stationary Sources	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Areawide Sources															
Solvent Evaporation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumer Products	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Architectural Coatings and Related Process Solv	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pesticides/Fertilizers	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Asphalt Paving/Roofing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Miscellaneous Processes	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07
Residential Fuel Combustion	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Farming Operations	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Construction and Demolition	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Paved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Unpaved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fugitive Windblown Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fires	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Managed Burning and Disposal	*0.08*	*0.08*	*0.08*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*
Cooking	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Miscellaneous Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Areawide Sources	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**
Mobile Sources															
On-Road Vehicles	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Off-Road Vehicles	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Mobile Sources	**0.25**	**0.25**	**0.26**	**0.27**	**0.27**	**0.27**	**0.27**	**0.16**	**0.16**	**0.16**	**0.16**	**0.17**	**0.17**	**0.17**	**0.17**
Total for Imperial County	**0.34**	**0.34**	**0.34**	**0.35**	**0.35**	**0.35**	**0.35**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
Totals may not add up due to rounding.

EEC ORIGINAL PKG

Table H-5. NH_3 Emissions by Major Source Category in Imperial County, 2016-2030
Imperial County PM_{10} Plan

Source Category	NH_3 (tons/day)														
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Stationary Sources															
Fuel Combustion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electric Utilities	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Cogeneration	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Manufacturing and Industrial	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Food and Agricultural Processing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Service and Commercial	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Other (Fuel Combustion)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Waste Disposal	1.49	1.49	1.49	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.51	1.51	1.51
Sewage Treatment	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Landfills	*0.07*	*0.07*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*
Other (Waste Disposal)	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*	*1.42*
Cleaning and Surface Coatings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laundering	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Degreasing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Coatings and Related Process Solvents	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Adhesives and Sealants	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Production and Marketing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Refining	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Petroleum Marketing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Petroleum Production and Marketing)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food and Agriculture	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Mineral Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Metal Processes	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Industrial Processes)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total Stationary Sources	**1.49**	**1.50**	**1.50**	**1.50**	**1.50**	**1.50**	**1.51**	**1.51**	**1.51**	**1.51**	**1.51**	**1.51**	**1.51**	**1.51**	**1.51**
Areawide Sources															
Solvent Evaporation	15.34	15.19	15.04	14.89	14.74	14.66	14.59	14.52	14.45	14.37	14.30	14.23	14.16	14.09	14.02
Consumer Products	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Architectural Coatings and Related Process Solv	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pesticides/Fertilizers	*15.34*	*15.19*	*15.04*	*14.89*	*14.74*	*14.66*	*14.59*	*14.52*	*14.45*	*14.37*	*14.30*	*14.23*	*14.16*	*14.09*	*14.02*
Asphalt Paving/Roofing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Miscellaneous Processes	15.36	15.37	15.38	15.40	15.41	15.41	15.41	15.42	15.42	15.42	15.43	15.43	15.43	15.44	15.44
Residential Fuel Combustion	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Farming Operations	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*	*14.80*
Construction and Demolition	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Paved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Unpaved Road Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fugitive Windblown Dust	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Fires	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Managed Burning and Disposal	*0.19*	*0.19*	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.18*	*0.17*	*0.17*	*0.17*	*0.17*
Cooking	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Other (Miscellaneous Processes)	*0.37*	*0.39*	*0.40*	*0.41*	*0.42*	*0.43*	*0.43*	*0.44*	*0.44*	*0.45*	*0.45*	*0.45*	*0.46*	*0.46*	*0.47*
Total Areawide Sources	**30.70**	**30.56**	**30.42**	**30.28**	**30.14**	**30.07**	**30.00**	**29.93**	**29.87**	**29.80**	**29.73**	**29.66**	**29.60**	**29.53**	**29.46**
Mobile Sources															
On-Road Vehicles	0.21	0.21	0.22	0.20	0.20	0.20	0.21	0.20	0.20	0.20	0.19	0.19	0.19	0.20	0.20
Off-Road Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mobile Sources	**0.22**	**0.21**	**0.22**	**0.21**	**0.21**	**0.20**	**0.21**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**
Total for Imperial County	**32.41**	**32.27**	**32.14**	**31.99**	**31.85**	**31.78**	**31.72**	**31.64**	**31.58**	**31.51**	**31.43**	**31.37**	**31.30**	**31.24**	**31.17**

Notes:
Emissions for Imperial County were queried from the California Emissions Projection Analysis Model (CEPAM), Version 1.05.
Totals may not add up due to rounding.

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Appendix I
Salton Sea Management Program Phase I: 10-year Plan (March 2017)

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Salton Sea Management Program
Phase I: 10-Year Plan
March 2017



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Introduction

Under the leadership of Governor Edmund G Brown Jr., the 2014 California Water Action Plan set forth a vision for California water management that balances statewide water supply security with the protection of public, economic and ecological health. The Salton Sea offers a unique opportunity to preserve these values by leveraging a convergence of support from federal, state, and local stakeholders for a smaller and sustainable sea achieved through the projects outlined in this plan.

The Salton Sea is California's largest lake. Thirty-five miles long and 15 miles wide, the desert lake extends from the Coachella Valley into the Imperial Valley. Though saltier than the ocean, the Sea supports an abundance of fish, a food source for millions of migratory birds on the Pacific Flyway. Managing the Sea's natural, agricultural, and municipal water inflows to maximize bird and fish habitat and minimize fine-particle air pollution will allow California to protect regional health, ecological wealth and a stable water supply.

The Salton Sea formed in the Salton Trough in Imperial and Riverside counties. Much of the trough is below sea level and has a long history of periodic inundation from the shifting delta of the Colorado River or from infrequent storm events. The last Colorado River inundation of the area occurred in 1905 when an irrigation canal inlet gate failed and flooded much of the area. Since then, lake inflows have been primarily from agricultural activities in the area. Inflows from the New and Alamo rivers are primarily farm return flow water, although there is some inflow from Mexico, particularly during large precipitation events. Over the last several decades, water levels at the Salton Sea have declined and salinity concentrations have increased due to climate fluctuations, agricultural conservation measures, cropping practices and reduced inflows from Mexico. Recent water transfers from the Imperial Valley have further accelerated the rate of lake elevation decline and have increased the rate of salinity concentration. Declining lake levels threaten important bird habitat and pose public health risk due to particulate air pollution.

Over the last 40 years numerous ideas and plans have been proposed by various entities to restore the Salton Sea. None have been implemented for a variety of reasons, including lack of a shared vision, funding constraints, and reduced inflows.

In 2015, Governor Edmund G. Brown Jr. formed the Salton Sea Task Force with principle staff and members of various state agencies to identify short- and medium-term goals to respond to air quality and ecological threats at the Salton Sea. The Task Force developed actions for the Salton Sea that included:

- Develop and implement the Salton Sea Management Program through departments within the California Natural Resources and Environmental Protection Agencies
- Improve public outreach and local partnerships
- Accelerate project implementation and delivery

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- Meet a short-term goal of 9,000 acres to 12,000 acres of dust suppression and habitat projects
- Establish a medium-term goal of 18,000 acres to 25,000 acres of dust suppression and habitat projects.

The State's Salton Sea Management Plan (SSMP) has several phases of development to protect air quality and ecosystem values at the Salton Sea. This draft technical memorandum prepared by the State of California outlines the SSMP's first, 10-year phase (Phase I Plan). It will guide State and federal actions to meet the commitments outlined in the Memorandum of Understanding (MOU) executed on August 31, 2016, and amended on January 18, 2017 by the Department of Interior (DOI) and the California Natural Resource Agency (CNRA). The MOU, among other things, identified a goal of developing projects to protect or improve air quality, wildlife habitat, and water quality as necessary to minimize human health and ecosystem impact at the Salton Sea in the mid-term. While guided by the MOU, the SSMP is a longer-term process that has been developed and will be implemented by the State of California. This first phase of development has been planned to expedite construction of habitat and to suppress dust on areas of playa that have been or will be exposed at the Salton Sea by 2028. The Phase I Plan outlines the process for developing additional management measurements for the Salton Sea that will be implemented in later phases.

The Phase I Plan also addresses the requirements of Assembly Bill 1095 (Garcia 2015) by including those projects deemed "shovel-ready projects" and including estimates of cost. Those projects include:

- Water backbone infrastructure, which will provide conveyance of river and Salton Sea water to air quality and habitat projects.
- SSMP air quality and habitat projects associated with the water backbone infrastructure
- The CNRA's Phase I Species Conservation Habitat Project (saline impoundments along the southern shore to support fish and wildlife)
- Red Hill Bay Project, an effort of the U.S. Fish and Wildlife Service and Imperial Irrigation District to restore habitat on the southeastern shore
- Torres-Martinez Wetland project, an effort of the Torres Martinez Desert Cahuilla Indians to build shallow wetlands along the northern edge of the Salton Sea.

The Phase I Plan considers the implications of the 17-year drought on the Colorado River. The drought may force reductions of Colorado River water to the Lower Basin States, which in turn could impact inflows to the Salton Sea. The U.S. Bureau of Reclamation, seven Colorado River basin states and key principals of several water management agencies have been developing a Drought Contingency Plan (DCP) that includes implemented and proposed actions to address the potential water shortage. The Department of Interior Order No. 3344 - *Actions to Address Effects of Historic Drought on Colorado River Water Supplies* (DOI, January18, 2017) further outlines the details of the DCP. One component of the Phase I Plan is to evaluate the current

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hydrologic modeling for the Salton Sea and to include some of the proposed actions in the model to evaluate their potential impact to Salton Sea inflows.

As the *Air Quality Planning and Implementation* section of this document notes, the air quality mitigation will consist of measures to keep exposed playa wet or vegetated. A series of Best Available Control Measures (BACM) are being evaluated by the Quantification Settlement Agreement (QSA) Water Transfer mitigation program, which was created under a 2003 agricultural-to-urban water transfer agreement involving the State of California, the Imperial Irrigation District, Coachella Valley Water District, and the San Diego County Water Authority. The work of determining these best strategies will be paid for by the QSA Joint Powers Authority. The Phase I Plan involves coordination among Imperial Irrigation District, Imperial County Air Pollution Control District, South Coast Air Quality Management District and other agencies to ensure that the latest information about how lakebed exposure may affect air quality is included in the development of BACM pilot projects.

In order to provide ample time for public input into this plan, the SSMP will schedule several regional workshops to solicit input from community members and stakeholders as well as provide necessary time for general public comment. This process will be announced via the program's website http://resources.ca.gov/salton-sea/.

Salton Sea Elevation and Exposure Modeling

A key issue at the Salton Sea is exposure of previously submerged lakebed, known as playa, as the lake surface shrinks. This playa exposure is subject to wind erosion and can be a source of fine airborne dust smaller than 10 micrometers, known as particulate matter 10, or PM10; as well as a source of PM 2.5. The dust is a significant health hazard and can contribute to respiratory illness in humans. It can also damage agricultural crops and wildlife and harm the region's tourism industry.

Understanding the extent, type and location of the exposed playa is important in developing a program to address playa emissivity. There also are regulatory requirements to provide an emission inventory, the creation of which demands an understanding of the extent of exposure possible over the course of the Phase I Plan.

The following is a brief explanation of the process used to create the playa exposure assumptions included in this 10-year plan.

Hydrology Inflow Modeling

As part of the initial environmental evaluation of the Imperial Irrigation District Water Conservation and Transfer Project (QSA water Transfer), the Salton Sea Accounting Model (SSAM) was used to estimate inflows and salt concentrations at the lake for the up to 75-year term of the QSA Water Transfer. This evaluation resulted in a series of mitigation measures designed to address water quality and to maintain the salinity trend at the lake. The measures also had a secondary effect of reducing the water elevation decline at the lake.

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In 2012, in response to concerns over the results of the previous modeling, the Salton Sea water inflow and salt balance projections were reevaluated using the Salton Sea Analysis model (SALSA), originally developed in 2006 for the California Department of Water Resources' Salton Sea Ecosystem Restoration Program's environmental documentation. The SALSA model was integrated into the GoldSim modeling platform to provide an interface that would more easily allow for alternative scenario comparisons, allow for customized simulations, and provide for a stochastic simulation mode to evaluate uncertainty. The revised model results were compared/correlated with the additional years of measured elevation data available from 2003 to 2012 (latest available information). Since then, Imperial Irrigation District (IID) has revised the model based on new data and those revisions are included in the exposure projections presented here. Since there is some difference of opinion on the results of the latest hydrology, the State will evaluate the hydrologic model, compare the results with earlier versions and make it available for review as part of the preparation of the SSMP.

Along with the original parameters of the model (agricultural return flow water, mitigation water delivered to the lake, precipitation, groundwater inflow from the Coachella Valley, evaporation, etc.), the revised model has inputs for water use by the Species Conservation Habitat Project and for water-dependent air quality mitigation. The water demands for the habitat and water-dependent air quality mitigation components are determined based on surface area, evapotranspiration rates, total dissolved solids concentrations, and flow-through volumes. These variables can be manipulated in the model inputs to mimic various management scenarios. The various assumptions integrated into the model will be provided to stakeholders as part of the review of the hydrology model. The State will complete a revision/calibration of the SALSA hydrology model. Additional field data will be integrated into the model.

Initial conditions for the model are from the United States Geological Survey (USGS) stream gauge data from December 31, 2012, which measured the lake elevation at -231.35 feet below mean sea level (MSL) based on the North American Vertical Datum of 1988 (NAVD88). The baseline for the salinity concentration is approximately 52.7 parts per thousand (ppt) based on the average of samples taken by the U.S. Bureau of Reclamation at three fixed locations in the lake in February 2012.

A Monte Carlo simulation (stochastic process) is used to provide multiple runs with changes to multiple variables, based on their probability distribution. The runs are then statistically analyzed and an end-of-year Salton Sea water elevation is calculated for each year. The inflow data is combined with lakebed topography (bathymetry) to estimate playa exposure around the lake.

Salton Sea Bathymetry

The revised Salton Sea bathymetric data was developed by consultants from a variety of sources including light detection and ranging (LIDAR) survey technology and boat-based acoustic sonar imagery. This data was manipulated to develop bottom contours for the lake and immediate shore area. It also was used to estimate sediment depth and composition around some areas of the lake. Data relating to the bathymetric model was

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converted to NAV88 using the National Geodetic Survey's VERTON calculator and a standard conversion factor of 2.113 feet.

In order to evaluate the accuracy of the playa exposure model, satellite (Landsat 5, 7 and 8)imagery of the Salton Sea was captured and a spectral water index was used to identify areas covered by water. This was then compared to the results of the playa exposure evaluation model and the existing data from the USGS gauge to compare the results. In general, the results were comparable. But the evaluation identified differences in areas around the bays of the New and Alamo rivers. This is likely the result of errors in the bathymetric data caused by limitations of acoustical sonar data in shallow water areas (while these areas are currently dry, portions were flooded with shallow water during the sonar survey). The bay areas that were exposed in 2016 have been included in the exposure acreage, and the revised hydrology will evaluate the issue and determine if the bathymetric data need to be further adjusted. This information will be included in the revised hydrologic model review process.

Salton Sea Playa Exposure

Based on the above data, Table 1 summarizes the predicted year by year playa exposure from late 2018 to 2028, which totals approximately 48,300 acres. Additional hydrologic analysis will be completed to include potential impacts from the DCP that may revise inflows to the lake, which in turn will cause changes to the exposure profile. Revisions to the hydrology will change the estimated exposed acreage. It is likely that revisions will be made on an annual basis, as new information becomes available, and the revisions will be made available for review by stakeholders.

The original estimates for total playa exposure from the QSA water transfer were approximately 45,000 acres, and the model had the lake stabilizing in approximately 2035. The environmental documentation for the QSA recognized that the amount of exposure might change, and included requirements in the air quality mitigation program that additional modeling be conducted to further evaluate exposure.

Table 1. 2018–2028 Annual Exposure (Acres/Year)

YEAR	ACRES
2018	3,500
2019	4,200
2020	5,000
2021	5,600
2022	5,500
2023	5,300
2024	4,900
2025	4,300
2026	3,900
2027	3,300
2028	2,800
TOTAL	**48,300**

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The exposure projections currently listed for the 10-year period differ from the projections for the original 2003 and later environmental document prepared as part of the QSA Water Transfer. As was noted previously, the State will evaluate the latest hydrology data and make the results of that evaluation available for review. There will be periodic comparisons of the actual playa exposed against what the model predicts will be exposed.

The SSMP Phase I Plan will be implemented within the exposed areas on the south and north ends of the lake. Some of the exposed area may not be emissive and will not require action from the Phase I Plan. The implementation process for the Phase I Plan is outlined in the *Implementation* section of this document.

Salton Sea Salinity

One of the measures incorporated into the QSA Water Transfer mitigation program was the revised Salton Sea Habitat Conservation Strategy, which required delivery of 800,000 acre feet of water to the Salton Sea to maintain the salinity trend at the lake. The delivery of this water mitigates to a large extent the decline in elevation of the lake. Delivery of this so-called “mitigation water” ends December 31, 2017.

The original and revised SALSA models calculate the salt concentration for the lake based on a simple mass balance algorithm. Salinity was modeled and then compared with measured salinity data from the U.S. Bureau of Reclamation’s salinity surveys conducted in February 2012. The model estimates that the salinity of the lake will be approximately 63.4 parts-per-thousand (ppt)at the end of 2018, and approximately 153.1 ppt in 2045. The most recent measurements of salinity (Reclamation 2016) recorded slightly over 59 ppt, which is higher than some of the model predictions.. Additional modeling will be conducted to confirm salinity trends and show any difference between the modeled and measured salinity. While the salinity projections may change based on the modeling, current projections can still be used for planning purposes.

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Phase I – Background

Phase I is designed to address playa exposure by developing habitat or dust suppression projects on exposed playa. The location of habitat projects will be determined primarily based on site logistics such as water availability, soil suitability, and compatibility within the overall habitat landscape. If the primary objectives are met, location of habitat will be further informed by emissivity potential of the playa. Determination of playa emissivity will drive the location of the dust suppression projects. The development of new methods for evaluating emissivity is part of the QSA Water Transfer Air Quality Mitigation Program and the Phase I Plan. The process for determining more advanced methods of measuring emissivity is an ongoing process that is being coordinated with the two local air districts and the California Air Resources Board. More detail regarding measurement of emissivity is included in the *Air Quality Planning and Implementation* section of this document.

The projected playa exposure acreage is based on data from IID's revised hydrology model and will be reviewed by the State and other stakeholders. Figure 1 (all figures are contained in Appendix 1) illustrates the projected lake elevation in 2003, 2018, 2023 and 2028. The exposed playa acreage included in the Phase I Plan is depicted as shaded areas (zones) on the north and south end of the lake. Figures 2 and 3 are of playa exposure at the New River. Figures 4 and 5 depict exposure at the Alamo River, and Figure 6 depicts exposure at the north end of the lake. For graphical and design development purposes, the area encompassed in the Phase I Plan is divided into three increments of playa exposure by year: 2003–2018; 2018–2023 (green shading); and 2023–2028 (blue shading). However, the Phase I Plan addresses annual exposure of playa areas, as noted in Table 2, starting in 2018. The habitat projects will be concentrated in the 2018–2023 and 2023–2028, exposure zones. BACM pilot projects and the water management ponds will be located in the 2003–2018 exposed zone because they require exposed playa, and the water management ponds are located to facilitate gravity flow. Appendix 4 includes a preliminary implementation schedule that will be updated as design advances.

Table 2 summarizes the projected exposure and the amount of treatment of exposed emissive playa on an annual basis. There is lag time between playa exposure and construction of habitat or dust suppression techniques. This delay accounts for the seasonal elevation change of the lake (water elevations during a given year vary based on seasonal changes in inflow volumes), wave action wetting the exposed playa, and desiccation of the playa soil after exposure. Initial evaluations by the air quality management program suggest that the lag time is approximately 1.5 years to two years. A two-year lag time will be used for the purposes of developing annual target numbers. There will be periodic calibrations to assure that the predicted exposure is accurate.

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Table 2. 2018–2028 Exposure and SSMP Phase I Projected Construction

YEAR	EXPOSED ACRES	PROPOSED CONSTRUCTION
2018	3,500	500
2019	4,200	1,300
2020	5,000	1,700
2021	5,600	3,500
2022	5,500	1,750
2023	5,300	2,750
2024	4,900	2,700
2025	4,300	3,400
2026	3,900	4,000
2027	3,300	4,000
2028	2,800	4,200
TOTAL	**48,300**	**29,800**

Table 2 notes more exposed playa area than proposed constructed area. Phase I concentrates on the north and south ends of the playa where the exposure is more pronounced. The proposed construction acreage is all of the shaded areas noted in Figures 1 to 6. The additional exposed area is primarily along the east and west sides of the lake. These areas are outside of the backbone water management infrastructure and will require additional development of water sources to be converted to habitat areas. These areas may require dust suppression methods to address emissions.

Some exposed areas around the lake may not require treatment, as they will be non-emissive or used for some other purpose, such as access for renewable energy projects or agriculture.

The Phase I Plan includes many of the concepts identified in the *Salton Sea Restoration and Renewable Energy Initiative* (Initiative) developed by IID and Imperial County in 2015 and revised in the IID's Backbone Infrastructure Concept Design memo of August 2016. Though the Initiative was developed primarily as a potential solution for exposed playa areas on the south end of the lake, the concept can also be applied to other areas around the lake. Phase I will incorporate two priority elements of the Initiative: 1) maintaining access for the development of renewable energy (primarily geothermal), and 2) incremental construction based on playa access and funding availability. The Torres-Martinez Desert Cahuilla Tribal nation (Torres) has developed plans for several projects on the north end of the lake that will be a part of Phase I. Habitat design will be informed by State and federal wildlife agencies, as well as academic and non-profit partners.

Dust suppression projects will be coordinated with the *Salton Sea Air Quality Mitigation Program* (IID/JPA July, 2016), the Imperial County Air Pollution Control District (ICAPCD), the California Air Resources Board (CARB) and the South Coast Air Quality Management District. The State will continue to coordinate with the Salton Sea Authority

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(SSA), the Water Transfer Joint Powers Authority, IID, and ICAPCD on the development of BACM pilot projects per Imperial County's recent request for letters of interest from affected landowners and the SSA's Natural Resource Conservation Service grant process. The *Air Quality Planning and Implementation* section of this document provides additional detail.

To expedite Phase I, the SSMP design team will include State staff and outside consultants developing the design criteria for the water backbone infrastructure, as well as habitat and dust suppression projects at the north and south end of the lake. The team will work closely with State agencies, IID, SSA, SSMP Committees, the QSA water transfer agencies, and other stakeholders during the development of the project plans.

SB 839 (Statutes of 2015-16) grants the Department of Water Resources design/build contracting authority for the SSMP. This authority will expedite and provides a more flexible design and construction process as well as potentially reducing project costs. Design criteria and preliminary construction design will be used to develop and advertise for a design/build consultant to implement Phase I projects.

Phase I Planning and Design

The State of California will use the amount/rate of playa exposure (subject to lag time and other constraints) to plan and implement each year's annual increment of construction of projects in the Phase I Plan. Each year at a specific timeframe (likely December), the State will determine actual playa exposure using methods similar to those described above for evaluating the playa exposure model's accuracy and adjust the hydrology model if needed. The evaluation will include measuring the emissivity and potential for toxic emissions of the playa to determine if the exposed area requires mitigation. The Phase I Plan will require a certain amount of adaptive management, as there may be seasonal fluctuations at the lake or changes in annual exposures that may require adjustments to Plan implementation.

The exposed area to the west of the New River (Figures 2 and 3, Appendix 1) is identified as the first site to be developed because much of the area was included in the Species Conservation Habitat Project (SCH) environmental documentation and will not require significant additional regulatory compliance effort. The second area developed will be to east of the New River (Figures 4 and 5, Appendix 1). This area will be developed after construction of the SCH is substantially completed. (The SCH serves as both habitat and the water management pond for the SSMP projects on the east side of the river.) Additionally, the Torres project located on the north end of the lake will be developed (Figures 10 and 11, Appendix 1). Permitting work on other areas is underway and will be completed prior to planned construction dates,. The State is currently trying to determine the most expedient process for regulatory compliance and will make every effort to utilize existing California Environmental Quality Act and permitting documentation in that process.

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Areas around the Alamo River (Figures 6, 7, 8, and 9, Appendix 1) will be developed later in the Phase I Plan, as they involve more access issues associated with geothermal development. The Red Hill Bay project is underway on the west side of the Alamo River (Figures 6 and 7, Appendix 1) and will be completed in 2017.

The development of the Phase I Plan is divided into water backbone infrastructure, habitat, and air quality components, as described in the following sections.

Water Backbone Infrastructure Design

The water backbone infrastructure (backbone) is part of the *Salton Sea Restoration and Renewable Energy Initiative* (IID 2015 and revised 2016), and is designed to supply agricultural return flow water for dust suppression, habitat projects and other potential land uses on the south end of the lake. The backbone will consist of a series of outlets from the Alamo and New rivers that supply agricultural return flow water to water management ponds located along the edges of the lakeshore adjacent to the rivers (Figure 1, Appendix 1). The water management ponds will include an inlet for Salton Sea water. The two water sources will be blended in the water management pond, and the resulting brackish water will be used for the habitat areas. The project water distribution system will deliver the brackish water from the water management ponds for habitat and dust suppression.

The Audubon report *Quantifying Bird Habitat at the Salton Sea - Informing the State of California's Salton Sea Management Plan*, October, 2016, details salinity levels tolerated by various avian species.. The Audubon report will help determine specific locations and salinity for the various habitat areas based on target species. Location of the various habitat types will be developed as part of the work planning effort that begins in March 2017.

The backbone is divided into sections based on the agricultural return flow water source. The New River is depicted in Figures 2 and 3 in Appendix 1, and the Alamo River is depicted in Figures 4 and 5 in Appendix 1. The river sections are further subdivided based on the location of the playa that will be served by each section, with the New River divided into east and west, and the Alamo River divided into north and south.

The State team (which includes various SSMP Advisory Committees), along with IID, the QSA Water Transfer agencies, and other stakeholders, will collaborate to develop design and construction standards for the Phase I water backbone delivery system. IID will be involved in the review and approval of the backbone system, as it will be connected to IID infrastructure. The criteria for the backbone water delivery system may include the following:

Geotechnical Evaluation

Utilizing existing data where practical, determine suitable substrate materials available for berm foundation and berm construction. This will be a limited evaluation similar to what was done for the SCH.

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River Delivery System

Evaluate the construction and operation cost of a pump system versus the development of a river check dam structure to facilitate gravity flow from the river.

Identification of Existing Habitat Areas

Evaluate existing habitat and vegetation along the eastern side of the lake to determine if portions can be stabilized or enhanced (Figures 8 and 9). Vegetation, ponded water, and saturated soils in these areas are likely caused by natural or artificial blockage of the agricultural drains in the area. Consider the potential for water quality issues (selenium) in these areas and the potential for impacts to desert pupfish.

Design Criteria

Determine process for assessing the value of engineering of projects with an emphasis on developing standards that compare project longevity against the costs of building and maintenance.

Design-Year Storm

Determine the appropriate design year storm and develop flood control measures to accommodate that flow. The evaluation may include the development of sacrificial berms, cutouts or armoring of the channel to pass large volumes of water from the river channel to the Sea.

Channels

Evaluate the potential for pipe systems instead of open channels for the distribution system. Evaluate size, structure and composition (lined vs. unlined) of the distribution system.

Water Management Ponds

Determine the final structure, size, and location of the water impoundment ponds. Determine sediment control system. Evaluate berm construction parameters (material, compaction etc.).

Easement and Lease Protocols

To the extent practical, develop standardized easement and lease agreements for IID parcels and other parcels that will be used for SSMP projects.

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Develop Contingency Plan for Funding Shortfalls

Develop a program to prioritize certain aspects of the Phase I Plan if funding is not available for the complete implementation. Considerations will include human health concerns, potential impacts to agricultural activities, and ecosystem management.

Operation, Maintenance, and Monitoring

Develop cost estimates for operation, maintenance, and monitoring activities associated with constructed facilities. The State will be responsible for implementing the operation, maintenance, and monitoring of the project. The DOI/CNRA MOU (Appendix 2) identifies federal funding for these activities for a ten-year period.

Compatibility with IID Draft Water Transfer Habitat Conservation Plan

The Phase I Plan will be developed to be compatible with the mitigation measures for desert pupfish, marsh birds, and other Salton Sea or drain species included in the draft Habitat Conservation Plan developed for the water transfer mitigation program.

Compatibility with IID/JPA Water Transfer Air Quality Mitigation Program

The State will coordinate with IID and their consulting team, ICAPCD, Water Transfer Joint Powers Authority, and South Coast Air Quality Management District (SCAQMD) to integrate compatible BACM pilot projects into Phase I of the SSMP. The State will coordinate with Water Transfer Joint Powers Authority partners to implement its air quality mitigation program. Efforts are underway to determine if accelerating portions of the air quality mitigation program are warranted. This coordination will be conducted through the existing Water Transfer Joint Powers Authority budget process and the existing mitigation development program for the water transfer.

This process will follow the four-step air quality mitigation guidelines outlined in the QSA Water Transfer environmental documentation.

Compatibility with Renewable Energy Projects

With the notable exception of the Red Hill Bay project, the initial projects described for Phase I are either outside or at the edges of the Known Geothermal Resource Area (KGRA). However, the remainder of the Phase I projects are within this zone. The State will continue to coordinate with the geothermal developers, regulatory agencies, and land owners to design the SSMP projects to minimize or eliminate conflicts with renewable energy development. Currently, the Phase I design assumes access provisions will be accommodated by the existing drain outlet corridors spaced approximately every half mile along the southeast portion of the lake. This may change as development proceeds.

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Water Backbone Infrastructure Implementation

The 2018–2023 water management ponds will be the first facilities constructed as part of the water backbone infrastructure, followed by the habitat and dust suppression projects associated with each individual pond. The water management ponds likely will be constructed at the highest ground elevation on the playa as is practical to facilitate gravity delivery of water to the habitat and dust suppression water distribution system. The ponds will provide a blend of agricultural return flow water and Salton Sea water to the habitat and water-dependent dust-suppression project areas in the 2018–2023 zone exposure area. A second water management pond will be constructed in each section later in the Phase I Plan progression after the air quality and habitat projects in the 2018–2023 playa exposure zone have been started (*Appendix 4: Project Schedule*). Construction of the second water management pond will be completed prior to playa exposure in the 2023–2028 playa zone so that it can be used to supply water to habitat and air quality projects in that zone. To the extent practical, the water management ponds will be designed and constructed to provide fishery habitat.

Initial construction will start in the area to the west of the New River (Figures 2 and 3, Appendix 1) to take advantage of existing permits and authorizations. As the construction design for the area west of the New River is completed, the environmental documentation will be finalized for the remaining sites, and implementation will follow on the east side of the New River (Figures 4 and 5, Appendix 1) and the north end of the lake (Figures 10 and 11, Appendix 1). As an access plan for renewable energy is developed on the areas around the Alamo River, the water management ponds will be sequenced, with the initial pond providing water to the 2018–2023 zonecompleted first, and the second pond completed as the lake continues to recede, exposing more playa.

The habitat and dust suppression project distribution system will consists of a series of channels or pipelines that will distribute water from the water management ponds to the various habitat and dust suppression cells. The system will be designed to provide access corridors for renewable energy development. The State will coordinate with IID, Imperial County, geothermal developers, and others to assure that adequate access is maintained.

Habitat Descriptions

The State has partnered with numerous state and federal agencies along with the SSA, IID, Imperial County, Audubon, the University of California, and other academic organizations to develop and fund habitat and dust suppression projects around the Salton Sea.

The State also contracted with Audubon to develop the Audubon technical report, *Quantifying Bird Habitat at the Salton Sea* (Audubon, November 2016). The report identifies and quantifies the current acreage of each habitat type comparing it to the

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amount of habitat in previous years, and will be used to guide habitat program design. It should be noted that development of the habitat types listed below (with the possible exception of playa habitat) also will provide adequate dust suppression in those areas. The different habitat types identified by the report, their importance, and their potential development opportunities are as follows:

Permanent Wetlands with Vegetation

This habitat type is primarily located around the Salton Sea where the agricultural drains back up and flood or where land is deliberately flooded for habitat. Vegetation varies from invasive species such as tamarisk to cattails and bulrush. It is unclear if this habitat type will persist or be recreated at the Salton Sea. The current selenium bioaccumulation mitigation process is to maintain salinity of the various habitat types at a level that precludes or significantly reduces the growth of vegetation within the habitat areas. The SSMP planning process will evaluate the existing areas and the potential for developing additional areas.

Dry Playa Habitat

Exposed dry playa provides some specific nesting and general foraging habitat value, particularly near the water shoreline. This habitat type will tend to follow the receding shoreline and will likely always be part of the Salton Sea ecosystem in areas immediately upslope of the existing shoreline. However, as the salinity of the center lake area increases, it could change the invertebrate population, thus reducing the forage opportunity for the lake's existing bird population.

Therefore, additional playa habitat might be created or marginal habitat may be enhanced with small woody debris and sparse vegetation to further promote nesting areas. These areas could be incorporated into the shallow habitat cells by fluctuating water elevations on the shoreward edge of the cell, or less emissive playa areas might be identified and developed as habitat.

Mudflat, Sandflat, and Beach Habitat

This habitat type is the water/land interface (from wet substrate to less than 0.5 feet of water depth) along the lake shoreline. This habitat type is likely to continue at the lake as the water elevation decreases. The beach areas are normally high in invertebrate populations (insect and other arthropods) and provide foraging habitat for birds, but the extent and quality of the habitat may be degraded by increased salinity. As salinity increases, the invertebrate population may change from less salt-tolerant species to more salt-tolerant species, though it is unclear how, or if, this colonization will occur. Changes in the invertebrate population in turn may impact bird species with specific diets.

The Red Hill Bay project, currently under construction, will contain areas of this habitat type as a foraging area for shore and wading birds. The SCH will have areas of this habitat type along the shallow shoreline and around some of the island structures. The

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SSMP shallow water habitat will contain areas of this habitat type along the shallower end of each pond.

Mid- and Deep-Water Habitat

The Audubon report described mid-water and deep-water as two different habitat types; they are combined here because it may be easier from a construction and management perspective to have both habitat types in one cell. The water depth in this habitat ranges from half a foot to more than 6 feet in depth. This type of habitat provides forage and refuge for fish and marine invertebrate populations. While there will be a considerable amount of mid- to deep-water habitat at the lake, the increases in salinity will likely render this habitat unsuitable for fish reproduction.

The areas noted below are designed, or could be modified, to provide initial mid- and deep-water habitat.

Species Conservation Habitat Project (SCH)

SCH is specifically designed as fish and avian habitat and will have areas that are more than 6 feet deep to accommodate a sustainable fishery. The project is located to the immediate east of the New River on exposed playa. It will be supplied water from an adjacent mixing basin that receives agricultural return flow water from the New River and saline water from the Salton Sea.

Torres- Martinez Wetland Project

The Torres-Martinez project on the north end of the lake is a mid- and deep-water habitat that should be suitable for fish. This project and the SCH will be used to evaluate construction and operation techniques to inform later development of mid- to deep-water habitat.

Water Management Ponds

The water management ponds included in the water backbone infrastructure may also serve as habitat for fish. These ponds will have berms that are six feet or less above the ground surface and likely will not impound water much higher than five feet above the ground surface. However, much of the material to build the berms will be excavated from the interior of the management pond and the total water depth will be deeper.

Red Hill Bay

While Red Hill Bay is generally considered shallow water habitat, there will be some areas of deeper water within the ponded areas. Additional evaluation is necessary to determine if these areas will sustain fish populations.

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Habitat Implementation

Habitat projects associated with the first water management ponds will be concentrated in the 2018–2023 playa exposure zone based on the annual exposure, although some habitat or dust suppression projects might be included in the lower elevations of the 2003–2018 playa exposure zone, depending on actual playa exposure and site logistics.

The Red Hill Bay and the SCH are located in the 2002–2018 playa exposure zone. Along with the planned water management ponds, they will cover portions of the 2003–2018 playa exposure zone as they dry, thus reducing or eliminating potential dust emissions from those areas. The State will work with ICAPCD and IID to locate BACM pilot projects in the 2003–2018 playa exposure zone to further reduce the potential for dust emissions. Additional habitat will be planned for the 2018–2023 and 2023–2028 exposed areas. To the extent practical, the SSMP will strive to provide multiple benefit projects that combine dust suppression with habitat enhancement and other positive benefits.

From approximately 2019 to 2021, the second series of water management ponds will be constructed on 2003–2018 exposed playa zone to provide water to the 2023–2038 playa exposure zone. Actual construction of habitat and dust suppression projects in the 2023–2028 zone will commence when portions of that area are dry enough to allow equipment access.

Air Quality Planning and Implementation

The SSMP air quality component is modeled after the IID/Water Transfer Joint Power Authority air quality mitigation program (*Salton Sea Air Quality Mitigation Program*, IID July 2016) for the Imperial Irrigation District Water Conservation and Transfer Project. The SSMP recognizes the four-step process outlined in the final EIR/EIS and concentrates on *Step 2 – Implementing a Research and Monitoring Program* to define the parameters of dust suppression needs and identify solutions, and *Step 4 – Implementing Feasible Dust Suppression Projects* (BACM pilot projects) at the Salton Sea.

The State's SSMP air quality mitigation program will include coordination with IID, Coachella Valley Water District, QSA Water Transfer Joint Powers Authority, SCAQMD, ICAPCD, and CARB to develop BACM and to further develop and implement the emission monitoring process. The *Salton Sea Air Quality Mitigation Program* (IID July, 2016) contains more details on the air quality mitigation effort.

The SSMP envisions a mix of both water-dependent and waterless dust suppression projects in all phases of the SSMP. Ongoing evaluations of the criteria for determining which dust suppression techniques will be used in specific areas will continue as the QSA Water Transfer Air Quality Mitigation Program and the SSMP are developed. Some of the techniques, such as enhanced vegetation, could be considered waterless

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measures if designed to intercept the groundwater level, but they would require surface water for establishment. Many of these techniques are currently being evaluated for efficacy and longevity in the 2003–2018 playa exposure zone. Most of the methods have not been in place long enough to determine longevity or durability, but evaluations will continue.

Water Dependent

The water-dependent dust suppression includes all water impoundment areas (both water management ponds and habitat) as well as vegetation enhancement techniques, and salt or surface crust formation areas. Currently, the SSMP design team is evaluating the potential for seasonal flooding of some areas to provide habitat during migration or nesting seasons, and then reduction of water levels to keep the surface near saturation, which should provide dust suppression. Vegetation enhancement requires some amount of water to irrigate the plant material and leach salts out of the upper portion of the root zone.

Salt crust formation requires some amount of water to form the crust and periodic inundation to stabilize the crust. Initial evaluations of naturally formed salt and surface crusts around the sea (DRI and IID PISWERL results) suggest that the surface crusting weakens with conditions of lower temperature and higher humidity (approximately December - March). More evaluation is needed to determine if the weakening of the crust is sufficient to cause those areas to fail stability testing. Additional evaluation of salt crusts and the development of better emissivity determination techniques, already underway as part of the QSA Water Transfer Mitigation program, will continue as part of the initial phases of the SSMP.

The following table summarizes the projected unit costs for water-dependent dust suppression methods. These costs will likely change as the evaluation process continues.

Table 3. Projected Cost for Water-Dependent Dust Suppression Techniques

DUST SUPPRESSION METHOD	COST PER/ACRE
Vegetation Enhancement	$9,000
Vegetation Swale	$17,000
Managed Vegetation	$25,000
Shallow Flood	$25,000
Brine Stabilization	$21,000

The State, IID, Torres-Martinez, and other landholders are also considering groundwater wells that tap the shallow aquifer to supply water to the enhanced vegetation areas. Much of this aquifer is a result of perched water from agricultural irrigation. While there are some concerns with water quality, this process may provide water to some areas that lack access to a surface water supply. The north end has the most potential for near-surface groundwater, but there are other areas where the

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techniques may be used. The costs for this dust suppression technique have not been developed. The IID/Water Transfer Joint Power Authority air quality management team is currently monitoring groundwater elevations in a number of sites around the lake.

Waterless

The waterless dust suppression techniques may require an initial application of water, but generally do not dependent on periodic application of surface water. Some of these treatments cost less than some water-dependent treatments, but may require more operation and maintenance. Projected unit costs for these methods are noted below. These preliminary cost estimates will change as more information is developed. Some of these methods are currently under evaluation for longevity and efficacy in several areas around the Salton Sea.

Table 4. Projected Cost for Waterless Dust Suppression Techniques

DUST SUPPRESSION METHOD	COST PER/ACRE
Surface Roughening	$400
Moat and Row	$14,000
Suppressants/Surface Stabilizers	$2,000
Gravel Cover (2 inch)	$36,000
Gravel Cover (4 inch)	$48,000

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Projected Costs and Funding

Project Costs

Cost projections for the various components of the Phase I Plan have been developed with the best available information. Projected costs include planning and design costs that are concentrated in the first years of the plan. The developed designs will be used throughout the 10-year implementation of the Phase I plan. The estimates are based on developing habitat in all of the shaded areas (except for renewable energy access or other identified land uses). These projections will change as additional information becomes available on site logistics and on the actual costs of the initial projects. Costs for the Red Hill Bay project and the SCH are not included in the projected costs as they are funded under other sources.

Appendix 3 includes a cost breakdown based on unit costs for each year. Annual costs, constructed acreage and funding availability are summarized in the following table:

Table 5. Projected Annual Cost, Acres Constructed, and Funding of SSMP Phase I 10-Year Plan

YEAR	NEWLY EXPOSED ACRES	PROPOSED CONSTRUCTION	PROJECTED TOTAL COST	AVAILABLE FUNDING	BALANCE
2018	3,500	500	$10.0 M	$10.0 M	($0.0) M
2019	4,200	1,300	$27.0 M	$27.0 M	($0.0) M
2020	5,000	1,700	$35.5 M	$35.5 M	($0.0) M
2021	5,600	3,500	$43.5 M	$7.5 M	($36.0) M
2022	5,500	1,750	$33.5 M	-	($33.5) M
2023	5,300	2,750	$35.5 M	-	($35.5) M
2024	4,900	2,700	$34.0 M	-	($34.0) M
2025	4,300	3,400	$42.5 M	-	($42.5) M
2026	3,900	4,000	$47.5 M	-	($47.5) M
2027	3,300	4,000	$37.5 M	-	($37.5) M
2028	2,800	4,200	$36.5 M	-	($36.5) M
TOTAL	**48,300**	**29,800**	**$383.0 M**	**$80.0 M**	**($303.0) M**

Expenditure Reporting and Process Accountability

CNRA will report each fiscal year on prior year expenditures made for SSMP implementation, availability of funds for future expenditures, and changes to the SSMP program.

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Existing Funding

Water Bond Funding (Proposition 1)

Proposition 1, the $7.5 billion water bond passed by California voters in 2014, provided $80.5 million to fund development, permitting, and implementation of the SSMP. This funding is available over the next several years. The expenditure of these funds is reflected in the existing funding column of Table 5 above.

Wildlife Conservation Board Funding for SSMP Projects

The California Wildlife Conservation Board (WCB) approved a $14 million grant in November 2016 to help fund the SSMP's SCH. The grant, along with approximately $21 million from Proposition 84, will fund the construction of an approximately 640-acre aquatic habitat area to support a fishery and provide habitat for Salton Sea avian species.

In 2013, the WCB funded the design and construction of the electrical power distribution system through a grant to IID. The WCB also awarded an approximately $1.85 million grant to the IID to begin work on the Red Hill Bay project, a joint venture project with IID, U.S. Fish and Wildlife, Sonny Bono Salton Sea National Wildlife Refuge, and the State of California.

U.S. Department of Agriculture

The U.S. Department of Agriculture (USDA) recently approved the Salton Sea Regional Conservation Partnership Program to address habitat, air, and water quality on agricultural lands around the Salton Sea. The SSA will administer the $7.5 million grant for water conservation, wetland creation, and air quality mitigation. The wetland creation and air quality management portions of the grant will be used to develop pilot BACM projects and wetland habitat projects on parcels with an agricultural history.

The USDA funding is not included in the projections above. As the program is finalized and grantees are identified, the funding will be accounted for in the annual expenditure reporting process. The success of this grant program is intended to be a proof-of-concept for potentially larger-scale USDA funding. This program could be expanded to include non-agricultural lands at the Salton Sea.

Potential Funding Sources

Water Transfer Joint Powers Authority

The State will work with the members of the Water Transfer Joint Powers Authority to determine if funding included in the existing mitigation program can be utilized for SSMP projects that further the goals of the Water Transfer mitigation program. Currently the

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State and IID are exploring acceleration of air quality mitigation efforts that will benefit both programs. The cost of the additional research into determining playa emissivity and methods that suppress dust are projected to range from $5 million to $8 million..

DOI/CNRA Memorandum of Understanding Funding

The MOU between DOI and the CNRA identified a framework for collaboration at the Salton Sea. The MOU calls for $30 million in federal funding over the next ten years for activities associated with the SSMP.

The amendment to the MOU further defines State and federal responsibilities related to dust emissions from the exposed playa at the Salton Sea.

Philanthropic Organizations

The Water Funder Initiative, a collaborative of leading philanthropic organizations, has committed to raise $10 million over the next five years to support implementation of a comprehensive plan to protect public health and the environment and promote renewable energy development at the Salton Sea.

Water Resource Development Act Funding

The Water Resources Development Act (WRDA) of 2016 maintains the $30 million funding identified in the 2007 WRDA bill. The U.S. Army Corps of Engineers (Corps) administers the part of the program pertinent to the Salton Sea. The 2016 Act recognizes the SSA as a preferred partner for funding agreements with the Corps. The 2016 Act also streamlines the methodology for the development and approval of related projects. This funding has not been appropriated.

USDA Partnerships and Funding

After successful implementation of the USDA/SSA grant noted above, additional funding may be possible through development of a partnership between the USDA and the SSMP using the Farm Bill (the Watershed Protection and Flood Prevention Act [PL566]). This program could address air quality, water quality and habitat on non-agricultural lands on and adjacent to the Salton Sea playa. This could include allowing public lands that endanger public health to be included in the USDA's Reserve Enhancement Program or the Environmental Quality Incentives Program.

Additional State and Local Funding

Funding and in-kind support may be available through future state appropriations, water agencies, local infrastructure financing districts, geothermal leases, and other public and private sources. The State will describe its ongoing evaluation of potential funding sources in the annual expenditure reporting process

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Development of Planning Criteria for Additional Phases of the SSMP

The State is committed to continuing the SSMP process and will also work with the SSMP Science Committee, other committees, and stakeholders to evaluate concepts for later phases of the SSMP. The evaluation will include a hydrologic analysis to estimate inflows to the lake and water quality concerns that might impact both the current and later phases of SSMP. Specific areas of concern for evaluation by the Science, Project, and Long Range Planning Committees include:

Determine Habitat Functional Values

State and federal wildlife agencies, Audubon, and other stakeholders, in cooperation with the Science Committee, will develop additional analysis to evaluate the carrying capacity of created habitat versus existing habitat.

Determine Water Use

There is no issue with water availability for the Phase I Plan. However, water demands for the later phases must be calculated and compared to the revised inflow models to determine water availability in the longer term.

Salinity

The Science Committee will work with the stakeholders to evaluate the impact of salinity on the various habitats at the Salton Sea. While a range of salinity has been established for the habitat areas, the Science Committee will evaluate that range to determine its effectiveness.

Water Quality in Constructed Habitat

The Science Committee will evaluate the potential water quality issues associated with the constructed habitat. The water quality parameters will include an evaluation of methods to control nutrient concentrations, metal concentrations, biological/chemical oxygen demand, and other water column constituents. The evaluation of various water quality treatments (treatment wetland cells, bioreactors, algal uptake, and chemical treatments) may also be evaluated.

Selenium Management

Currently, the management of selenium bioaccumulation is based on managing salinity to reduce or eliminate vegetation, thus interrupting, or at least restricting, the bioaccumulation pathway. The Science Committee will look at other potential methods that might be more effective in selenium management.

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Development of Best Available Control Measures

The State will work with IID and ICAPCD to integrate the development of BACM into the habitat design.

Harbor and Ancillary Facilities

Evaluate the potential for reconnecting, inundating, or treating harbors and boat docks along the east and west sides of the lake as part of the SSMP, and for reducing odor and vector issues. In some cases, this could include making the harbor functional for shallow draft boats.

Water Import Projects

Before consideration by the SSMP, the State will require that any water import project proposal include an engineering and logistic feasibility study conducted on behalf of the proponent by an accredited or licensed engineering, planning, or equivalent organization recognized by the State of California. The criteria for consideration of any such proposal will include the following requirements: (1) identify planning, development, construction, and operation costs, and (2) identify the funding source for each. Specifics on how the proposal would address salinity and other water quality concerns will also be required. Schedules detailing the phases and funding needs of each project must be provided.

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Adaptive Management, Monitoring, and Contingency Planning

Adaptive management will be fundamental to the success of the SSMP. The adaptive management program will include review by the SSMP Science Committee, the other SSMP committees and the Salton Sea stakeholders. The program relies heavily on the early development of projects (SCH, Red Hill Bay, and other areas) to test aspects of design, construction, and management. These early lessons learned will be valuable in the efficient and economic development of later phases of the SSMP.

An adaptive monitoring program is under development and will be implemented by the State. It will include the identification of a fish stocking program for the SCH (and later habitat), development of a monitoring and management program for existing avian and fishery habitat, and a water quality monitoring program. It is anticipated that a draft of the plan will be available in 2017. Additionally, the California Department of Fish and Wildlife is in the process of evaluating a potential wider-scale monitoring program for the lake that could be combined with the current U.S. Bureau of Reclamation monitoring efforts and ongoing efforts of others. The monitoring program will be developed in compliance with the USGS guidelines for the Salton Sea monitoring and will utilize existing data to the extent practical.

At this point, the Phase I Plan is not fully funded. The State will continue to monitor the existing and potential funding sources and measure those against the projected costs for the projects in the implementation plan. Adjustments may be required to the plan to maintain adequate dust suppression in some areas while delaying the construction of water infrastructure and habitat (the more costly components). The State will coordinate with the stakeholders as adjustments to the Phase I Plan are considered.

The development of this contingency process will be evaluated starting in 2018 and will be done in two- to five-year increments over the course of the Phase I Plan. As part of the initial tasks undertaken in Phase I, a series of specific metrics will be developed to help assess funding opportunities and match them against projected costs for Phase I.

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Outreach

The State is committed to a transparent and open process in the development and implementation of the SSMP. To that end, a set of advisory committees has been formed that meet periodically to discuss specific topics. Those committees include a Science Advisory Committee and committees on air quality, long-range planning, and a public outreach committee. The Public Outreach Committee conducted a series of 13 public outreach meetings around the greater Salton Sea area from April to August 2016 to introduce the SSMP to the public and to solicit input on Salton Sea issues and concerns.

The UC Riverside and UC Irvine Salton Sea programs conducted a series of voluntary surveys of meeting participants (pre- and post-meeting) to gauge the effectiveness of the communication effort. Approximately 43 percent of meeting attendees participated in the surveys. Approximately 36 percent felt they had gained knowledge on the Salton Sea and indicated an increase in their belief that the State was actively addressing issues at the Salton Sea. When asked to prioritize the issues of concern at the Sea, they identified environmental health, public health, and nature as their top three concerns.

One of the things identified after the last series of meetings was the difficulty in contacting some communities and the need to have more robust environmental justice outreach. CNRA, with support from State Water Resources Control Board, developed a communication plan that addresses those concerns and will help guide future outreach efforts. The State is working with several outreach firms and is developing a social media outreach program.

In order to provide ample time for public input into this plan, the SSMP will schedule several regional workshops to solicit input from community members and stakeholders as well as provide necessary time for general public comment. This process will be announced via the program's website http://resources.ca.gov/salton-sea/.

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Conclusion

As the Salton Sea shrinks for a variety of reasons, air quality in Riverside, Imperial, and surrounding counties suffers, because particulates small enough to be dangerous to human health are picked up by the wind from the exposed lakebed. Huge populations of resident and migratory birds are at risk, too, especially the fish-eating birds that depend upon the tilapia that will no longer be able to survive in the Salton Sea if it grows increasingly salty. Sustainable habitat and air quality management at the Salton Sea is critical for the protection of regional public and ecological health, as well as the management of a stable Colorado River supply for California.

This draft Phase 1 Plan aims to protect public health and wildlife by focusing on the north and south ends of the sea where playa exposure is expected to be greatest and availability of agricultural return flows facilitate lowest cost habitat and air quality project development. The draft plan also includes a process for identifying management strategies for implementation in later phases.

As inflows to the Salton Sea decline over the next decade, this 10-year draft plan aims to mitigate harm to communities and ecosystems. The State is committed to leveraging resources, coordinating with a multitude of other agencies, engaging stakeholders, managing adaptively and learning as much as possible from the wildlife habitat and dust suppression projects now or soon to be underway.

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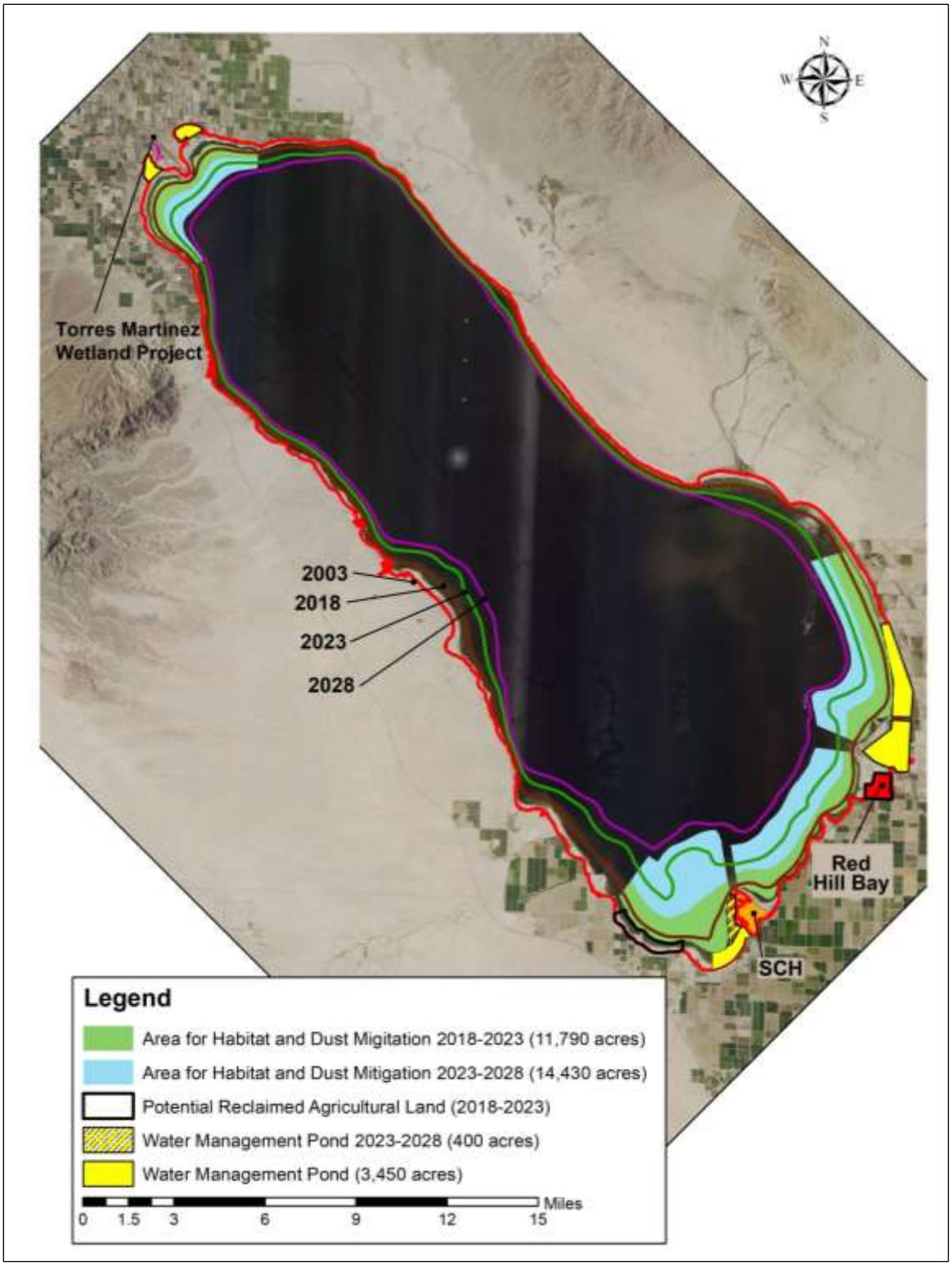
Appendix 1. Figures

Figure 1. Salton Sea Management Program Overview (2018–2028)



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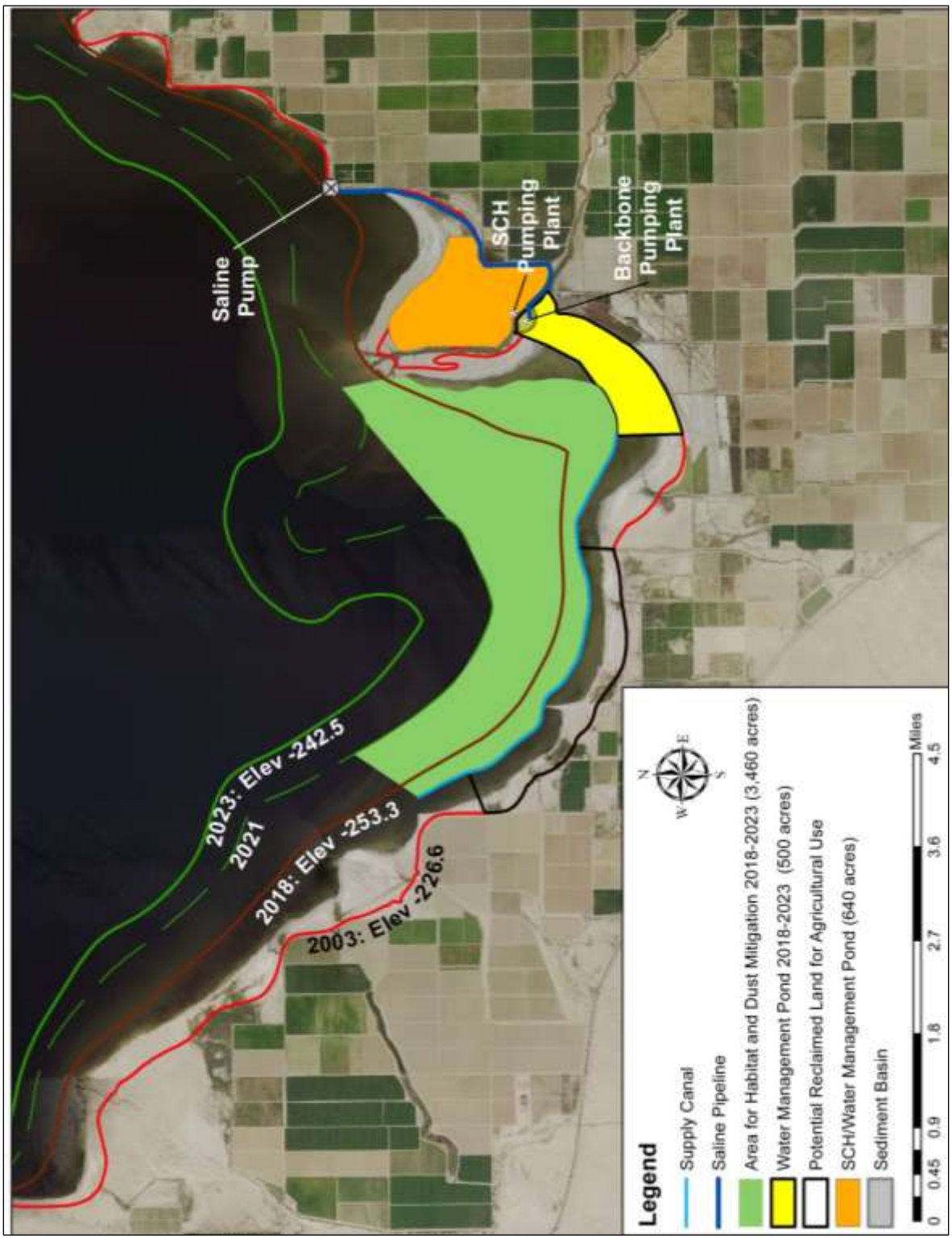

Figure 2. Salton Sea Management Program - SCH Phase 2 (2018-2023)

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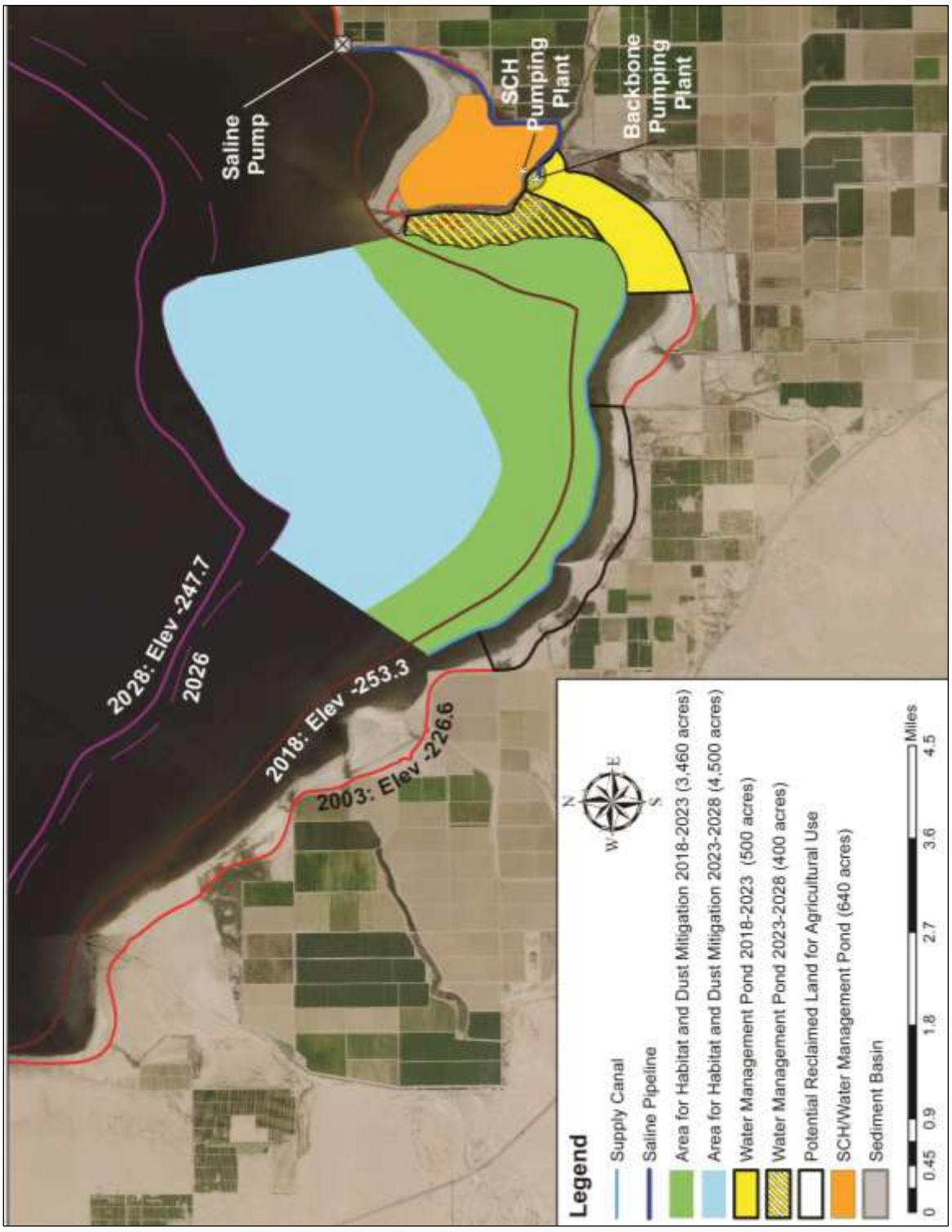

Figure 3. Salton Sea Management Program - SCH Phase 2 (2023–2028)

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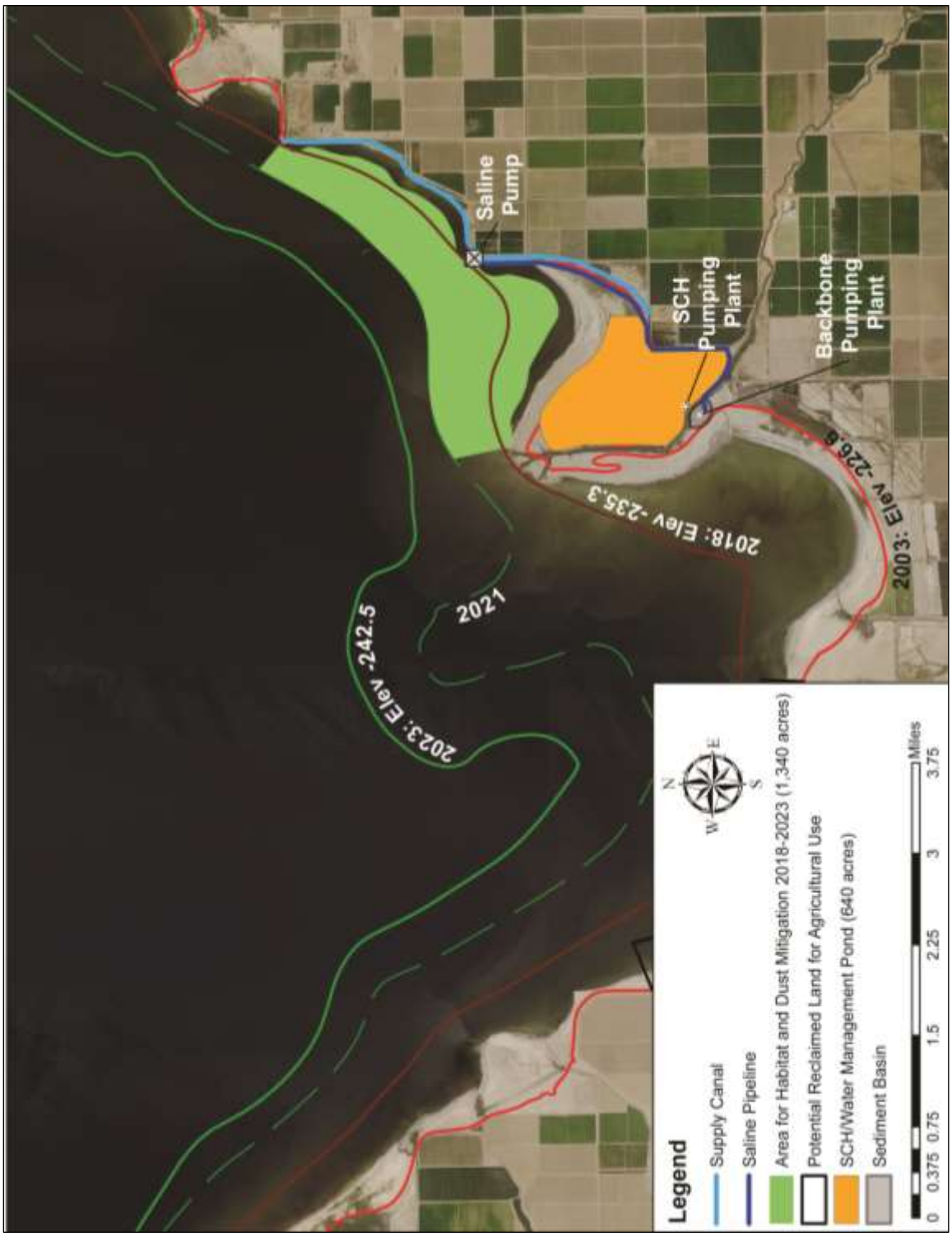

Figure 4. Salton Sea Management Program - New River East (2018–2023)

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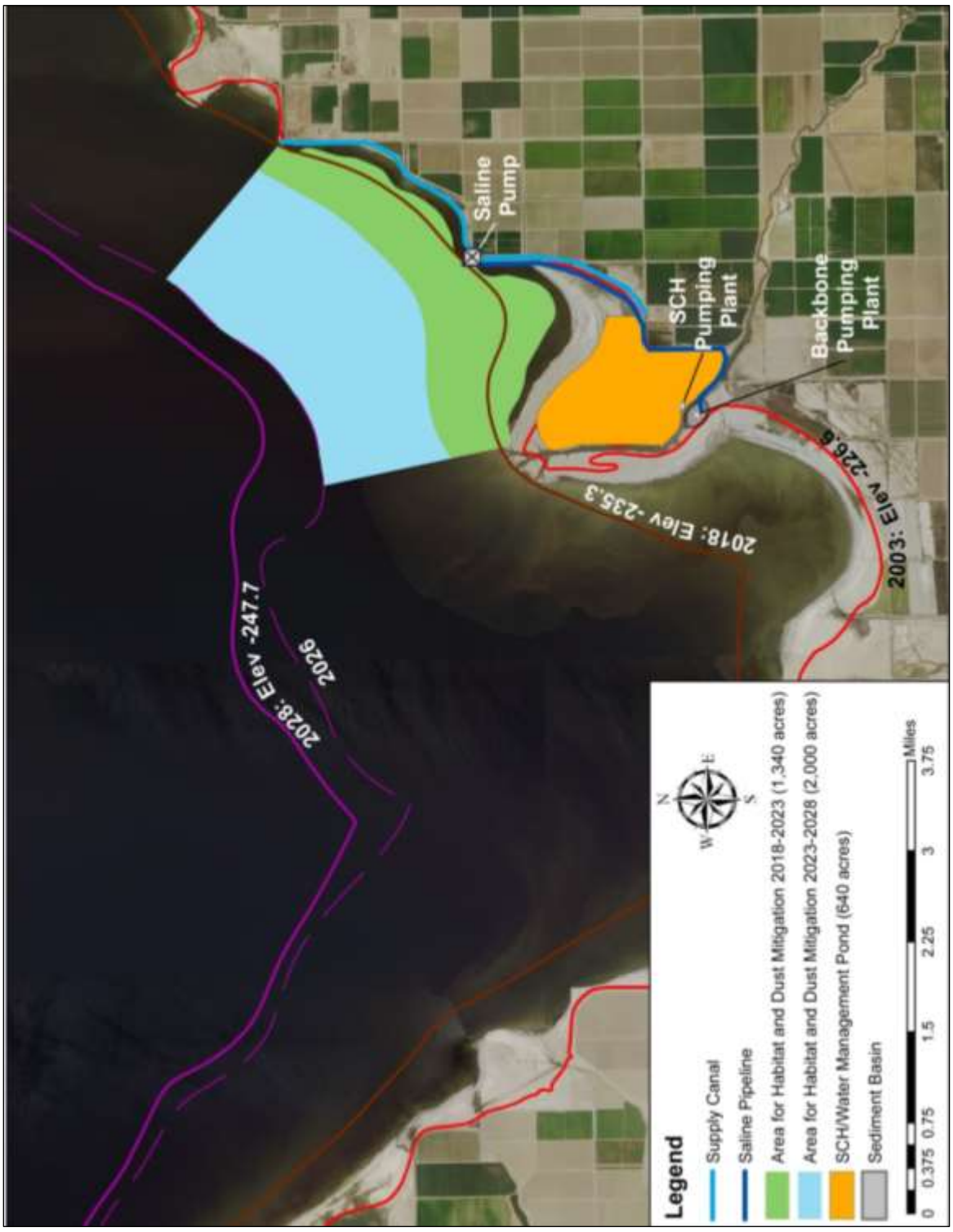

Figure 5. Salton Sea Management Program – New River East (2023–2028)

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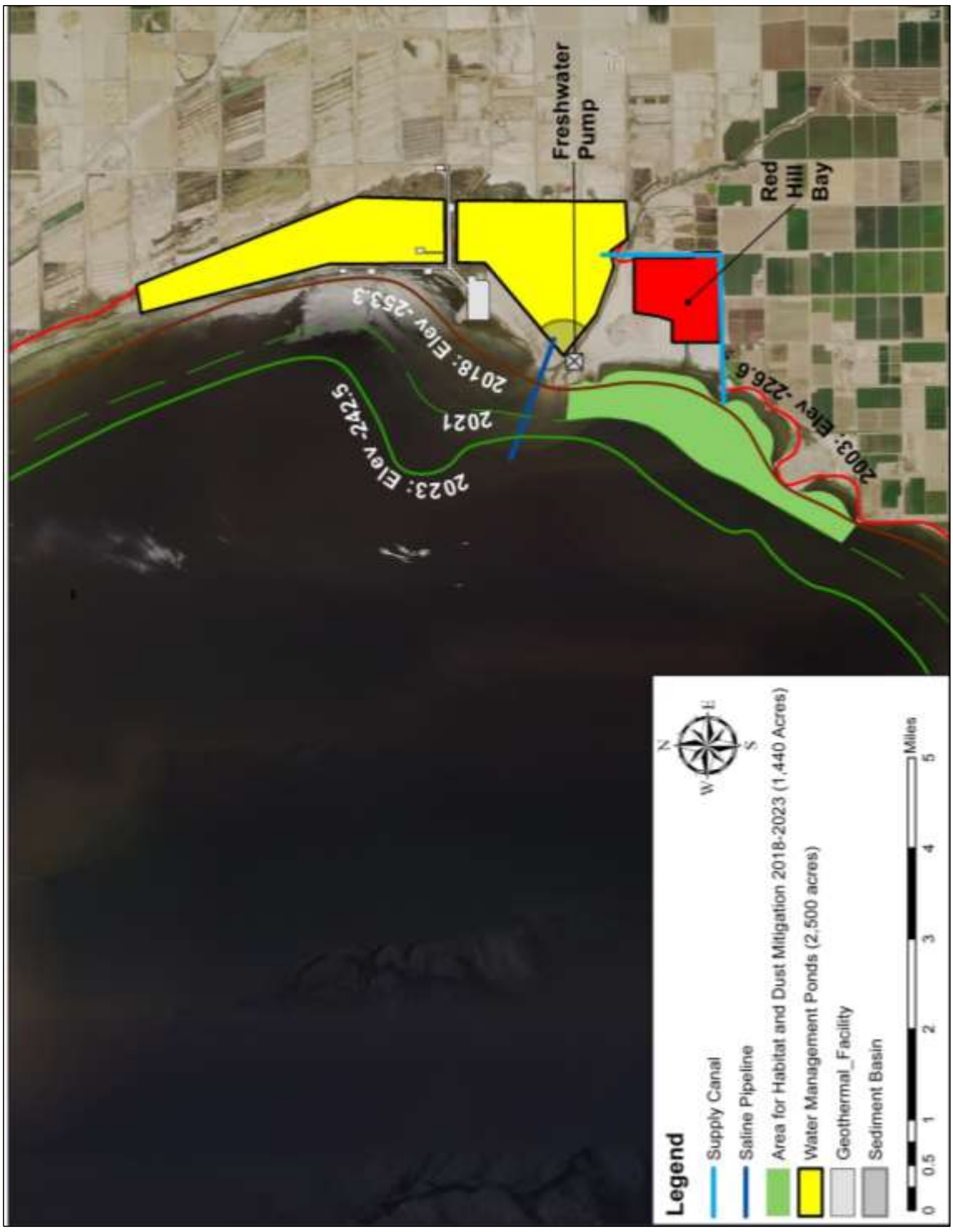

Figure 6. Salton Sea Management Program – Alamo River South (2018–2023)

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Figure 7. Salton Sea Management Program – Alamo River South (2023–2028)

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Figure 8. Salton Sea Management Program – Alamo River North (2018–2023)

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Figure 9. Salton Sea Management Program – Alamo River North (2023–2028)

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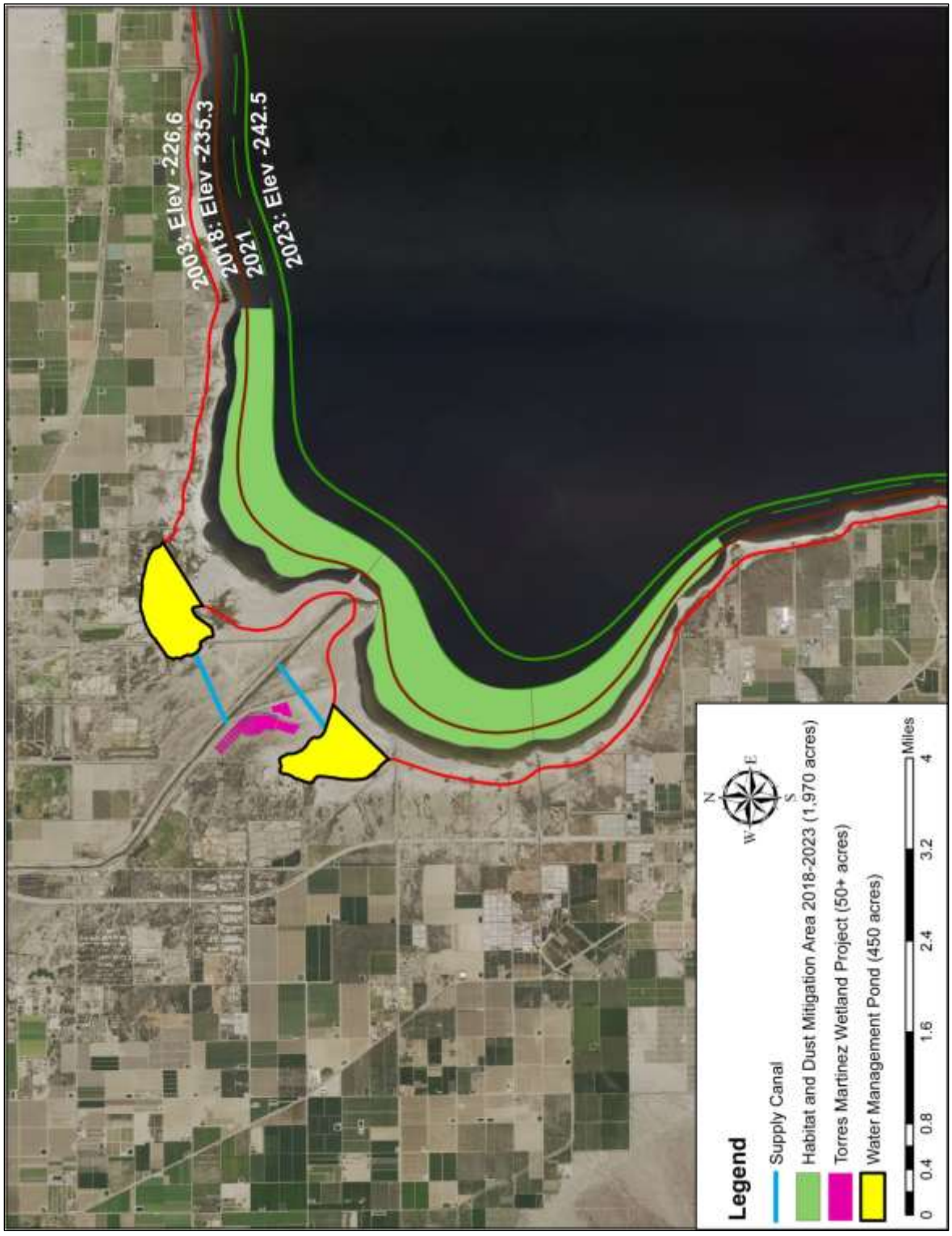

Figure 10. Salton Sea Management Program – Whitewater River (2018–2023)

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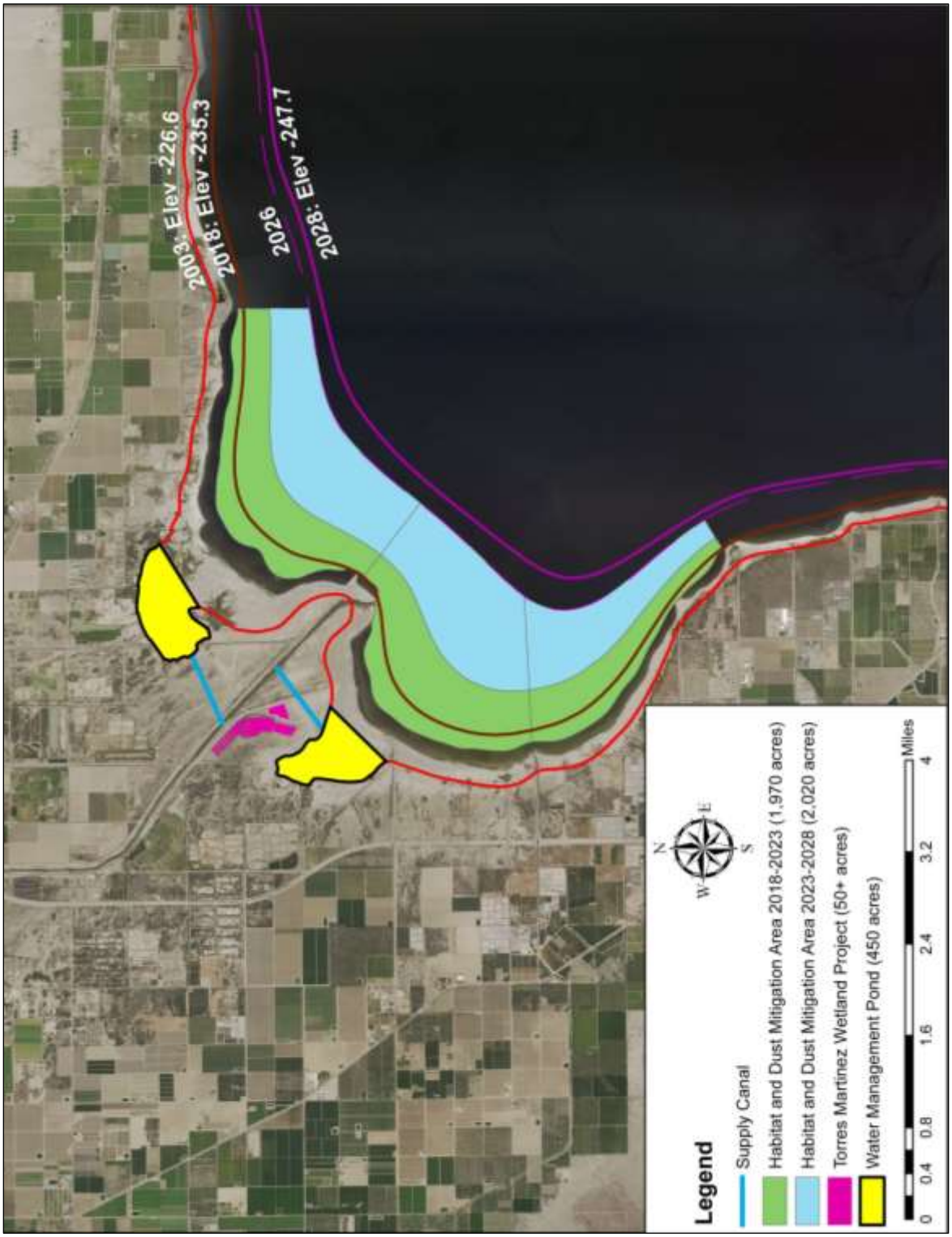

Figure 11. Salton Sea Management Program – Whitewater River (2023–2028)

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Table 3-1

	NEW RIVER WEST	NEW RIVER EAST	ALAMO RIVER SOUTH	ALAMO RIVER NORTH	ALAMO COMBINED	WHITEWATER RIVER
BBI (acres)	900	640	1,250	1,250	2,500	450
Habitat (acres)	8,000	3,400	3,600	7,200	10,800	4,000
Channel (ft)	-	-	-	-	-	-
Pipelines (ft)	23,239	10,513	18,613	18,613	18,613	7,493
Pumps	3,750,000		3,750,000	3,750,000	3,750,000	3,750,000
2018–2023 Low berm (ft)	69,626	42,281	44,506	88,796	133,301	86,123
2023–2028 Low berm (ft)	30,548	23,807	25,999	47,159	73,159	36,640
2018–2023 Pond high berm (ft)	25,191	-	32,600	42,489	75,089	28,148
2023–2028 Pond high berm (ft)	24,154					
Spillways	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
Flow control structures	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
River crossing structure	$25,000	-	$25,000	$25,000	$25,000	
Flood control measure (River banks)	$2,112,000		$2,112,000	$2,112,000	$2,112,000	$2,112,000
Electrical	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
Habitat features						
Design	$7,691,145	$1,943,858	$5,412,207	$7,722,339	$12,142,247	$5,800,410
Contingency - CT	$11,536,718	$2,915,788	$8,118,310	$11,583,508	$18,213,370	$8,700,615
Mobilization/Site prep	$6,991,950	$1,767,144	$4,920,188	$7,020,308	$11,038,406	$5,273,100
Construction mgmt (15%)	$10,487,925	$2,650,716	$7,380,282	$10,530,462	$16,557,609	$7,909,650
TOTAL COST	**$76,911,450**	**$19,438,584**	**$54,122,068**	**$77,223,388**	**$121,422,466**	**$58,004,100**
TOTAL COST + CT + MOBIL + MGMT	**$106,627,238**	**$26,948,946**	**$75,032,867**	**$107,059,697**	**$168,335,692**	**$80,414,775**

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Table 3-2

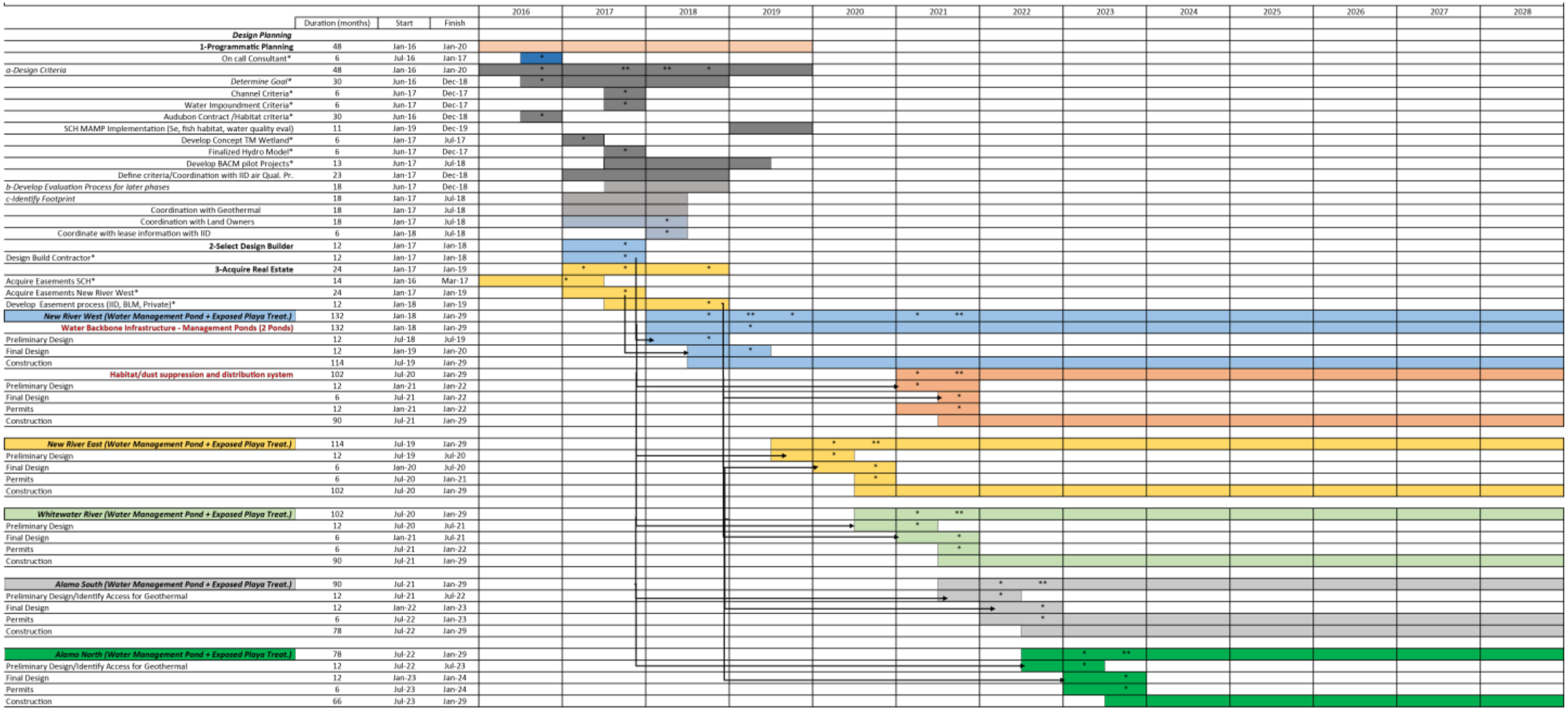
YEAR	COST	ACRES
2018	$10.00	500
2019	$27.00	1,300
2020	$35.50	1,700
2021	$43.50	3,500
2022	$33.50	1,750
2023	$35.50	2,750
2024	$34.00	2,700
2025	$42.50	3,400
2026	$47.50	4,000
2027	$37.50	4,000
2028	$36.50	4,200
TOTAL	**$383.00**	**29,800**

Table 3-3

	UNIT	UNIT COST	SOURCE
Saline Pump Station (45 cfs)	each	$2,500,000	DWR/DOE (SCH)
River Pump Station (75cCfs)	each	$1,250,000	DWR/DOE (SCH)
Berm (Water Storage)	foot	$800	IID/DWR/DOE (SCH)
Berm (Low Berm)	foot	$200	IID/DWR/DOE (SCH)
HDPE Pipeline			
24 Inch	foot	$225	DWR/DOE (SCH)
36 Inch	foot	$300	DWR/DOE (SCH)
Flow Control Structures	each	$100,000	DWR/DOE (SCH)
Outlets/Spillways	each	$50,000	DWR/DOE (SCH)
River Crossing Structure	each	$25,000	DWR/DOE (SCH)
Access Roads	foot	$150	DWR/DOE (SCH)
Habitat Features			
Tall Island	each	$200,000	DWR/DOE (SCH)
Loafing Island	each	$30,000	DWR/DOE (SCH)
Small Island	each	$100,000	DWR/DOE (SCH)
Habitat Channel	foot	$10	DWR/DOE (SCH)
Sheet Piles	foot	$200	DWR/DOE (SCH)
Electrical Work		$1,000,000	IID - SCH

Appendix 3. Ten-Year Phase I Plan Schedule

	Duration (months)	Start	Finish
Design Planning			
1-Programmatic Planning	48	Jan-16	Jan-20
On call Consultant*	6	Jul-16	Jan-17
a-Design Criteria	48	Jan-16	Jan-20
*Determine Goal**	30	Jun-16	Dec-18
Channel Criteria*	6	Jun-17	Dec-17
Water Impoundment Criteria*	6	Jun-17	Dec-17
Audubon Contract /Habitat criteria*	30	Jun-16	Dec-18
SCH MAMP Implementation (Se, fish habitat, water quality eval)	11	Jan-19	Dec-19
Develop Concept TM Wetland*	6	Jan-17	Jul-17
Finalized Hydro Model*	6	Jun-17	Dec-17
Develop BACM pilot Projects*	13	Jun-17	Jul-18
Define criteria/Coordination with IID air Qual. Pr.	23	Jan-17	Dec-18
b-Develop Evaluation Process for later phases	18	Jun-17	Dec-18
c-Identify Footprint	18	Jan-17	Jul-18
Coordination with Geothermal	18	Jan-17	Jul-18
Coordination with Land Owners	18	Jan-17	Jul-18
Coordinate with lease information with IID	6	Jan-18	Jul-18
2-Select Design Builder	12	Jan-17	Jan-18
Design Build Contractor*	12	Jan-17	Jan-18
3-Acquire Real Estate	24	Jan-17	Jan-19
Acquire Easements SCH*	14	Jan-16	Mar-17
Acquire Easements New River West*	24	Jan-17	Jan-19
Develop Easement process (IID, BLM, Private)*	12	Jan-18	Jan-19
New River West (Water Management Pond + Exposed Playa Treat.)	132	Jan-18	Jan-29
Water Backbone Infrastructure - Management Ponds (2 Ponds)	132	Jan-18	Jan-29
Preliminary Design	12	Jul-18	Jul-19
Final Design	12	Jan-19	Jan-20
Construction	114	Jul-19	Jan-29
Habitat/dust suppression and distribution system	102	Jul-20	Jan-29
Preliminary Design	12	Jan-21	Jan-22
Final Design	6	Jul-21	Jan-22
Permits	12	Jan-21	Jan-22
Construction	90	Jul-21	Jan-29
New River East (Water Management Pond + Exposed Playa Treat.)	114	Jul-19	Jan-29
Preliminary Design	12	Jul-19	Jul-20
Final Design	6	Jan-20	Jul-20
Permits	6	Jul-20	Jan-21
Construction	102	Jul-20	Jan-29
Whitewater River (Water Management Pond + Exposed Playa Treat.)	102	Jul-20	Jan-29
Preliminary Design	12	Jul-20	Jul-21
Final Design	6	Jan-21	Jul-21
Permits	6	Jul-21	Jan-22
Construction	90	Jul-21	Jan-29
Alamo South (Water Management Pond + Exposed Playa Treat.)	90	Jul-21	Jan-29
Preliminary Design/Identify Access for Geothermal	12	Jul-21	Jul-22
Final Design	12	Jan-22	Jan-23
Permits	6	Jul-22	Jan-23
Construction	78	Jul-22	Jan-29
Alamo North (Water Management Pond + Exposed Playa Treat.)	78	Jul-22	Jan-29
Preliminary Design/Identify Access for Geothermal	12	Jul-22	Jul-23
Final Design	12	Jan-23	Jan-24
Permits	6	Jul-23	Jan-24
Construction	66	Jul-23	Jan-29



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Appendix 4. DOI/CNRA MOU with Amendment

MEMORANDUM OF UNDERSTANDING

BY AND BETWEEN

THE UNITED STATES DEPARTMENT OF THE INTERIOR

AND

THE STATE OF CALIFORNIA NATURAL RESOURCES AGENCY

REGARDING THE COORDINATION OF ACTIVITIES TO MANAGE THE SALTON SEA

I. INTRODUCTION AND BACKGROUND

The Salton Sea (Sea), an endorheic water-body, is California's largest lake and located in Imperial and Riverside Counties. The Sea is the modern incarnation of Lake Cahuilla, a prehistoric, intermittent freshwater sea that filled and evaporated multiple times over thousands of years as the Colorado River (River) meandered on its delta—shifting between emptying into the Gulf of California, or diverting northwest, into the Salton Trough.

In 1905 when the River flood flows breached an inadequate diversion structure (built by what was then the California Development Company), the full might of the River emptied once again into the basin. After 2 years the River's course was engineered back to the Gulf, and left behind was the Salton Sea. In 1924, certain specified lands beneath the Sea were designated a drainage reservoir by Presidential Order. Where the Sea would have evaporated once more, agricultural runoff from the Imperial and Coachella Valleys (with water from the Colorado River) and other sources has maintained its elevation and affected its composition over the last century.

The Sea loses approximately one million acre-feet of water a year to evaporation. Early on, the accumulation of salts and nutrients in the terminal lake, by its sustaining agricultural drainage waters, were acknowledged as a challenge to the future viability of the Sea. From the start, various studies were conducted to assess the issue, but no comprehensive actions were taken. Thirty or more species of sport fish were stocked by the California Department of Fish and Game between 1929 and 1956, and soon the Sea was enjoying more yearly visitors than Yosemite National Park. After a period of developmental boom and recreational success at the Sea, a series of storms and heavy River water use in 1977 and 1978 caused widespread flooding and inundation of seaside developments, and the properties were soon abandoned.

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Recognizing that the QSA only provided mitigation flows for the Sea through 2017, and the need for projects that would acknowledge the current and projected resource conditions at the Sea, the State established the Salton Sea Task Force, by order of the Governor of California, in May 2015. Through the work of the Task Force, the State recognizes that immediate implementation of sustainable habitat and air quality management and mitigation at the Sea through a Salton Sea Management Program is critical for the protection of regional air quality, natural resources at the sea, and the management of a stable River water supply for California. After meetings with key stakeholders, the Task Force identified acreage targets for wildlife habitat, mitigation, and other projects, and found that implementation of a successful Salton Sea Management Program depends on the following three principles: 1) strong Federal, State, and local partnerships; 2) clear and achievable milestones with State-directed plans to achieve them; and 3) committed participation from all stakeholders who share the goals of protecting air quality, reducing habitat impacts, and maintaining a secure Colorado River Water Supply. These three principles are driving State-led decisionmaking on short, medium, and long term plans and projects, and require coordinating all available fiscal and technical resources to deliver them in an expedited manner.

The United States and the State have significant and complementary interests regarding development and enhancement of activities that provide certainty to the Sea, anticipate changes in the Sea's elevation, water quality and associated regional environment, and recognize the multiple values and unique opportunities the Sea embodies in the face of a changing climate, resource constraints, and the need to build resiliency and certainty in affected Tribal and regional communities.

II. PARTIES

This Memorandum of Understanding (MOU) is entered into by and between the United States through the Department of the Interior (DOI), and the State of California, through the California Natural Resources Agency (CNRA), and, hereafter referred to as "the Agencies," and will become effective as of the latest date shown below on the signature page.

The Agencies recognize the unique role and interests of tribal governments, including jurisdiction and decisionmaking, in the future of the Sea. The United States recognizes the United States' trust responsibility to all federally recognized Indian tribes and the duty to engage in meaningful government-to-government consultation prior to any action related to the Sea that impacts a tribe. Future activities to address conditions at the Sea must recognize Federal and State responsibilities to any affected tribes pursuant to applicable law (including settlement acts) and agreements, ensure protection of trust resources, and work in a spirit of partnership with affected Indian tribes.

Though not a party to this MOU, other Federal and State agencies, local governments and agencies, and non-profit, philanthropic, and academic institutions are recognized as potentially having jurisdiction, resources, decisionmaking roles, and common interests at the Sea, and will be essential to include for successful management activities and outcomes at the Sea. The Agencies will coordinate and consult with all of these entities as appropriate to develop specific tasks, timelines, and form subsequent agreements to further future partnership at the Sea.

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III. PURPOSE

The Agencies enter into this MOU to ensure that long-term coordination between the Federal and State and Government will be recognized as a priority and will occur in order to facilitate prompt and informed decisionmaking regarding the natural and economic resources of the Sea.

The Agencies recognize that the purpose of this coordination is to facilitate specific, incremental and sequential projects in a timely manner that improve upon air and water quality, existing obligations to Native American communities, fish and wildlife habitat, water security, resource management processes and decisionmaking economic opportunities, and collaboration of scientific research efforts. Coordinating limited resources will be necessary to achieve common goals that address the natural resources and regional interests associated with the Sea.

IV. OBJECTIVES

Recognizing the State's role as lead on Sea management, in line with the findings of the Salton Sea Task Force, and the United States' agreement through this MOU to support the goals and principles of the Salton Sea Management Program (SSMP), and in furtherance of the purpose of this MOU, the Agencies affirm their commitments to undertake the following objectives:

A. In order to facilitate prompt decisionmaking, permitting accountability, and high-level coordination, the Agencies shall each identify at least one senior level policy official to participate in a Salton Sea Working Group (SSWG) tasked with ensuring interagency continuity in Sea management efforts and overseeing the implementation of—and any necessary updates to—this MOU.

B. The Agencies will work together as they coordinate with affected Colorado River Basin States, tribes, and local governments regarding implementation of this MOU.

C. The Agencies recognize that the State has identified a goal of 25,000 acres of wildlife habitat, air and water quality projects, and other projects as necessary to minimize human health and ecosystem impacts at the Sea in the mid-term (through 2025). See "Salton Sea Task Force – Agency Actions" – Attachment 1. The Agencies acknowledge this goal as critical, and a common target to reasonably work toward.

D. The Agencies will undertake an analysis of current Federal and State laws applicable to the Salton Sea to assess existing authorities, identify common objectives, explore opportunities to align authorities that benefit the purpose of this MOU, and inform areas for further coordination.

E. The Agencies will perform a funding analysis that identifies all current Federal and State spending on programs, projects, and studies related to, potentially benefiting, or impacting the Sea. The analysis should also identify opportunities to better coordinate and match existing spending and programs, and provide a foundation for further discussions on the anticipated financial need to reach acreage goals and creative means to meet them.

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F. The Agencies will, within existing authorities, perform an analysis of land ownership, any existing Indian settlement obligations, leases, and other land use agreements in the region to facilitate project development and identify necessary coordination between parties to achieve the purpose of this MOU.

G. The Agencies will, within existing authorities, expand and integrate Sea science and monitoring programs to better inform decisionmaking, coordinate investigations, and aid adaptive management of the Sea. The Agencies will also assess the cost benefit of sharing office or other physical spaces in order to reduce the cost of science activities and increase their efficacy.

H. The Agencies will pursue a multi-year partnership with United States Department of Agriculture (USDA) Natural Resources Conservation Service, tribal governments, local agencies, and others, to advance projects to protect air quality and improve water quality of major inflows to Sea habitat.

I. The Agencies shall make every effort to ensure resources are allocated to expedite and prioritize permitting processes at the Sea.

J. The Agencies will explore the feasibility of developing a common decision support system that integrates the analyses called for in this MOU, the existing wealth of studies and data on the Sea, and any additional information necessary, into a single platform that facilitates the work of the Salton Sea Management Program and the purpose of this MOU.

In furtherance of these Objectives, the United States agrees to pursue the following, in accordance with applicable statutes, and to the extent appropriate and consistent with legislative appropriations, approved budgets, and funding opportunities:

1. $20 million to operation and maintenance costs of habitat and dust suppression projects associated with the SSMP;
2. $10 million for State managed monitoring of SSMP projects;
3. Continued USGS scientific and technical support on Sea issues during the implementation of the SSMP;
4. Continued USGS scientific input on, and review of, selenium management measures and target concentrations for selenium in created habitat at Sea;
5. Consideration of a Pilot Project under Phase 2 of the Colorado River Basin Study to continue the ongoing innovative and collaborative efforts underway at the Sea to increase security for California's Colorado River water supplies, consistent with DOI's efforts to increase security for other Basin States' water supplies.

V. GENERAL PROVISIONS

A. This MOU is subject, as applicable, to the laws of the United States of America and the State.

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B. Nothing in this Agreement may be construed to obligate the United States or the State to any current of future expenditures in advance of the availability of legislative appropriations. Nor does this agreement obligate the United States or the State to spend funds on any particular project or purpose, even if funds are available.

C. The mission requirements, funding, personnel, and other priorities of the Agencies may affect their ability to fully implement all the provisions identified in this MOU.

D. Specific activities that involve the transfer of money, services, or property between the Agencies will require execution of separate agreements or contracts.

E. Nothing in this MOU is intended to or will be construed to restrict the Agencies from participating in similar activities or arrangements with other public or private agencies, organizations, or individuals.

F. Any information furnished between the Agencies under this MOU may be subject to the Freedom of Information Act, 5 U.S.C. 552, et seq. (FOIA) and the California Public Records Act, Gov. Code 6250, et.seq. (CPRA). The United States and the State agree to consult each other regarding any such relevant requests and prior to releasing potentially privileged or exempt documents, subject to any applicable regulatory, statutory, or judicial timeframe.

G. This MOU is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States or the State; their respective departments, agencies, or entities; their respective officers, employees, or agents; or any other person.

H. The Agencies anticipate consensus implementation of this MOU. In the unforeseen event that any disputes arise between the Agencies, the respective representatives and leadership of DOI and CNRA will work promptly to resolve any such matter.

I. This MOU shall remain in effect for an initial term of 10 years after its effective date and may be renewed if both Parties agree. This MOU may be terminated at any time by mutual consent of both Parties, or unilaterally by either Party after 30-days written notice to the other Party of intent to terminate.

J. Either Party to this MOU will consult with the other party in a timely manner prior to release of any statements for publication or public dissemination that refers to this MOU, to the Parties in connection with this MOU, or the name or title of any employee of the Parties in connection with this MOU.

K. Nothing in this MOU may be interpreted to imply that the United States endorses any product, service or policy of the State. Nothing in this MOU may be interpreted to imply that the State endorses any product, service or policy of the United States. Neither Party will take any action or make any statement that suggests or implies such type of endorsement.

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L. The DOI and CNRA may amend or modify this MOU only by agreement of both Parties.

VI. APPROVALS

For the Department of the Interior:

Michael L. Connor
Deputy Secretary

8/31/16
Date

For the State of California:

John Laird
Secretary for Natural Resources

8/31/16
Date

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CALIFORNIA natural resources AGENCY

CalEPA California Environmental Protection Agency

Salton Sea Task Force
Agency Actions

The implementation of sustainable habitat and air quality management and mitigation at the Salton Sea through a Salton Sea Management Program is critical for the protection of regional air quality, natural resources at the sea, and the management of a stable Colorado River Supply for California. The Salton Sea Task Force recognizes the contributions of the local leadership, plans, and initiatives that have informed the Task Force process. Following meetings with key stakeholders, the Task Force finds that implementation of a successful Salton Sea Management Program depends on the following three principles: 1) strong state, federal, and local partnerships; 2) clear and achievable milestones with state-directed plans to achieve them; and 3) committed participation from all stakeholders who share the goals of protecting air quality, reducing habitat impacts, and maintaining a secure Colorado River Water Supply. These three factors will drive decision-making on a short- and a medium-term plan while leveraging fiscal and technical resources to deliver projects in an expedited manner.

The Natural Resources Agency will take the following actions over an accelerated timeline:

- **Begin immediate implementation and further development of Salton Sea management plan**
  - The plan will prioritize actions that respond to air quality and natural resources impacts while incorporating opportunities for regional economic development, including recreational and renewable opportunities that benefit implementation of the plan.
  - A science advisory committee will be utilized to provide scientific expertise into plan development.
  - Colorado River stakeholders will be asked to assist with the development of the plan. The Salton Sea Authority and its members will be asked to help facilitate local involvement.

- **Improve public outreach and local partnership**
  - Air quality and environmental impacts of a reduced Salton Sea will be felt foremost by the residents of the region. The state will provide a meaningful public forum to discuss Salton Sea issues locally and to develop future plans and actions.

- **Accelerate project implementation and delivery**
  - The state will work with Salton Sea, Colorado River partners to accelerate planning, state and federal permitting and construction.

- **Meet a short-term goal of 9,000-12,000 acres of habitat creation and dust suppression projects at the sea**
  - Projects to meet short-term goals will be achievable with available funding.
  - Short-term projects will address dust suppression and natural resources needs while laying the foundation for a long-term Salton Sea management framework.
  - Projects will be staged to address the expected progression of playa exposure and designed to provide access corridors for renewable energy development on those lands.

- **Set medium-term goal of 18,000-25,000 acres of habitat creation and dust suppression projects at the sea**
  - Funding plans to meet medium-term goals will need to be developed by the state with Salton Sea and Colorado River partners.

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Ensure Oversight by Regulatory Agencies:

- The State Water Resources Control Board will regularly monitor and assess progress on the implementation of the Salton Sea Management Program, including the development of management plans and funding options, and any potential action by the State Board.
- The State Water Resources Control Board will periodically hold public workshops as part of its monitoring and assessment function.
- The State Water Resources Control Board will work with the Colorado River Regional Water Board and the Administration to improve water quality and upstream co-benefits in the New River and the Alamo River.
- The California Air Resources Board will coordinate with local partners to address air quality impacts from the Salton Sea, work with Imperial and South Coast air districts to monitor air quality, and provide technical and scientific expertise to ensure effective mitigation of dust impacts from exposed playa.

Consider opportunities for increasing renewable energy development at and around the Salton Sea:

- As part of the implementation of the Clean Energy and Pollution Reduction Act of 2015 (SB 350), the California Energy Commission and the Public Utilities Commission will evaluate how renewables at and around the Salton Sea will further the goals of the integrated resources plans, including a balanced resource mix and the minimization of localized air pollutants.
- Within the next year, as part of planning to meet the 2030 greenhouse gas goals, the Public Utilities Commission, the Energy Commission and the Independent System Operator will consider renewable energy opportunities at and around the Salton Sea and the region, and any additional transmission that may be needed for the near term or long term.

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Addendum to the August 31, 2016, Memorandum of Understanding

By and Between

The United States Department of the Interior

and

The State of California Natural Resources Agency

Regarding

The Coordination of Activities to Manage the Salton Sea

Whereas the Parties to the August 31, 2016, Memorandum of Understanding (MOU) have worked assiduously since its adoption to better identify actions and strategies that can further the purposes of the MOU; and

Whereas the Parties wish to ensure that there is a seamless and continuous effort in furtherance of the goals of the MOU during 2017, given the end of the mitigation flows identified in the 2003 Quantification Settlement Agreement (QSA) agreements, the importance of actions to support implementation of existing Colorado River conservation actions, and additional actions that may be taken in light of the ongoing historic drought on the Colorado River.

Therefore, the Parties find and agree that it is appropriate to supplement the MOU as follows:

1. The State of California (State) will coordinate with the Joint Powers Authority (JPA) parties to develop and implement a plan to facilitate and expedite use of the remainder of the JPA funds on projects to mitigate air quality impacts from emissions in the Salton Sea area resulting from the implementation of the QSA. The State will advocate, through the existing JPA budget process, for a plan that addresses air quality impacts as early as possible, while also maximizing cost-effective use of the funds to accomplish mitigation of air quality impacts. The State will consider strategies that will expend all the JPA funds by December 31, 2025, but such consideration will not foreclose strategies that extend the use of such funds beyond such date if such an approach is found to be more cost-effective and appropriate.

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2. The Parties will comply with all applicable requirements of the Federal Clean Air Act and all implementing rules and regulations in connection with potential air quality emissions from Salton Sea playa lands owned or managed by the Parties that are exposed as a result of decline in elevation of the Salton Sea.

3. The State will adjust current targets for air quality and habitat projects at the Salton Sea when hydrology modeling is completed to reflect updated anticipated rates of exposure.

4. The Parties will coordinate on opportunities for renewable energy and economic development in the Salton Sea area as part of the Phase I - 10 year plan.

Signatures

For the Department of the Interior:

Michael L. Connor
Deputy Secretary

Date

For the State of California:

John Laird
Secretary for Natural Resources

January 18, 2017
Date

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Appendix J
Salton Sea Air Quality Mitigation Program (July 2016)

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Salton Sea Air Quality Mitigation Program

Prepared for:
Imperial Irrigation District
in coordination with the County of Imperial

Prepared by:
Formation Environmental, LLC
Air Sciences Inc.
PlanTierra LLC

JULY 2016

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Appendix B – Exposed Playa PM_{10} Inventory

Appendix C – Off-Sea PM_{10} Inventory

Appendix D – Standard Operating Procedures

Appendix E – Dust Conrol Measure Descriptions

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LIST OF ABBREVIATIONS

AOI	Area of Interest
BACM	Best Available Control Measure
BLM	Bureau of Land Management
CAA	Clean Air Act
CARB	California Air Resources Board
CFR	Code of Federal Regulations
CMP	Conservation Management Practice
CSC	Cox Sand Catcher
CVWD	Coachella Valley Water District
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ICAPCD	Imperial County Air Pollution Control District
IID	Imperial Irrigation District
IIDSS	Imperial Irrigation District Support System
KGRA	Known Geothermal Resource Area
LiDAR	Light Detection and Ranging
MNDWI	Modified Normalized Difference Water Index
MPH	Miles Per Hour
MWD	Metropolitan Water District of Southern California
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NTS	Naval Test Station
OHV	Off-Highway Vehicles
PEIR	Programmatic Environmental Impact Report
PI-SWERL	Portable In-Situ Wind Erosion Laboratory
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 Microns in Aerodynamic Diameter
$PM_{2.5}$	Particulate Matter less than 2.5 Microns in Aerodynamic Diameter
PVID	Palo Verde Irrigation District
QSA	Quantification Settlement Agreement
RACM	Reasonable Available Control Measures
SC	Salton City
SCAQMD	South Coast Air Quality Management District
SDCWA	San Diego County Water Authority

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SIP	State Implementation Plan
SPI	Sediment Profile Imaging
SSAM	Salton Sea Accounting Model
SS AQM Program	Salton Sea Air Quality Mitigation Program
SVRA	State Vehicular Recreation Area
SWIR	Short-Wave Infrared
SWRCB	State Water Resources Control Board
TEOM	Tapered Element Oscillating Microbalance
TIG	Terrestrial Image Georeferencing
tpd	Tons Per Day
tpy	Tons Per Year
UAV	Unmanned Airborne Vehicle
USGS	United States Geological Survey
VDE	Visible Dust Emissions
$\mu g/m^3$	Micrograms Per Cubic Meter

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EXECUTIVE SUMMARY

This Salton Sea Air Quality Mitigation Program (SS AQM Program) was prepared by Imperial Irrigation District (IID) to provide a comprehensive, science-based, adaptive approach to address air quality mitigation requirements associated with the transfer of up to approximately 300,000 acre-feet per year of conserved water under the Quantification Settlement Agreement (QSA).[1] The conserved water transfer reduces the volume of agricultural return flow to the Salton Sea, thereby exposing the playa and increasing the potential for dust emissions that could affect communities near and around the Sea. The required air quality mitigation measures to address these potential dust emissions are generally defined as: 1) restricting access to the exposed playa, 2) researching and monitoring the exposed playa, 3) creating or purchasing offsetting emission reduction credits and 4) implementing direct emission reduction measures on the exposed playa.[2] This SS AQM Program expands upon these general mitigation measures with detailed methods to assess playa dust emissions and identify options to mitigate them. This SS AQM Program also provides support and options for land management decisions associated with the playa as the Salton Sea recedes.

Dust emissions, or $PM_{2.5}$ and PM_{10}[3], are hazardous to human health. Imperial County is currently designated as a serious nonattainment area for PM_{10} due, in part, to windblown dust. Future exposed playa is anticipated to be a new source of dust emissions; however, until it is exposed, the location, frequency and magnitude of future emissions are unknown. The objective of this SS AQM Program is to proactively detect, locate, assess and identify options to mitigate dust emissions from exposed Salton Sea playa. This program includes steps to characterize the actual emission potential of exposed playa as the Salton Sea recedes and options to proactively prevent the occurrence of significant dust emissions. This program also includes steps to understand dust emissions from desert areas adjacent to the Salton Sea, which is critical for distinguishing playa dust emissions from off-Sea sources and for understanding the potential impact of off-Sea sources on exposed playa.

A large portion of the Salton Sea is located in Imperial County, within the jurisdiction of the Imperial County Air Pollution Control District (ICAPCD). A smaller portion of the Salton Sea is in Riverside County, within the jurisdiction of the South Coast Air Quality Management District (SCAQMD). IID anticipates that some or all of the information from this SS AQM Program will be considered in future revisions to the Imperial County PM_{10} State Implementation Plan (SIP). The Imperial County PM_{10} SIP is the regulatory document that guides dust control efforts within Imperial County. This SS AQM Program was developed in coordination with the County of Imperial to be consistent with and provide additional technical and scientific information to inform the ICAPCD SIP revision process.

[1] Impact AQ-7 is identified in the *Final Imperial Irrigation District Water Conservation and Transfer Project, Draft Habitat Conservation Plan Environmental Impact Report/Environmental Impact Statement*, SCH #99091142 (Final EIR/EIS), and the associated mitigation requirements are found in the *Imperial Irrigation District Water Conservation and Transfer Project Mitigation, Monitoring and Reporting Program*, dated September 2003 (MMRP).

[2] Mitigation Measure AQ-7 of the MMRP.

[3] Particulate matter less than 2.5 and 10 microns in diameter.

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This executive summary provides the key questions to be answered by this SS AQM Program. It summarizes each component of the program and provides a flow chart of program implementation (Figure ES-1).

Air Quality Regulatory Framework

- **What air quality regulations influence this SS AQM Program?**

  The Clean Air Act (CAA) and State Implementation Plans (SIP). The CAA is a United States federal law designed to control air pollution at the national level. It requires the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the public from airborne contaminants known to be hazardous to human health. Under the CAA, states are required to submit a SIP describing how air basins designated as nonattainment areas will be brought into compliance with federal and state ambient air quality standards. The SIP contains the plan for attaining the standards as soon as possible, but in no more than five years, based on the severity of the air pollution and the difficulty posed by obtaining cleaner air. The ICAPCD is the designated agency for developing and implementing the SIP for Imperial County, as is SCAQMD for Riverside County.

  Imperial County Air Pollution Control District Rules and Regulations. ICAPCD regulates fugitive dust emissions in Imperial County through its PM_{10} SIP and Regulation VIII rules. The Regulation VIII rules are based, in part, on an emissions inventory of fugitive dust sources (e.g., construction activities, agricultural operations, disturbed open areas). Rules are developed for each source category and identify the dust control measures (Best Available Control Measures or BACM) to reduce emissions. The type and intensity of dust control measures (e.g., apply water, establish vegetation, apply gravel or chemical stabilizers/suppressants) required to reduce emissions vary for each fugitive dust source.

  Regulation VIII is divided into seven rules. Three of the rules—800, 804 and 806—are relevant to this SS AQM Program. Rule 800 contains the definitions, exemptions, general requirements, administrative requirements and test methods that are applicable to all Regulation VIII rules. Rule 804 applies to open areas that contain disturbed surface area. The Salton Sea is currently categorized as an "open area" and ICAPCD can order implementation of dust control on the Salton Sea playa based on the current Rule 804. Rule 806 applies to agricultural operation sites and pertains to this SS AQM Program because some future exposed Salton Sea playa could be reclaimed for agricultural use.

  South Coast Air Quality Management District Rules and Regulations. SCAQMD regulates fugitive dust emissions in Riverside County and specifically within the Coachella Valley. Fugitive dust emissions are regulated through the Coachella Valley PM_{10} SIP and Regulation IV rules. Regulation IV is divided into several rules and rules 403 and 403.1 are relevant to this SS AQM Program. Rule 403 applies to any activity or man-made condition capable of generating fugitive dust. Rule 403.1 is a supplemental rule and it applies specifically to fugitive dust sources in the Coachella Valley. The dust control measures identified in the rules are similar to those identified in the ICAPCD rules.

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Emissions Inventory and Monitoring Program

- **When and where will exposed playa occur?** The timing and location of future playa exposure is a function of the Salton Sea floor elevation and the Sea's response to inflows, salt loads and evaporation rates. A hydrologic model will be used to simulate projected playa exposure. These simulations will provide planning-level information about the timing and location of anticipated playa exposure. In addition, actual playa exposure will be mapped to provide a real time understanding of playa exposure and to validate the hydrologic model results. Playa exposure will be mapped using Landsat satellite imagery and a combination of United States Geological Survey gauge elevation data and high-resolution bathymetric data (collected in 2005). Results will be used to track actual playa exposure as it occurs, guide monitoring of exposed playa surfaces and adjust assumptions related to future hydrologic model projections.

- **How will the surface characteristics of the playa be determined?** The surface characteristics of exposed playa will be variable and must be reliably mapped because they are directly related to emission potential. Extensive survey methods originally developed for Owens Lake are being adapted for use at the Salton Sea. This includes monitoring protocols to accurately map existing playa surface characteristics (analogous to soil map units) using remotely sensed data resources and ground-based surface evaluations. Ground-based surface evaluations include detailed characterization of surface properties related to erosion (e.g., crust type, crust thickness, soil moisture). These datasets will then be used as calibration data to spatially map playa surface types, vegetation and other surface characteristics using LiDAR (Light Detection and Ranging), UAV (unmanned aerial vehicle) imagery and other sources of satellite-based imagery. These mapping efforts will be done periodically to provide an updated inventory of exposed playa surface units and associated physical characteristics.

- **How will the emission potential of different playa surface types be assessed?** The vulnerability of different playa surfaces to erosion is known to be highly variable. This SS AQM Program will assess which playa surfaces and conditions are actually emissive and establish PM_{10} emission rates for different types of surfaces. Emission potential will be assessed using a device called a Portable In-Situ Wind Erosion Laboratory (PI-SWERL). After placement on the ground surface, the PI-SWERL simulates varying wind speeds and measures the number and size of suspended particles within the device, thus providing an estimate of emission potential under a range of simulated wind conditions. PI-SWERL sampling will occur monthly on each identified playa surface type. Monthly results will facilitate a better understanding of the "dust season" on different parts of the playa. The dust season refers to times of the year when dust emissions typically occur under different climate and soil conditions.

- **How will actively emissive playa dust source areas be identified?** Active dust source areas must be quickly and reliably mapped so that dust control needs can be identified, prioritized and implemented. Active dust source areas will be mapped based on photographic, video and/or visual observations of dust plumes and the presence of erosion and depositional surface features. A high-resolution satellite or UAV image will be collected after each wind event where dust plumes are observed. The imagery will provide a photo-interpretive base for delineating source areas and

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focusing field investigations. Photographic evidence will also be collected for each delineated source area and linked to a GPS (global positioning system) location. Emission rates for each source area will be developed using the PI-SWERL.

- **How will dust emissions from desert areas around the Salton Sea be assessed?** Dust emissions and dust source areas from open areas adjacent to the Salton Sea affect this SS AQM Program in two ways: 1) dust emissions from the surrounding desert sources will mix with emissions from newly exposed playa, making it difficult to distinguish playa dust emissions from the surrounding off-Sea dust emissions and 2) sand intrusion from active alluvial fans and from dune migration toward the playa will increase the emissions potential of exposed playa due to the associated surface disturbance and erosion.

  This SS AQM Program will assess dust emissions from areas adjacent to the Salton Sea to establish the location, timing and magnitude of off-Sea emissions. The approach includes: (1) using data from the existing PM_{10} monitoring network to show the frequency, magnitude and direction of PM_{10} concentrations in the desert areas west of the Salton Sea; (2) a network of fixed sand motion monitoring instruments placed within various surface types; (3) video monitoring to provide visual evidence of dust emissions; and (4) PI-SWERL sampling to characterize the emission potential of various surface types (e.g., dry washes, alluvial fans, sand sheets, dunes). This information will be used to confirm the location and timing of off-Sea emissions and to support an updated PM_{10} emission inventory for the open area source category in the Imperial County PM_{10} SIP.

- **How will playa emissions data be evaluated and reported?** As playa is exposed, the surface characteristics and emission potential will be rigorously evaluated to provide multiple lines of evidence related to playa emissions, as described in the preceding sections. These data will be used to estimate emissions from high wind events and to quantify the tons of PM_{10} generated from each source area on the playa for each specific wind event. Maximum daily (tons per day) and total annual emissions (tons per year) will also be estimated. In addition, the California Puff (CALPUFF) modeling system will be used to model the impacts of the maximum daily emissions from exposed playa sources at monitoring stations located around Imperial and Riverside Counties. Initially, results from these evaluations will be used to establish criteria to prioritize dust source areas that have high emission potential. Once criteria are established, source areas with high emission potential will be prioritized for proactive dust control measures. Depending on the prioritization, proactive dust control measures may be implemented as soon as practicable or incorporated into the Annual Proactive Dust Control Plan for the following year (described in the following sections). Playa emissions will be summarized and reported in an annual Playa Inventory and Monitoring Report.

Dust Control Strategy / Planning and Implementation

- **What dust control measures are allowed by the ICAPCD Regulation VIII rules?** The Salton Sea is currently categorized as an "open area" under ICAPCD rules. Under Rule 804, if visible dust emissions (VDE) in open areas exceed 20 percent opacity or if stabilized surface conditions are not met (pursuant to Rule 800 specifications), then Best Available Control Measures (BACM) must be implemented. BACM for open areas include: (1) applying water or chemical dust suppressants to all

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un-vegetated areas, (2) establishing 50% vegetative cover on previously disturbed areas, (3) paving, applying and maintaining gravel or applying and maintaining chemical dust suppressants and (4) alternative BACM as approved by the ICAPCD. After implementation of BACM, monitoring is required to determine whether the stabilized surface criteria have been achieved.

IID and ICAPCD recognize the need for playa-specific surface stability definitions and emissions measurement methods, alternatives to VDE, alternative BACM and modified performance criteria. As this SS AQM Program is implemented, results will help guide the development of these playa-specific parameters.

- **How will decisions regarding implementation of dust control measures on exposed playa be made?** The overarching goal of this SS AQM Program is to identify the tools that can be used to prevent exposed Salton Sea playa from becoming a significant source of PM_{10} emissions based upon the best available science. A large part of implementing an effective dust control strategy is to identify and implement those dust control measures (DCMs) on emissive playa surfaces *before* they reach thresholds that prompt regulatory orders for dust control. This approach provides increased flexibility for implementing effective dust control measures in the most cost effective manner and for facilitating immediate dust control actions at the Salton Sea. The proactive dust control strategy will include broad-scale implementation of DCMs that are protective of air quality, but also adaptable given the variables regarding temporal exposure and the magnitude of future emissions.

  On an annual basis and as playa is exposed each year, the surface characteristics and emission potential will be rigorously evaluated (i.e., Emissions Inventory and Monitoring Program). Initially, results from these evaluations will be used to establish criteria to identify areas of exposed playa that have high emission potential and prioritize dust control needs and measures. Criteria will be developed for each playa evaluation method (e.g., surface survey, PI-SWERL data, video monitoring), such that any individual line of evidence could be used to identify areas for proactive control. Once the criteria are established, IID will use the monitoring results to develop an Annual Proactive Dust Control Plan. The Annual Proactive Dust Control Plan will inform and take into account current and future land management and land use planning efforts, including those associated with Salton Sea restoration efforts by the State and other activities and projects planned by agencies and/or individuals for specific areas of the playa.

  After each Annual Proactive Dust Control Plan is reviewed and approved, if necessary, by the IID board, DCMs may be implemented in accordance with that plan. Yearly results from the Emissions Inventory and Monitoring Program will be used to prioritize DCM implementation on an on-going basis. As DCMs are implemented, they will be monitored to confirm that adequate surface stabilization is maintained. If the initial proactive DCM does not maintain a stabilized surface, the DCM will be further enhanced. This approach allows resources to be allocated efficiently and effectively, and in an expeditious manner to prevent significant sources of PM_{10}. The dust control strategy also includes development and testing of new DCMs and a playa traffic management plan as described below.

- **How will DCMs be selected for the unique conditions at the Salton Sea?** The dust control strategy includes the development and testing of new DCMs that are specifically tailored to the climate and

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soil conditions on and around the playa and that make efficient use of available resources. Some DCMs have been field-tested and proven to be effective and some DCMs need additional research prior to use at the Salton Sea. For those DCMs needing additional research, pilot field testing (pilot projects) may be pursued. Pilot projects allow IID to gain experience and understanding of locally-adapted methods of dust control and the site-specific factors that could affect their feasibility and cost. Pilot projects also are useful for determining the effectiveness of dust control and refining design criteria for full-scale implementation. This helps develop efficient and effective approaches for the design, construction and operation of DCMs on the playa.

- **How will off-highway vehicle (OHV) traffic be managed?** The dust control strategy includes development and implementation of a playa traffic management plan focused on public outreach and education. Extensive desert areas around the Salton Sea attract recreationalists and OHV traffic. Due to proximity, it is highly likely that OHV use would expand onto the playa as the Salton Sea recedes. This activity will disturb the natural stability of playa crust and soil surfaces and increase erodibility and PM_{10} emissions, as well as disturb DCMs being implemented on the playa. Prevention of vehicle-related disturbances is the most important and cost-effective measure available to prevent and control dust emissions.
- **How will information related to this SS AQM Program be shared with others?** This SS AQM Program is focused on monitoring and mitigating dust emissions from exposed Salton Sea playa. There are numerous agencies and landowners involved in activities at the Salton Sea from an air quality and habitat perspective. Communication and coordination among these agencies is essential to the success of this SS AQM Program. IID will coordinate implementation of this SS AQM Program with these agencies and provide an annual progress report.

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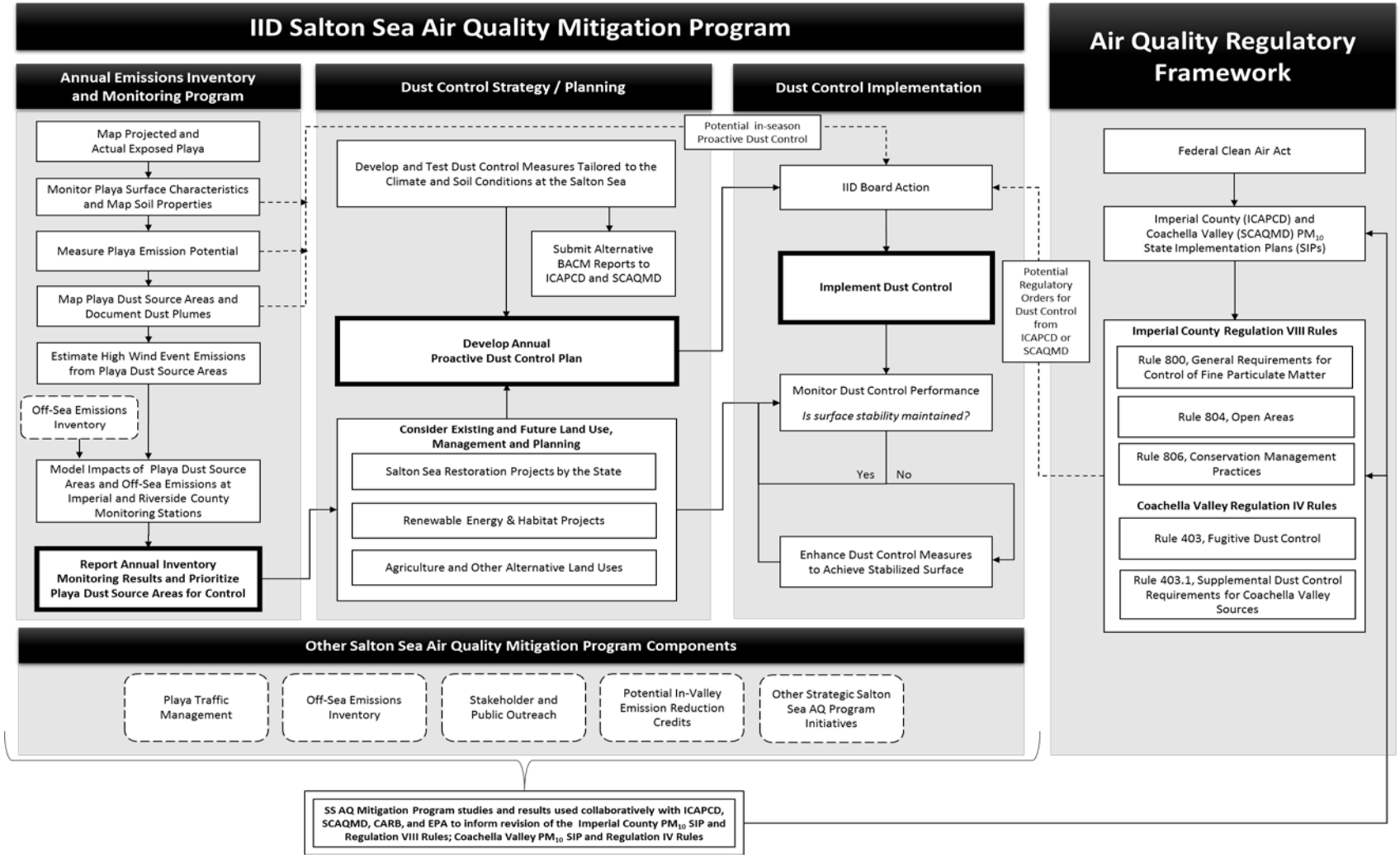
FIGURE ES-1. SS AQM PROGRAM COMPONENTS AND WORKFLOW. Each component of this SS AQM Program is used to identify, prioritize and guide implementation of dust control measures on exposed Salton Sea Playa. This flowchart identifies important program components and how they are used to guide dust control implementation.



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1 INTRODUCTION

This document sets out the general parameters of the Salton Sea Air Quality Mitigation Program (SS AQM Program) prepared for the Imperial Irrigation District (IID). As explained in more detail below, this SS AQM Program expands on the air quality monitoring and mitigation requirements resulting from the conserved water transfers under the Quantification Settlement Agreement (QSA). The objective of this SS AQM Program is to proactively detect, locate, assess and identify options to mitigate dust emissions from exposed Salton Sea playa. This SS AQM Program also provides scientific support and options for land management decisions associated with the playa as the Salton Sea recedes.

This SS AQM Program provides a comprehensive, science-based, adaptive approach to address air quality mitigation requirements to assist in the decision-making process for implementation of air quality mitigation. This program has a limited focus and does not expand into other areas that may provide air quality mitigation as a secondary benefit, but serves other primary purposes, such as habitat creation and restoration or renewable energy development. Further, this program is not intended to provide a restoration plan for the Salton Sea or to make predetermined decisions regarding the implementation of air quality mitigation. This SS AQM Program provides for an annual on-going process to detect, locate, assess and identify options to mitigate dust emissions from exposed Salton Sea playa, which ultimately provides the scientific support to the IID to make decisions regarding the implementation of specific mitigation measures. Several outside factors will contribute to the decision-making process and this program is intended to work with and in light of those factors, including in coordination with any other Salton Sea restoration and mitigation activities taken by other agencies and/or stakeholders. The technical details supporting this document are included in the appendices.

2 BACKGROUND AND REGULATORY FRAMEWORK

This section describes the background and regulatory framework for this SS AQM Program, including the the conserved water transfers under the QSA that are expected to accelerate Salton Sea playa exposure beginning in 2017 and the air quality monitoring and mitigation requirements under the QSA. The regulatory framework is discussed next, including the Clean Air Act (CAA) and its requirements for submitting a State Implementation Plan (SIP) for nonattainment areas, the Imperial County PM_{10} SIP, the Coachella Valley PM_{10} SIP, various Imperial County Air Pollution Control District (ICAPCD) and South Coast Air Quality Management District (SCAQMD) rules that guide future dust control efforts on the Salton Sea playa, and the Environmental Protection Agency (EPA) Exceptional Event Rule.

2.1 THE QUANTIFICATION SETTLEMENT AGREEMENT AND THE JOINT POWERS AUTHORITY

The QSA is a series of agreements that provide for a long-term conserved water transfer of up to 303,000 acre-feet annually from IID to the San Diego County Water Authority (SDCWA) and the

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Coachella Valley Water District (CVWD).[4] These conserved water transfers under the QSA allow California to limit its demand on Colorado River water to its annual 4.4 million acre-feet entitlement and ensures water supply reliability throughout Southern California.

The QSA caps IID's annual consumptive water use to 3.1 million acre-feet and provides for the transfer of conserved water outside of Imperial County. IID conserves the water for transfer through various conservation programs. The transfer of the conserved water means less water is applied to the farm land within the Imperial County, which in turn means reduced agricultural return flows into the Salton Sea causing the Sea elevation to recede over time.

2.1.1 THE QSA AIR QUALITY MONITORING AND MITIGATION REQUIREMENTS

Pursuant to the California Environmental Quality Act (CEQA), California Public Resources Code sections 21000 et seq., the environmental impacts of the conserved water transfers under the QSA were analyzed in an environmental impact report[5] and then monitoring and mitigation measures were included in a Mitigation, Monitoring and Reporting Program (MMRP) to ensure that identified impacts are monitored and mitigated for the life of the QSA.[6] The Final EIR/EIS identified potential air quality impacts from windblown dust from exposed Salton Sea playa as a result of the conservation of up to approximately 300,000 acre-feet reducing the volume of agricultural inflows to the Sea.[7] The requirements for monitoring and mitigating dust emissions from the exposed Salton Sea playa are identified in the Final EIR/EIS[8] and as Mitigation Measure AQ-7 in the MMRP.[9] The specific section of the Final EIR/EIS is provided in Appendix A of this SS AQM Program for reference. The Salton Sea air quality monitoring and mitigation requirements, in pertinent part, are as follows:

1. **Restrict Access**: Public access, especially off-highway vehicle access, would be limited, to the extent legally and practicably feasible, to minimize disturbance of natural crusts and soils surfaces in future exposed shoreline areas.
2. **Research and Monitoring**: A research and monitoring program would be implemented incrementally as the Sea recedes. The research phase would focus on development of information to help define the potential for problems to occur in the future as the Sea elevation is reduced slowly over time. Research would:
    a. Study historical information on dust emissions from exposed shoreline areas.
    b. Determine how much land would be exposed over time and who owns it.

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[4] Or the Metropolitan Water District of Southern California in place of CVWD under certain circumstances. For more details see the *Quantification Settlement Agreement By and Among Imperial Irrigation District, The Metropolitan Water District of Southern California and the Coachella Valley Water District* and the *Agreement for Acquisition of Water Between Coachella Valley Water District and the Metropolitan Water District of Southern California*, both dated October 10, 2003.
[5] *Final Imperial Irrigation District Water Conservation and Transfer Project, Draft Habitat Conservation Plan Environmental Impact Report/Environmental Impact Statement*, SCH #99091142 (Final EIR/EIS)
[6] *Mitigation, Monitoring and Reporting Program for the IID Water Conservation and Transfer Project EIR/EIS*, dated June 2008 (MMRP).
[7] Section 3.16.2, pages 3-70 to 3-71.
[8] Section 3.9.5, pages 3-50 to 3-52.
[9] Impact AQ-7, Table 1, pages 21-22.

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c. Conduct sampling to determine the composition of "representative" shoreline sediments and the concentrations of ions and minerals in salt mixtures at the Sea.
d. Analyze [data] to predict responses of Salton Sea salt crusts and sediments to environmental conditions, such as rainfall, humidity, temperature and wind.
e. Implement a meteorological, PM_{10} and toxic air contaminant monitoring program to begin under existing conditions and continue as the [Sea recedes]. The goal of the monitoring program would be to observe PM_{10} problems or incremental increases in toxic air contaminant concentrations associated with [receding Sea levels] and to provide a basis for mitigation efforts.
f. If incremental increases in toxic air contaminants (such as arsenic or selenium, for example) are observed at the receptors and linked to emissions from exposed shoreline caused by [receding Sea levels], conduct a health risk assessment to determine whether the increases exceed acceptable thresholds established by the governing air districts and represent a significant impact.
g. If potential PM_{10} or health effects problem areas are identified through research and monitoring and the conditions leading to PM_{10} emissions are defined, study potential dust control measures specific to the identified problems and the conditions at the Salton Sea.

3. **Create or Purchase Offsetting Emission Reduction Credits**: This step would require negotiations with the local air pollution control districts to develop a long-term program for creating or purchasing offsetting PM_{10} emission reduction credits.[10]
4. **Direct Emission Reductions at the Sea**: If sufficient offsetting emission reduction credits are not available or feasible, Step 4 of this mitigation plan would be implemented. It would include either, or a combination of:
    a. Implementing feasible dust mitigation measures; and/or
    b. If feasible, supplying water to the Sea to re-wet emissive areas exposed by the [receding Sea].

In addition to the Final EIR/EIS Salton Sea air quality monitoring and mitigation requirements, the QSA is subject to compliance with the terms and conditions of several state and federal permits and approvals. This includes the California State Water Resources Control Board (SWRCB) Revised Order WRO 2002-0013 approving the water transfers (SWRCB Order). This SWRCB Order incorporated the Final EIR/EIS air quality mitigation measures. The SWRCB Order additionally requires IID to evaluate dust control measures to determine their feasibility and delegates to the Water Rights Division Chief the authority to determine, in consultation with the ICAPCD, SCAQMD and the California Air Resources Board (CARB), whether any dust mitigation measures identified are feasible.

[10] Note: ICAPCD and SCAQMD do not currently support programs for creating or purchasing PM_{10} emission reduction credits. Therefore, this SS AQM Program does not address PM_{10} emission reduction credits. However, this SS AQM Program does not preclude future negotiations with local regulatory agencies to investigate the development of a long-term program for creating or purchasing offsetting PM_{10} emission reduction credits.

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This SS AQM Program does not alter or replace any of these Salton Sea air quality monitoring and mitigation requirements. Rather, it expands on and provides greater detail of these monitoring and mitigation requirements. The Salton Sea playa that is exposed as a direct result of the water transfers under the QSA is subject to the air quality monitoring and mitigation requirements described above under the Final EIR/EIS and the SWRCB Order, in addition to all other federal, state and local laws, rules and regulations pertaining to air quality.

2.1.2 THE QSA JOINT POWERS AUTHORITY

Under the QSA and supporting legislation, the State of California has assumed financial responsibility for QSA-related mitigation, with the exception of the first $133 million (in 2003 dollars) in QSA mitigation costs paid by CVWD, SDCWA and IID.[11] The *Quantification Settlement Agreement Joint Powers Authority Creation and Funding Agreement* was entered into by the State of California, CVWD, SDCWA and IID in October 2003. In that agreement, the Quantification Settlement Agreement Joint Powers Authority (QSA JPA) was created to pay for environmental mitigation requirements and costs "by and through the collection, holding, investing and disbursing of funds."[12] The funds managed by the QSA JPA are from the water agencies for the first $133 million (in 2003 dollars) and then from the State of California for environmental mitigation costs in excess of that limit.[13]

The QSA JPA must adopt an annual budget for the payment of environmental mitigation costs.[14] As IID, or any other party implementing mitigation, incurs direct costs for environmental mitigation activities under the approved budget, IID, or that other party, is reimbursed by the QSA JPA for those costs.[15] The QSA JPA is allowed, but not required, to "adopt a long-term financing plan to assure that sufficient funds are available to meet the reasonably expected annual costs" for environmental mitigation.[16]

Concurrent with the QSA, IID prepared a draft Habitat Conservation Plan (HCP) to cover permitting under the Endangered Species Act (ESA) for activities done under the QSA including conservation programs and mitigation measures. The HCP was prepared in coordination with the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Wildlife (CDFW) and provides specific biological conservation measures for implementation of the QSA, which were included in the MMRP for the QSA. Mitigation measures associated with the HCP are managed by an Implementation Team (IT), which is set forth in the HCP and corresponding mitigation measures. The IT is not directly responsible for managing air quality mitigation, except to the extent that implementation of any air quality mitigation might have an impact on the species covered in the HCP or other wildlife.

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[11] For a detailed discussion regarding California's Salton Sea restoration and QSA mitigation obligations under the QSA and State legislation see the *Petition of Imperial Irrigation District for Modification of Revised Water Rights Order 2002-0013* filed with the California State Water Resources Control Board on November 18, 2014 (http://www.iid.com/water/salton-sea-initiative/swrcb-petition). For the contractual obligations associated with restoration and mitigation see the *Quantification Settlement Agreement Joint Powers Authority Creation and Funding Agreement* and the *Environmental Cost Sharing, Funding, and Habitat Conservation Plan Development Agreement*, both dated October 10, 2003.

[12] Section 2.2 of the QSA JPA Creation and Funding Agreement.

[13] Articles IX and XIV of the QSA JPA Creation and Funding Agreement.

[14] Section 10.1 of the QSA JPA Creation and Funding Agreement.

[15] Section 10.3 of the QSA JPA Creation and Funding Agreement.

[16] Section 10.2 of the QSA JPA Creation and Funding Agreement.

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Nevertheless, the IT provides recommendations to the QSA JPA for adjustments to implementation of the HCP-related mitigation measures and corresponding adjustments to the annual budget. IID coordinates with and keeps the IT informed of air quality mitigation activities to ensure that all activities are in compliance with the HCP and associated permits.

IID, in coordination with the QSA JPA and the IT, prepares an annual budget for review and approval by the QSA JPA. The annual budget is done on a fiscal year basis. As part of that process, IID identifies the air quality mitigation activities that are anticipated for the upcoming year and includes those mitigation costs in the QSA JPA annual budget. Approval of the budget represents a determination by the QSA JPA that the mitigation costs in the budget are subject to reimbursement by the QSA JPA funding. After approval of the budget, IID implements the various mitigation activities included in the annual budget and submits periodic invoices to the QSA JPA for reimbursement. This SS AQM Program anticipates that IID will continue to coordinate with the QSA JPA on inclusion in the annual QSA JPA budget of the air quality monitoring and mitigation activities identified in this program according to the regular process.

2.1.3 Salton Sea Mitigation Water

The SWRCB Order requires IID to deliver mitigation water to the Salton Sea for a period of 15 years, until the end of 2017. The mitigation water is delivered to the Salton Sea in accordance with a schedule that increases each year associated with the ramping up of the water conservation schedules for that 15-year period and reaching a peak amount in 2017 of 150,000 acre-feet.[17] The primary purpose of the delivery of the mitigation water to the Salton Sea was intended to avoid salinity impacts to the Sea specifically affecting fish and wildlife for 15 years.[18] However, a secondary effect of the mitigation water delivered to the Salton Sea is to artificially supply a portion of the reduced flows to the Sea thereby benefitting the elevation by postponing the recession of the Sea to a significant extent until after the mitigation water ceases to be delivered in 2017. The 15-year period assumed that the State would have a Salton Sea restoration plan developed during that time and implementation of restoration activities would be underway.[19]

2.1.4 Salton Sea Restoration

In addition to the QSA mitigation funding obligations, under the QSA and supporting legislation, the State of California has assumed responsibility to restore the Salton Sea, including the associated financial responsibility, with the exception of $30 million in funds contributed to the Salton Sea Restoration Fund by CVWD, SDCWA and IID.[20] The State of California has embarked upon a Salton Sea restoration program.[21] That program is being carried out concurrent with the air quality monitoring and

[17] Exhibit D of the QSA JPA Creation and Funding Agreement.
[18] For further details regarding the purpose of the 15 years of Salton Sea mitigation water see the SWRCB Order, the *Final Addendum to the IID Water Conservation and Transfer Project, Final EIR* dated September 2003, and the HCP.
[19] For further detail see IID's SWRCB Petition (footnote 11) and the SWRCB Revised Water Rights Order 2002-0013.
[20] See footnote 11. See also the California State Auditor's *Salton Sea Restoration Fund: The State Has Not Fully Funded a Restoration Plan and the State's Future Mitigation Costs are Uncertain, Report 2013-101* dated November 2013 (https://www.bsa.ca.gov/reports/agency/301 and http://www.bsa.ca.gov/pdfs/reports/2013-101.pdf).
[21] See http://resources.ca.gov/salton-sea/.

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mitigation activities set forth in this SS AQM Program. IID anticipates that this program and the implementation of the air quality monitoring and mitigation coming out of this program can inform the State's Salton Sea restoration program and decisions being made under that program. This SS AQM Program provides scientific-based options for addressing air quality that can be used as part of the State's restoration activities. Nevertheless, the State's Salton Sea restoration program and funding associated with those restoration activities is separate from this SS AQM Program.

2.2 THE CLEAN AIR ACT

The CAA[22] is a United States federal law designed to control air pollution at the national level. It requires the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the public from airborne contaminants known to be hazardous to human health. The CAA contains many requirements related to air quality programs and activities. Two areas of those requirements have a direct bearing on this SS AQM Program. They are air quality and emission limitations[23] and plan requirements for nonattainment areas.[24]

The CAA declares that protecting and enhancing the nation's air quality promotes public health.[25] The law encourages prevention of regional air pollution and establishment of regional control programs.[26] It also provides technical and financial assistance for air pollution prevention at both the state and local government level.[27] The CAA also covers cooperation, research, investigation, training and other activities related to air quality.[28] Grants for air pollution planning and control programs and for interstate air quality agencies and program cost limitations are also included in the CAA.[29]

The CAA mandates air quality control regions designated as either attainment or nonattainment areas.[30] Attainment areas are those that meet the national standards for primary or secondary ambient air quality.[31] Nonattainment areas are those that do not meet the standards.[32] Imperial County and Coachella Valley are currently designated as *serious* nonattainment areas for PM_{10}.

Additionally, the CAA contains the requirements for nonattainment areas.[33] Under the CAA, states are required to submit a SIP describing how the nonattainment areas will be brought into compliance with federal and state ambient air quality standards.[34] The SIP contains the program for attaining the

[22] 42 United States Code sections 7401 et seq.
[23] 42 USC sections 7401-7431.
[24] 42 USC sections 7501-7515.
[25] 42 USC section 7401(b).
[26] 42 USC sections 7401(a) and (b).
[27] 42 USC sections 7401(a) and (b).
[28] 42 USC sections 7402-7403.
[29] 42 USC sections 7405-7406.
[30] 42 USC section 7407.
[31] 42 USC section 7410.
[32] 42 USC section 7410.
[33] 42 USC sections 7501-7515.
[34] 42 USC section 7410.

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standards as soon as possible but in no more than five years, based on the severity of the air pollution and the difficulty posed by obtaining cleaner air.[35]

The CAA is implemented according to Title 40 of the Code of Federal Regulations Part 51. According to the federal regulations, SIPs must include the following elements:[36]

- **Emission Inventory**: Detailed inventory of emissions from point and area sources. The inventory must be based upon measured emissions or, where measured emissions are not available, documented emission factors.
- **Control Strategy**: Control strategy for bringing the area into attainment with federal and state air quality standards. The control strategy should identify the sources to be controlled, as well as the type and intensity of control measures applied to reduce emissions. This includes identification of the responsible agency, as well as procedures for monitoring compliance and handling violations.
- **Control Estimate**: Summary of emission levels projected to result from application of the control strategy.
- **Attainment Demonstration Modeling Analysis**: A demonstration of adequacy of the control strategy by means of applicable models, databases and other requirements found in the EPA's Guideline of Air Quality Models.
- **Contingency Planning**: Contingency measures to be applied in the event that the standards are not achieved in the specified time period.

SIPs must be approved by the EPA, or revised if approval is contingent on making changes, and must specify whether local governments or the State will implement and enforce the various changes.[37]

The ICAPCD is the responsible regulatory agency for the SIP in Imperial County and the SCAQMD is the responsible regulatory agency for the SIP in Riverside County. The roles and applicable air quality rules of each local regulatory agency are described below.

2.3 IMPERIAL COUNTY AIR POLLUTION CONTROL DISTRICT

The ICAPCD is the local regulatory agency for air quality compliance within Imperial County. The ICAPCD has a board of directors that adopts the policies and regulations for air quality within Imperial County and is managed by the Air Pollution Control Officer. In addition to developing SIPs for Imperial County as required by the CAA, the ICAPCD has adopted the *Rules and Regulations of the Imperial County Air Pollution Control District*, which includes eleven regulations (Regulations I to XI) each of which is broken down into separate rules.[38]

[35] 42 USC section 7502.
[36] 40 CFR Part 51, subpart G.
[37] 40 CFR Part 51, subparts A and F.
[38] Located at http://www.co.imperial.ca.us/AirPollution/index.asp?fileinc=comprules.

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2.3.1 IMPERIAL COUNTY PM_{10} SIP

On August 11, 2009, the ICAPCD Board held a public hearing and unanimously adopted the *Final 2009 Imperial County State Implementation Plan for Particulate Matter Less Than 10 Microns in Aerodynamic Diameter* (IC 2009 PM_{10} SIP).[39] The IC PM_{10} SIP was based on emission inventory projections for the period of 2006-2010 compared against the baseline year of 2005. Highlights of the IC 2009 PM_{10} SIP include the following:

- Five exceedance days (that is, days exceeding the federal 24-hour PM_{10} standard) were recorded during the period from 2006 through 2008, with 24-hour average PM_{10} concentrations ranging from 167 to 291 micrograms per cubic meter ($\mu g/m^3$). For any given exceedance day, from one to five compliance monitors were affected.
- Two of the exceedance days were associated with PM_{10} transport from Mexico. On each of these days, a single compliance monitor was affected (Grant Calexico). The remaining three exceedance days were associated with high wind speed conditions. On high wind days, two to five compliance monitors were affected.
- On low wind speed days, significant sources of dust included tilling, entrained dust from unpaved roads and open areas. Ninety-nine percent of emissions from open areas were from non-populated areas such as dunes, grasslands and barren areas.
- On an annual basis, wind-blown dust sources accounted for 73 percent of the total PM_{10} emissions in the Imperial County. Other large dust sources include: entrained dust from unpaved roads (19.4 percent of the total) and farming (3.3 percent of the total). All other sources were individually less than one percent of the total emissions.
- The IC 2009 PM_{10} SIP control strategy reduced the maximum daily emissions from 235 tons per day (tpd) to 219 tpd, a difference of 16 tpd.
- The control strategy focused on (greatest to least reduction): entrained city/country roads (reduction of 8.04 tpd), tilling (reduction of 2 tpd), non-pasture agricultural land (reduction of 1.99 tpd), other open areas (reduction of 1.19 tpd), wind-blown dust on unpaved farm roads (reduction of 1.11 tpd), wind-blown dust from city/county roads (reduction of 0.69 tpd) and "track out" (reduction of 0.37 tpd). All other sources were individually reduced less than 0.3 tpd.
- The IC 2009 PM_{10} SIP assumed a restoration program would be implemented at the Salton Sea and therefore did not account for future emissions from exposed playa.
- Dust emissions from the open desert areas located west of the Salton Sea were not captured by the IID special purpose monitoring network because it had not been established yet and therefore did not influence the IC 2009 PM_{10} SIP control strategy.

The ICAPCD is preparing a 2016 PM_{10} SIP as required by the CAA and the EPA regulations. This updated PM_{10} SIP may evaluate two major changes in the conditions and assumptions used as the basis for the IC

[39] ENVIRON International Corporation, 2009 (http://www.arb.ca.gov/planning/sip/planarea/imperial/imperialsip.htm and http://www.co.imperial.ca.us/airpollution/attainment%20plans/final%20ic%202009%20pm10%20sip%20document.pdf).

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2009 PM_{10} SIP: (1) a more comprehensive method for estimating exposed playa emissions and (2) CARB certified data from the six special purpose PM_{10} monitors operated and maintained by IID around the Salton Sea (see Section 3.1.2.5.1). The latter changes may influence the overall dust control strategy in Imperial County because the IID special purpose monitors indicate source areas that were either nonexistent in the years leading up to the IC 2009 PM_{10} SIP, or were not captured by the PM_{10} monitoring network established at the time.

2.3.2 Imperial County Air Pollution Control District Regulation VIII

The ICAPCD Regulation VIII was adopted on October 10, 1994, and revised on November 25, 1996, to comply with Reasonably Available Control Measures (RACM) to control fugitive dust emissions. On November 11, 2005, this regulation was revised again to include Best Available Control Measures (BACM) and was further divided in a series of seven individual rules. On October 16, 2012, the ICAPCD again adopted revisions to several of the rules contained in Regulation VIII to address further BACM concerns by EPA. On April 12, 2016, the ICAPCD adopted revisions to one rule, Rule 804 pertaining to disturbed open areas and described in further detail below, to provide a process for approval of alternative BACM not already listed as BACM for disturbed open areas in the rule.

Regulation VIII contains BACM as required by the CAA for "serious" PM_{10} nonattainment areas. Regulation VIII requires BACM for source categories such as: construction activities, disturbed open areas, paved roads and agricultural operations. Regulation VIII allows operators to determine the control techniques sufficient to limit visible dust emissions to 20 percent opacity and, if applicable to that source, to implement requirements for a stabilized surface. Dust control plans and recordkeeping are also required under the Regulation's provisions. Regulation VIII also includes test methods and standards.

Regulation VIII is divided into seven rules. Three of the rules—800, 804 and 806—are relevant to this SS AQM Program. Each relevant rule is described below.

2.3.2.1 Rule 800, General Requirements for Control of Fine Particulate Matter

Rule 800 contains the definitions, exemptions, general requirements, administrative requirements and test methods that are applicable to all Regulation VIII rules. Section C of Rule 800 contains the definitions that are essential to understanding each specific rule. Section F contains the general requirements that establish basic guidelines for dust control material(s), specifies requirements that the dust control material(s) must meet ICAPCD, SWRCB, CARB and EPA regulations, and contains guidelines for development of Bureau of Land Management (BLM) and Border Patrol dust control plans. Section G contains administrative requirements for test methods. Appendices A and B contain the test methods for visual determination of opacity and determination of surface stabilization, respectively. The latter contains methods for determining: visible crust strength (ball drop test), threshold friction velocity (sieve measurements to assign soil texture), surface protection from flat and standing vegetation and surface stabilization from rock armoring using the rock test method.

Rule 800 requires recreational off-highway vehicle (OHV) areas to apply BACM to mitigate fugitive dust emissions. On each day of an off-road event and/or competition during which 50 average vehicle daily

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trips per day will occur on an unpaved road segment, the owner or operator shall limit Visible Dust Emissions (VDE) to 20 percent opacity and comply with the requirements of a stabilized unpaved road by application, reapplication, or maintenance of at least one of the following control measures:

- Watering;
- Applying uniform layer of washed gravel;
- Paving;
- Restricting access;
- Restricting speed below 15 mph;
- Applying chemical or organic dust suppressants;
- Applying "road mix;" or
- Using any other method that can be demonstrated to effectively limit VDE to 20 percent opacity and meets the conditions of a stabilized unpaved road surface.

2.3.2.2 Rule 804, Open Areas

Rule 804 applies within rural areas to any open area of 3 acres or more that contains at least 1000 square feet of disturbed surface area. This rule pertains to the Salton Sea because exposed playa around the Sea qualifies as open areas under this rule. Section D of the rule contains exemptions for agricultural operation sites subject to Rule 806 and recreational OHV Use Areas on public lands subject to Rule 800. Section E contains requirements to apply BACM to limit VDE to 20 percent opacity and meet conditions for stabilized surface, and to install barriers to prevent unauthorized vehicle access to stabilized areas. Section F sets forth the permissible BACM for open areas. BACM for open areas includes: (1) applying water or chemical dust suppressants to all unvegetated areas, (2) establishing vegetation on previously disturbed areas, (3) paving, applying and maintaining gravel, or applying and maintaining chemical dust suppressants and (4) implementing alternative BACM that has gone through the approval process set forth in section G.

2.3.2.3 Rule 806, Conservation Management Practices

Rule 806 applies to all agricultural operation sites of 40 or more acres in size. This rule pertains to the Salton Sea because some exposed playa could be reclaimed for agricultural use (this occurred during previous dry periods). Section C of the rule contains definitions that are essential to understand the main terms and Conservation Management Practices (CMPs) in this rule. Section D contains requirements for agricultural operation sites to implement at least one CMP for land preparation and cultivation, harvest activities, unpaved roads and unpaved traffic areas. This section also contains guidelines for operators to develop alternative CMPs. In addition, this section requires the owner/operator to prepare a CMP plan and make it available upon request. Section E contains CMPs for land preparation and cultivation, harvesting, unpaved roads and unpaved traffic areas. Section F contains guidelines to develop a CMP plan.

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2.4 SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

The SCAQMD is the local regulatory agency for air quality compliance within Riverside County. SCAQMD has a governing board that adopts the policies and regulations for air quality within Riverside County and is managed by the Executive Officer. SCAQMD has adopted a SIP specifically for the Coachella Valley, which includes the Salton Sea Air Basin and establishes controls needed to demonstrate expeditious attainment of the PM_{10} standards in that area. SCAQMD has also adopted the *Rules of the South Coast Air Quality Management District*, which includes thirty-five regulations (Regulations I to XXXV) each of which is broken down into separate rules.[40]

2.4.1 COACHELLA VALLEY PM_{10} SIP

On June 21, 2002, the SCAQMD held a public hearing and adopted the *Final 2002 Coachella Valley PM_{10} State Implementation Plan* (CV 2002 PM_{10} SIP).[41] After years of demonstrating attainment of the PM_{10} standards, PM_{10} levels in the years 1999-2001 did not demonstrate attainment of the annual average PM_{10} National Ambient Air Quality Standards, but Coachella Valley had attained the 24-hour PM_{10} standard since 1993. The CV 2002 PM_{10} SIP addressed the rise in PM_{10} levels and established additional controls needed to demonstrate expeditious attainment of the PM_{10} standards. The CV 2002 PM_{10} SIP modified previous analyses and programs, including additional control measures for construction and earthmoving activities, farming, paved and unpaved roads, parking lots, vacant lands and farming. As required by the CAA and the EPA regulations, the CV 2002 PM_{10} SIP included a revised emissions inventory, a control strategy and a demonstration of attainment. At the time of adoption, the SCAQMD committed to revising the CV 2002 PM_{10} SIP with the latest approved mobile source emission estimates, planning assumptions and fugitive dust source emission estimates.[42]

On August 1, 2003, the SCAQMD held a public hearing and adopted the *Final 2003 Coachella Valley PM_{10} State Implementation Plan* (CV 2003 PM_{10} SIP).[43] The CV 2003 PM_{10} SIP contained an updated emissions inventory, emission budgets and attainment modeling.

2.4.2 SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT REGULATION IV

The SCAQMD Regulation IV generally addresses prohibitions relating to air quality. The rules regulating PM_{10} that are relevant to this SS AQM Program include Rules 403 and 403.1.

2.4.2.1 RULE 403, FUGITIVE DUST

Rule 403 applies to any activity or man-made condition capable of generating fugitive dust. Section C of the rule contains the definitions necessary to understand the rule. Section D sets out requirements and prohibitions relating to fugitive dust emissions. For instance, no person shall cause or allow the

[40] Located at http://www.aqmd.gov/home/regulations/rules/scaqmd-rule-book.
[41] Located at http://www.aqmd.gov/home/library/clean-air-plans/coachella-valley-pm10-plan and http://www.aqmd.gov/home/library/clean-air-plans/coachella-valley-pm10-plan/final-2002-cv-pm10-plan.
[42] http://www.aqmd.gov/home/library/clean-air-plans/coachella-valley-pm10-plan.
[43] Located at http://www.aqmd.gov/docs/default-source/clean-air-plans/pm10-plans/final-2003-coachella-valley-pm10-state-implementation-plan.pdf?sfvrsn=2.

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emissions of fugitive dust from any active operation, open storage pile, or disturbed surface area such that 1) the dust remains visible in the atmosphere beyond the property line of the emission source or 2) the dust emission exceeds 20 percent opacity, if the dust emission is the result of movement of a motorized vehicle. Section G provides exemptions to the rule. Table 1 of the rule sets out control measures permitted to address certain source categories.

2.4.2.2 Rule 403.1, Supplemental Fugitive Dust Control Requirements for Coachella Valley Sources

Rule 403.1 applies only to fugitive dust sources in Coachella Valley. Section C of the rule contains the definitions necessary to understand the rule. Section D sets out the general requirements of the rule. Section E provides the requirements for a fugitive dust control plan and other requirements for construction projects or other earth-moving activities. Section F identifies the requirements for a fugitive dust control plan, including submittal and approval. Section G specifies wind monitoring implementation requirements and Section I provides the exemptions to the rule.

2.5 EPA Exceptional Event Rule

Because of its extremely dry climate and vast areas of undeveloped desert land, PM_{10} concentrations in Imperial County and the Coachella Valley are dominated by fugitive dust emissions. The primary sources of high PM_{10} concentrations in Imperial County are: (1) soil disturbance caused by wind and human activity, (2) transport of high PM_{10} concentrations from Mexicali, Mexico, and (3) occasionally, wildfires. High PM_{10} concentrations caused by uncontrollable natural events such as high winds and wildfires may qualify as "Exceptional Events" under current EPA rules and therefore may be excluded from compliance calculations. These events must be properly documented according to the EPA's Exceptional Event Rule guidelines. Both ICAPCD and IID will commit resources and work together to 1) identify and document potential exceptional events that may have been influenced by Salton Sea exposed playa and/or open areas in the surrounding area and 2) apply to EPA for concurrence on the documentation in order to exclude these data in future attainment determinations.

3 SS AQM Program Description

This SS AQM Program is divided into three parts: (1) an updated PM_{10} emission inventory for playa and non-playa sources, (2) a control strategy for playa sources only and (3) a general estimated cost analysis. The program objectives are six-fold:

1. Identify and characterize playa sources as the Salton Sea recedes to facilitate implementation of proactive dust control measures[44] and BACM (currently defined by Rule 804).
2. Investigate the location, magnitude, seasonality and frequency of dust emissions in the desert areas located west of the Salton Sea. This will facilitate future support documentation to exclude data clearly associated with Exceptional Events.

[44] This is the monitoring portion of Objective 3.

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3. Proactively control dust emissions from exposed Salton Sea playa to prevent the occurrence of significant dust emissions.
4. Pilot-test new dust control measures that are specifically tailored to the climate and soil conditions on and around the Salton Sea playa and that make efficient use of available resources and submit for approval successfully tested dust control measures as potential new alternative BACM according existing rules.
5. Identify opportunities to establish new procedures and rules and/or improve existing procedures and rules to fully and successfully implement this SS AQM Program.
6. Develop a general understanding of associated estimated costs and cost areas needing further analysis.

Objectives 1 and 2 are addressed in the PM_{10} emission inventory section (Section 3.1). Objectives 3, 4 and 5 are addressed in the dust control strategy section (Section 3.2). Objective 6 is addressed in the estimated cost analysis section (Section 3.3).

3.1 PM_{10} Emissions Inventory

This section describes the methods used to characterize dust emissions from playa and non-playa sources around the Salton Sea.

3.1.1 Playa Sources

Playa exposure and its associated surface and emissions characteristics are a major focus of this SS AQM Program. Research and monitoring are focused on understanding the location and timing of playa exposure, salt crust surface characteristics and the associated emission potentials.

3.1.1.1 Approach

This section describes the methods that will be used to evaluate playa emissions as the Salton Sea recedes. The generalized approach is as follows:

- Observe and document the extent of playa exposure (see Section 3.1.1.2).
- Characterize the emission potential of exposed playa surfaces (see Section 3.1.1.3).
- Record the time and location of dust plumes or any other indication of dust emission activity (see Section 3.1.1.4).
- Map active source areas using remote sensing methods (see Section 3.1.1.5).
- Quantify total annual and daily dust emissions from active source areas (see Section 3.1.1.6).
- Model dust emissions to evaluate potential impacts at PM_{10} compliance monitors (see Section 3.1.1.7).

Each bullet is described in the sections below. As mentioned above, this information is required to facilitate the proactive dust control planning described in Section 3.2.

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3.1.1.2 PLAYA EXPOSURE

Projecting future playa exposure as well as tracking actual playa exposure and land ownership of exposed playa is an important aspect of this SS AQM Program. Each component is described below.

3.1.1.2.1 PROJECTED FUTURE EXPOSURE

The timing and location of future playa exposure is a function of the hydrologic response of the Salton Sea to external forces, such as inflows, salt loads and evaporation rates. The Salton Sea Accounting Model (SSAM) was originally developed by Reclamation to simulate the effects of the water transfers under the QSA on Salton Sea surface elevation and salinity. In 2006, the hydrologic modeling framework was revised to incorporate additional data, water balance improvements and add flexibility to the model. The updated model is called the Salton Sea Analysis model (or SALSA model) developed for the Programmatic Environmental Impact Report (PEIR) for the Salton Sea Ecosystem Restoration Program, which was prepared under the direction of the California Department of Water Resources and the California Department of Fish and Wildlife[45] on behalf of the Natural Resources Agency.[46] The SALSA model has since been updated further and is referred to as the SALSA2 model. CH2M[47] is currently preparing a hydrology analysis of the Salton Sea using the SALSA2 model. Details regarding the most recent updates to the model and the assumptions used for the hydrology modeling and analysis will be described in a separate report prepared by CH2M for IID anticipated to be released in the summer of 2016.

The SALSA2 modeling and projected Salton Sea playa exposure is important to this SS AQM Program for several reasons. Projecting future exposed playa will assist in the PM_{10} emission inventory by identifying where, when and the amount of exposed playa that will contribute to the inventory. The SALSA2 modeling will be used for comparative purposes to actual exposed playa as the Salton Sea recedes and will thereby inform the PM_{10} emission inventory as it is carried out. The comparisons that will be drawn are described in further detail below. Additionally, projections of the exposed playa will be used as a tool for planning and decision-making for determining the best use of resources in implementation of the various steps of this program, including the dust control strategy (Section 3.2). Anticipating where, when and the amount of playa that will be exposed will help shape the development of the dust control strategy. Finally, projecting the exposed playa directly attributable to the water transfers under the QSA will allow for the mitigation requirements under the QSA to be fulfilled in accordance with the QSA Final EIR/EIS and the SWRCB Order. While the SALSA2 model is the most current hydrologic modeling, any future updated modeling and projections can be used in the same manner in this SS AQM Program.

3.1.1.2.2 ACTUAL PLAYA EXPOSURE

Monitoring of the actual Salton Sea surface elevation and associated playa exposure is important for understanding potential air quality impacts. This information will provide a real-time understanding of actual playa exposure as it occurs and will help to validate the SALSA2 model results. Two independent

[45] Formerly the California Department of Fish and Game.
[46] Formerly the California Resources Agency.
[47] CH2M Hill, Inc.

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methods have been developed to quantify actual playa exposure. Each is summarized below. Technical details on monitoring actual exposed playa are in Appendix B.

USGS Salton Sea Elevation. Salton Sea elevation is monitored continuously by the United States Geological Survey (USGS).[48] The monitored Sea elevation data provide the basis for extracting a shoreline from high-resolution bathymetric data (Figure 3-1). All data from the USGS gauge are collected in National Vertical Datum of 1929 (NGVD29). To ensure consistency when using the bathymetric data or comparing to SALSA2 model results, all data must be converted to North American Vertical Datum of 1988 (NAVD88) using the standard conversion factor of 2.113 feet (given the geographic coordinates of the gauge and using the National Geodetic Survey's VERTCON calculator). GIS tools have been developed to provide near real-time estimates of shoreline location and therefore playa exposure (as compared to the modeled projections of playa exposure described above).

A subset of USGS-based Salton Sea elevation and gauge readings have been compiled from 2003 to 2015 (year-end Sea elevations) (Table 3-1). These USGS-based Sea elevation and gauge readings can be compared to SALSA2 model projections or other hydrologic modeling projections in the future. Results from this comparison can indicate the accuracy of the modeling projections for Sea elevations and consistency with the bathymetric data.

TABLE 3-1. USGS GAUGE EXPOSURE ESTIMATES

USGS Gauge Reading (Month)	Average Monthly USGS Salton Sea Elevation (ft NAVD88)	USGS / Bathymetry Playa Exposure (Acres)
12/2003	-229.0	Baseline (0 Acres)
12/2005	-226.9	207
12/2006	-227.6	2,071
12/2008	-228.5	5,244
12/2009	-229.5	7,653
11/2011	-230.2	8,254
12/2013	-230.8	10,029
11/2014	-232.0	12,787
06/2015	-231.7	12,074

[48] USGS Site 10254005 Salton Sea NR Westmoreland, CA.

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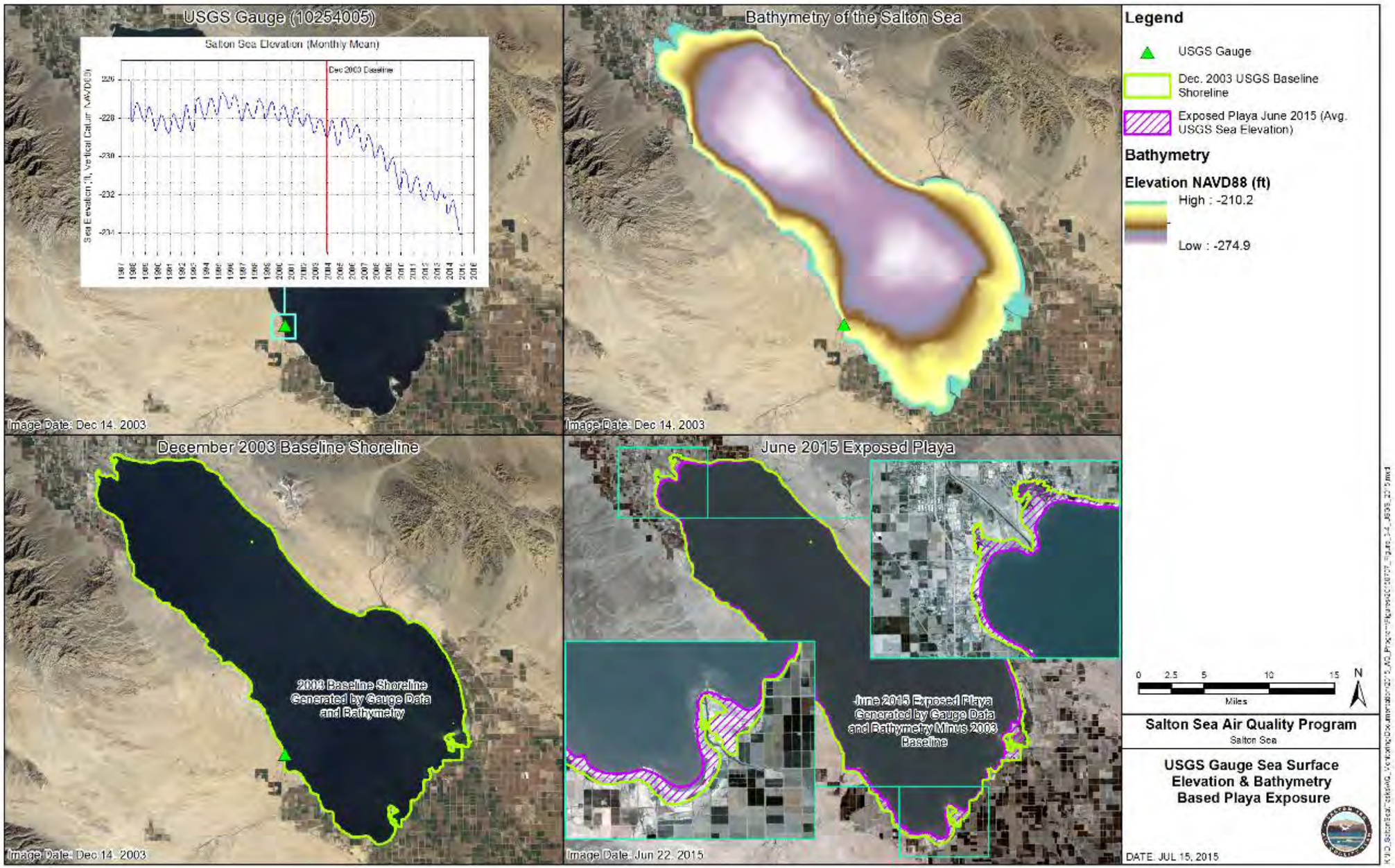
FIGURE 3-1. USGS GAUGE LOCATION AND SHORELINE EXTRACTION PROCESS FOR JUNE 2015

The USGS gauge Salton Sea surface elevation for June 2015 was used to demonstrate actual playa exposure from December 2003 to June 2015.



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Landsat Satellite Imagery: The accuracy of the USGS gauge-based shoreline is a function of the Salton Sea elevation data from the USGS as well as the precision of the underlying bathymetric data. Therefore, an independent method for assessing exposed playa was developed using satellite imagery. Specifically, the Landsat 5 (1984 to 2013), Landsat 7 (1999 to present) and Landsat 8 (2013 to present) satellites provide current and historic imagery on an 8-to-16-day basis for the Salton Sea. A spectral water index called the Modified Normalized Difference Water Index (MNDWI) (Equation 1) was used to identify standing water associated with the Salton Sea from Landsat imagery. MNDWI is based on the fact that water absorbs energy at shortwave-infrared (SWIR) wavelengths. The integration of the green band into the equation reduces noise associated with other land-based features.[49] A date-specific threshold of MNDWI was then established to isolate the Salton Sea water body and associated shoreline (Figure 3-2).

EQUATION 1 - MNDWI

$$MNDWI = \frac{\rho\ green - \ \rho\ SWIR}{\rho\ green + \ \rho\ SWIR}$$

Table 3-2 depicts the Landsat MNDWI playa exposure compared to USGS gauge Sea elevation playa exposure (year-end Sea elevations). Results indicate that the two methods produce comparable actual playa exposure estimates and are in a 1:1 relationship with an R^2 of 0.98 (Figure 3-3). Further evaluation of individual dates revealed that the USGS gauge and bathymetric approach over-estimated playa exposure in the southern portion of the Salton Sea north of the Alamo River (Figure 3-4). These differences are likely due to errors in the bathymetric model. Acoustic sonar data (captured in 2005 and used as the basis for the bathymetric model) are unreliable in waters less than 1-meter deep (e.g. bay areas around the New and Alamo Rivers). The Landsat MNDWI does not rely on the bathymetric data, so it is able to accurately quantify the Salton Sea extent and therefore playa exposure (Figure 3-4).

Actual playa exposure will continue to be monitored and reported on a quarterly basis using the Landsat imagery as well as the USGS Sea elevation approach. Results of the quarterly monitoring will be shared with the Imperial County and ICAPCD. Results will also be used to update future SALSA2 model projections. Technical details on the monitoring are provided in Appendix B.

[49] Lei Ji, Li Zhang and Bruce Wylie, *Analysis of Dynamic Thresholds for the Normalized Difference Water Index* (2009).

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FIGURE 3-2. LANDSAT MNDWI PLAYA EXPOSURE ESTIMATE

Landsat imagery and the MNDWI water index is used to delineate the Salton Sea shoreline for 2003 and 2015.

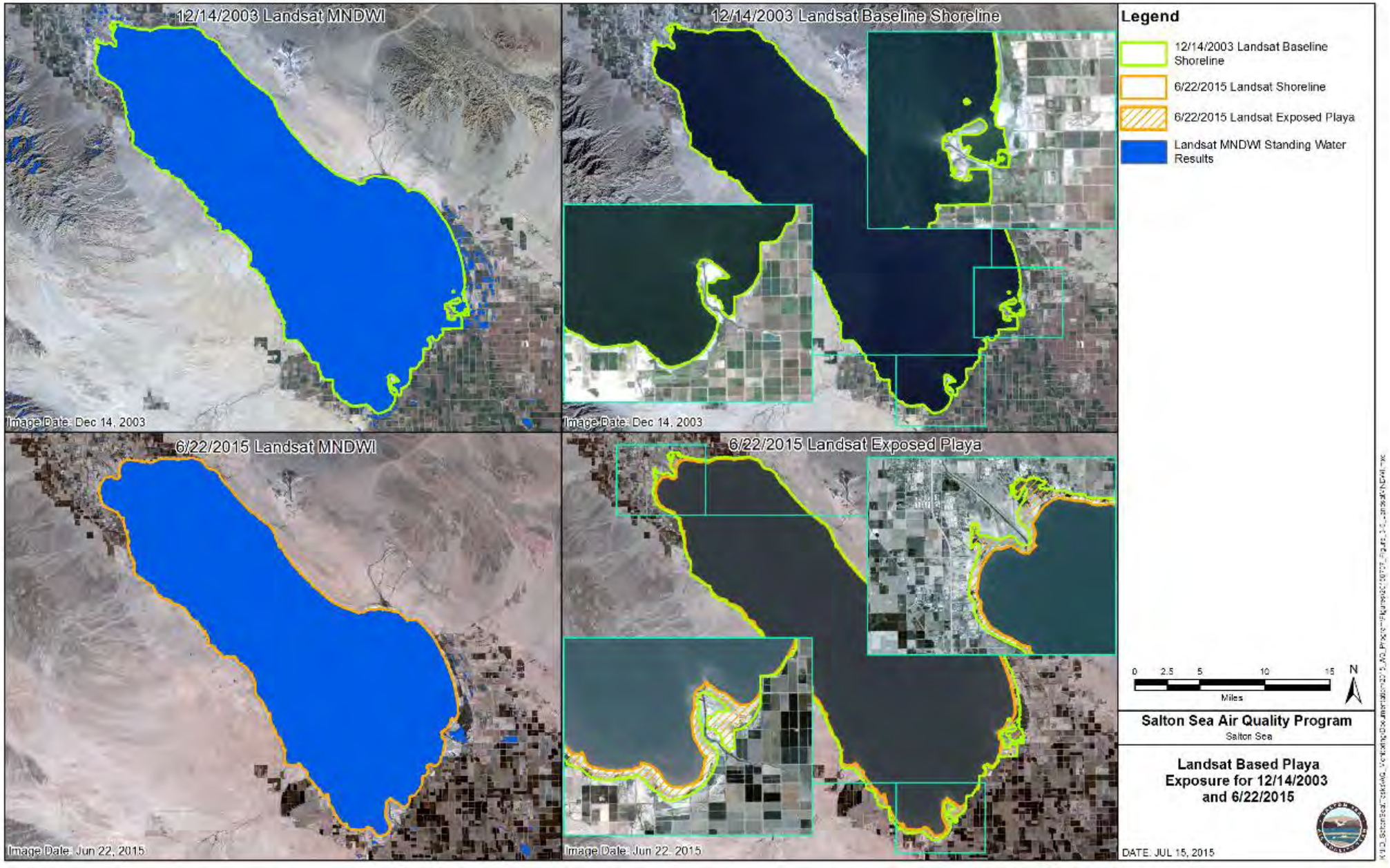

TABLE 3-2. LANDSAT MNDWI AND USGS GAUGE PLAYA EXPOSURE ESTIMATES

Landsat MNDWI Date	Landsat MNDWI Playa Exposure (Acres)	USGS Gauge Reading (Month)	Average Monthly USGS Salton Sea Elevation (ft NAVD88)	USGS / Bathymetry Playa Exposure (Acres)
12/15/2003	Baseline (0)	12/2003	-229.0	Baseline (0)
11/17/2005	478	12/2005	-226.9	207
12/06/2006	1,848	12/2006	-227.6	2,071
12/11/2008	3,565	12/2008	-228.5	5,244
12/14/2009	7,050	12/2009	-229.5	7,653
11/02/2011	8,499	11/2011	-230.2	8,254
12/25/2013	10,242	12/2013	-230.8	10,029
11/26/2014	13,470	11/2014	-232.0	12,787
06/22/2015	12,619	06/2015	-231.7	12,074

FIGURE 3-3. LANDSAT MNDWI VS. USGS GAUGE PLAYA EXPOSURE

Landsat MNDWI playa exposure regressed against USGS gauge estimates. Results show the strong relationship and consistent relationship between the two actual playa exposure monitoring methods.

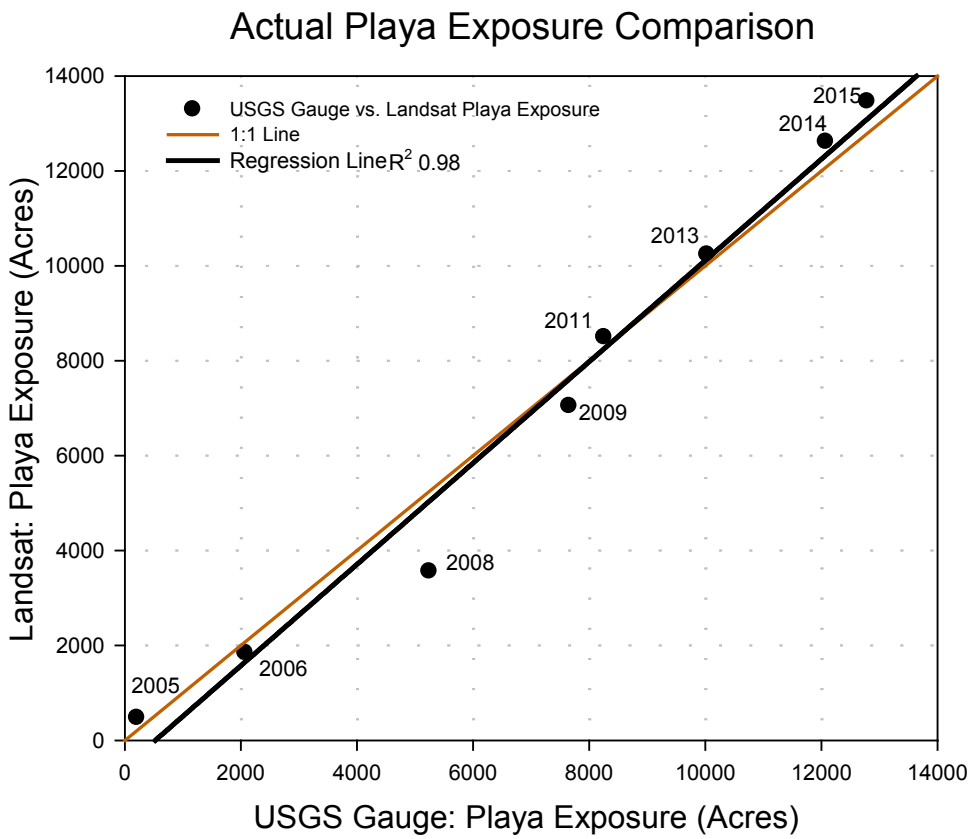

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FIGURE 3-4. LANDSAT MNDWI AND USGS GAUGE EXPOSURE FOR 2008

Landsat imagery was able to accurately capture the shoreline in 2008 around the Alamo and New River areas. These shallow water areas have limited acoustic data for generation of the bathymetric layer and therefore are more error-prone when used to generate playa exposure at certain Salton Sea elevations.



3.1.1.2.3 EXPOSED PLAYA LAND OWNERSHIP

The incremental projected and actual playa exposure data will be overlain with land ownership information. Landowners are responsible for compliance with the air quality requirements contained in the local rules and regulations within that district (i.e., ICAPCD or SCAQMD). The playa exposed as a direct result of the water transfers under the QSA involves the added monitoring and mitigation requirements under the QSA Final EIR/EIS and the SWRCB Order. This added layer of compliance does not change the underlying air quality requirements for land within either local district. The overlay of the projected and actual playa exposure data with the land ownership information simply provides planning level information of land actually impacted or expected to be impacted by the receding Salton Sea.

3.1.1.3 SURFACE CHARACTERISTICS

Playa salt crusts, sand sheets, beach deposits and soil surfaces (surfaces) are a major focus of this SS AQM Program because they represent potential sources of PM_{10} emissions. The mechanisms for production of PM_{10} emissions from playas are relatively well understood. In general, large sustained emissions from playas occur when sand, or sand-sized particles, are moved by high wind (generally 15 miles per hour or greater) such that they begin to bounce or "saltate" across the playa surface. As the moving particles repeatedly impact the fragile salt crust, they can dislodge smaller particles into the air and generate dust. This also can expose underlying and sometimes more erodible soil layers. While the mechanism of saltation is well understood, the vulnerability of different playa surfaces to erosion is not well understood and is known to be highly variable (both spatially and temporally). For instance, some playa surfaces have characteristics that make them more susceptible to erosion (i.e., fluffy, loose salt crust), whereas other surfaces are rigid and sturdy and strongly resist erosion.

Overall, playa surfaces dominated by coarser-textured (sandy) soils have more predictable emissions because emissions are largely a factor of saltating sand. In contrast, emissions from playa surfaces with finer-textured, clay soils have less predictable emissions because of sensitivity to environmental influences (e.g., climatic, hydrologic and anthropogenic). For example, annual weather patterns, including timing of precipitation events, high wind speeds, diurnal temperature changes, depth to groundwater and relative humidity can cause playa surface mineralogy dynamics to change, and increase (or decrease) the potential risk of erosion. The emission inventory under this SS AQM Program will identify the playa surface characteristics and surface mineralogy dynamics that create salt crust conditions vulnerable to erosion. These activities will be designed to provide a better understanding of salt crust formation and erosion at the Salton Sea.

Research and monitoring of playa surface characteristics are divided into two broad categories: existing playa and future playa. Each is described below. Technical details on this monitoring approach are provided in Appendix B.

3.1.1.3.1 EXISTING PLAYA

Existing playa surfaces provide insight into the range of conditions that may be reasonably expected as other playa surfaces are gradually exposed. Specifically, properties controlled by evaporate (water-

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soluble salt) mineral dynamics (e.g., surface type, surface crust thickness and surface crust hardness) will be mapped and monitored because they are directly related to the spatial and temporal nature of PM_{10} dust emissions.[50]

Extensive playa surface survey monitoring methodology originally developed for Owens Lake is being adapted for use at the Salton Sea. This includes monitoring protocols and methodology to accurately map existing playa surface characteristics (analogous to soil map units) using remotely sensed data resources and ground-based surface evaluations. Ground-based surface evaluations include detailed characterization of surface properties related to erosion (Table 3-3). These datasets will then be used as calibration data to spatially map playa surface types, vegetation and other surface characteristics using LiDAR (Light Detection and Ranging), UAV (unmanned aerial vehicle) imagery and other sources of satellite-based imagery (Figure 3-5). These mapping efforts will be done periodically to provide an updated inventory of exposed playa surface units and associated physical characteristics. These data will be used in the assessment of playa emissions potential (see Section 3.1.1.4). Surface classification and mapping methodology will be further adapted as playa exposure progresses and a wider diversity of playa surface categories may become apparent.

[50] Buck, B., J. King, and V. Etyemezian. Effects of Salt Mineralogy on Dust Emissions, Salton Sea, California (2011), Soil Sci. Soc. Am. J. 75:1958–1972. doi:10.2136/sssaj2011.0049.

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FIGURE 3-5. EXAMPLE PLAYA SURFACE CLASSIFICATION MAP

This playa surface classification map was developed using high-resolution aerial imagery and LiDAR data. Playa surface map units and vegetation characteristics provide information related to emissions potential of exposure playa.



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TABLE 3-3. SURFACE PROPERTIES COLLECTED DURING SURFACE CHARACTERIZATION EVENTS

Surface Property	Description
Crust Type	Crust categories may include: smooth, botryoidal, weak botryoidal, hummocky and networked. The dominant crust type of the observation area will be characterized, and if other types are present in smaller amounts, they will be noted as inclusions. Additional crust categories may be developed specifically for the Salton Sea Playa.
Crust Thickness	Crust thickness is measured from the top of salt crust to the top of soil. In some places, the salt crust will be divided into two distinctly different layers: top crust and sub crust. Top crust is usually a harder, salt-cemented crust that forms a shell over the surface. Sub crust usually has weak structure (i.e., soft or crumbly) and extends from the bottom of the top crust to the underlying, often looser soil. In some cases, a top crust will exist without a sub crust and will be directly overlaying the soil. Total crust thickness is considered the sum of top crust and sub crust.
Soil Moisture	Soil moisture will be qualitatively assessed for the first one to two inches of soil directly below the crust. Soil moisture can be classified based on USDA-NRCS classification parameters (Schoenenberger et al., 2002). Soils will usually range from slightly moist to saturated where crust exists and dry to saturated where no crust exists.
Crust Relief	Crust relief is measured to provide a more refined understanding of surface roughness. Roughness affects wind resistance and surface wind velocities and is therefore useful in wind-erosion modeling. Crust relief is determined by measuring the distance from the bottom of a crust depression to the top of a typical crust ridge. Networked, botryoidal and hummocky crusts usually have the greatest relief.
Crust Hardness	Crust hardness indicates the degree of erosion resistance. Crust hardness can be characterized by the amount of force necessary to crush the salt crust by hand according to USDA-NRCS guidelines (Schoenenberger et al., 2002). On average, smooth and weak botryoidal crust types are the softest, while networked and hummocky crusts are harder. Hardness of both top crust and sub crust will be assessed if distinct surface and sub crusts are present. In addition, the "ball drop method" will be used to evaluate crust hardness at each location using Rule 800 specifications
Penetration Resistance	Penetration resistance can be measured with a penetrometer. A penetrometer is inserted through the total crust depth to assess crust resistance. Local penetration resistance can vary substantially and will be measured at several points to calculate an average penetration resistance for a crust type.
Surface Erosion	Surface erosion is generally characterized as a percentage of total crust area that appears to have been eroded by wind. This can be done with visual or remote-sensing techniques.
Free Surface Sand	Free surface sand is visually determined by estimating the percentage of free, sand-sized particles in a square meter of playa surface. The amount of free sand can vary seasonally with crust development, because forming crusts can encapsulate surface sand as they harden. Free sand particles on the surface are often very fine and settle into very small depressions in crust surfaces.
Percentage Vegetation, Overflow and Other Features	Percent surface area of vegetative cover, dune area, berm area, overflow area and representative playa area will be estimated. These estimates will provide a distribution of small inclusions relative to the dominant mapped surface condition. These features also have implications for the formation of crusts and erodibility; percent overflow area and vegetative cover are probably the most influential of these features. The surface area assessment can be performed visually (from the ground) or using remote-sensing techniques.

3.1.1.3.2 FUTURE PLAYA

This SS AQM Program will assess inundated playa soils using datasets and analyses related to Salton Sea floor bathymetry and sediment characteristics. Acoustic sonar data collected by the Bureau of Reclamation were analyzed to provide planning level information on surface soil characteristics of the currently inundated playa. These data were collected at two sonar frequencies (50 khz and 200khz) and combined with ground-truth data of soil sediment characteristics (Figure 3-6). The resulting spatial maps predict surface sediment texture, soft sediment depth, surface roughness/complexity and barnacle bed locations. These data are valuable for understanding the types of soils and surfaces that

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will be exposed as the Salton Sea recedes and for establishing monitoring protocols for specific soil types. In addition, results also provide insight into the types of dust control measures that may work well in specific regions of future exposed playa.

If additional datasets and analyses are required to provide greater detail on currently inundated playa soils, then they will be developed as part of this SS AQM Program. This may include optical Salton Sea floor mapping products designed to quantify sediment characteristics. This can be accomplished using various techniques, but the most promising technique is Sediment Profile Imaging (SPI). SPI is an optical remote monitoring technique used to image, measure and analyze the physical, chemical and biological parameters in aquatic environments to a depth of eight inches or more.

3.1.1.4 Assessing the Emission Potential of Exposed Playa Surfaces

This SS AQM Program will assess which playa surfaces and conditions are actually emissive and identify source areas associated with erosion events. This section describes the purpose of assessing emission potential, the field measurement system and the sampling program.

3.1.1.4.1 Purpose

Periodically assessing the emission potential of exposed Salton Sea playa will serve three purposes:

1. Periodic updating of the emission inventory for exposed Salton Sea playa. To the extent practical, the emission inventory will be refined to differentiate the *active* exposed playa sources (see Section 3.1.1.5).
2. Characterizing the "dust season(s)" on the Salton Sea playa; that is, the times of the year when dust emissions typically occur under different climate and soil conditions.
3. Establishing PM_{10} emission rates (in units of mass per unit area per unit time, e.g. $\mu g/m^3$) for different types of exposed playa. The data will be used to model the PM_{10} contributions at nearby monitoring stations.

The next two sections describe the measurement system and how it will be used on Salton Sea playa.

3.1.1.4.2 Field Measurement System

The emission potential of exposed playa surfaces will be assessed using a device called the Portable In-Situ Wind Erosion Laboratory (PI-SWERL), developed by Vicken Etyemezian and others at the Desert Research Institute, Reno, Nevada (Figure 3-7). The PI-SWERL instrument is an open-bottomed, cylindrical chamber with a top-mounted, direct-current motor that spins a metal ring inside the chamber about 2.5 inches above, and parallel to, the soil surface. Principles of fluid mechanics allow simulation of the turbulence conditions that produce dust storms in the surrounding environment. The spinning ring creates a shear stress profile (which produces turbulence), lofting soil and dust particles, and passing them through particle samplers (both sand-sized and dust-sized particles). The PI-SWERL electronically measures the number and size of suspended particles over the duration of a test cycle, typically less than 10 minutes. By controlling the speed of the ring to simulate varying wind speeds, the potential for a soil surface to produce PM_{10} dust emissions can be determined under a range of simulated wind conditions.

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FIGURE 3-6. SOIL CHARACTERISTICS OF FUTURE EXPOSED PLAYA FROM ACOUSTIC SONAR DATA

Acoustic sonar data from the Bureau of Reclamation were used to map sediment characteristics of future exposured playa. This information will be used for planning monitoring activities and dust control as playa is exposed.

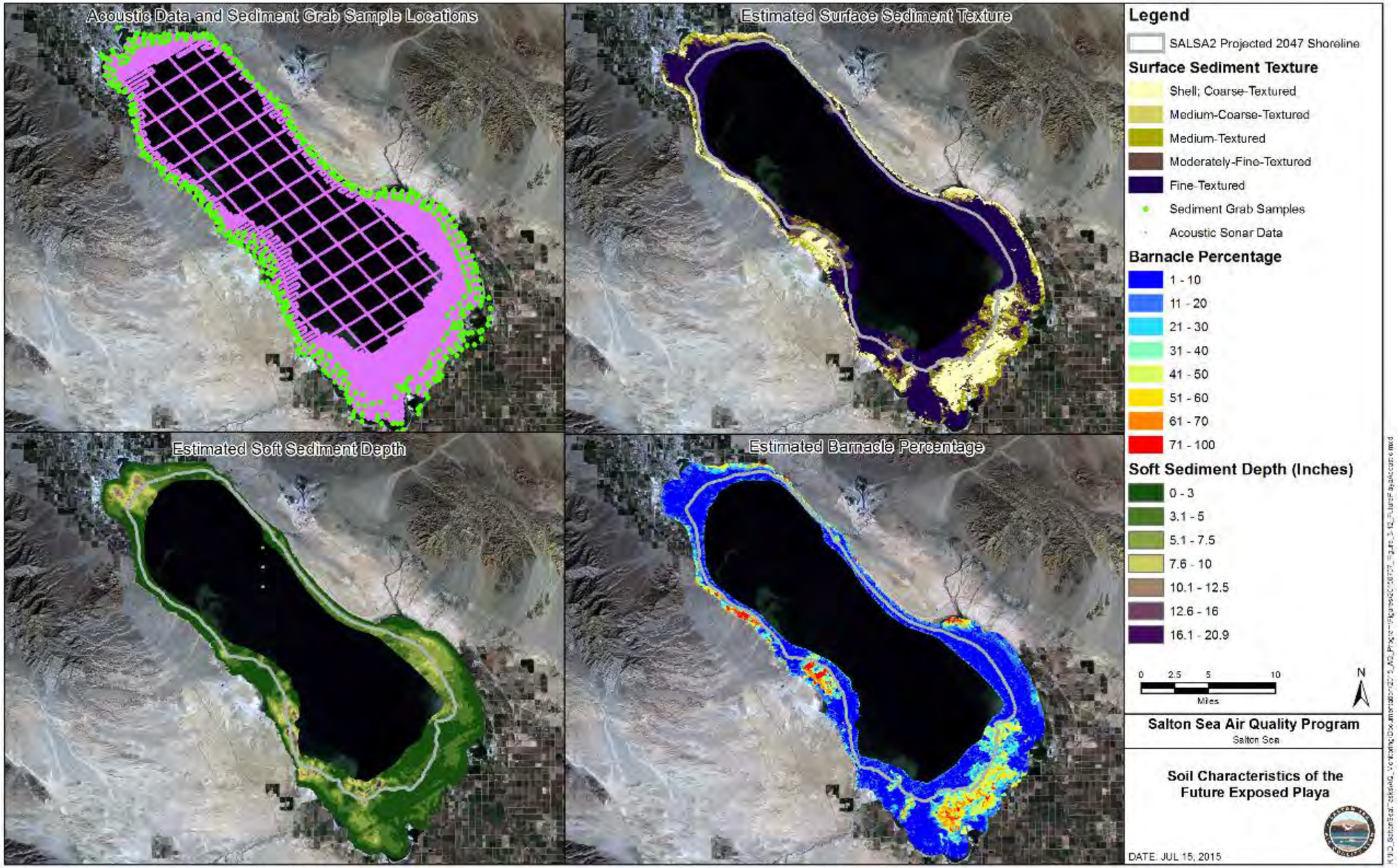

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FIGURE 3-7. PORTABLE IN-SITU WIND EROSION LABORATORY (PI-SWERL)

The PI-SWERL (silver chamber on the right side of photograph) uses a tri-wheeled buggy (left side of photograph) to transport the instrument and all supporting components. The PI-SWERL measures 30 centimeters (roughly 12 inches) in diameter.



The PI-SWERL is a highly portable, easy-to-use device that measures potential sand motion and dust emissions from surfaces under field conditions. The advantage of the PI-SWERL over the traditional rectangular field wind tunnels is its portability combined with rapid testing at a site. The ease and speed of conducting tests allows the investigator to perform many replicate measurements in an efficient manner (typically 25-35 tests daily). The instrument has been used to evaluate potential sand motion and PM_{10} emissions throughout the southwestern United States, as well as abroad.[51]

3.1.1.4.3 PI-SWERL OPERATION ON SALTON SEA PLAYA

This SS AQM Program includes a PI-SWERL sampling program. PI-SWERL sampling will occur monthly on each identified playa surface type, barring wet soils or other conditions that might limit site access. Monthly results will facilitate a better understanding of the "dust season" on different parts of the

[51] King, James, et al. 2011. Dust emission variability at the Salton Sea, California, USA. Aeolian Research 3.1: 67-79; Macpherson, Torin, et al. 2008. Dust emissions from undisturbed and disturbed supply-limited desert surfaces. Journal of Geophysical Research: Earth Surface (2003–2012) 113.F2; Goossens, Dirk, and Brenda Buck. 2009. Dust dynamics in off-road vehicle trails: measurements on 16 arid soil types, Nevada, USA. Journal of environmental management 90.11: 3458-3469; Bacon, Steven N., et al. 2011. Total suspended particulate matter emissions at high friction velocities from desert landforms. Journal of Geophysical Research: Earth Surface (2003–2012) 116.F3.

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Salton Sea playa. Each surface type will be randomly sampled with a fixed number of replications. Replications are essential for understanding the range of variability that exists within an identified surface type.

The PI-SWERL sampling program will occur across the entire exposed playa, not just the portion that is actively emissive. However, additional sampling will occur within and around the active source areas. Appendix B contains a detailed sampling plan, including the process for determining the number of sampling locations and replications within each surface type.

3.1.1.5 Delineating Active Areas on Exposed Playa

The success of the proactive dust control program described in Section 3.2.1 depends on having available the means to quickly and reliably map dust sources over the vast areas of exposed Salton Sea playa. An efficient way to accomplish this would be to take high-resolution aerial photographs of the playa during high-wind events. The photographs would be evaluated to reveal areas with the highest dust concentrations, which would help to differentiate source areas from more dispersed dust plumes. Relatively low altitude flights over the surface should allow closer inspection of surface activity.

Another approach, albeit somewhat more complicated and costly, would involve traversing the playa with scanning LiDAR mounted on a commercial aircraft. Dust sources would be revealed by filtering out the ground and any low-return-intensity signals indicating a dispersed dust plume. The filtered results would be associated with the highest dust concentrations from or near the point of emissions.

Mapping the playa several times during a single high wind event and then comparing the results across several high wind events would produce a greater understanding of where and how often dust emissions are occurring on the playa. The information would be applied to help prioritize proactive dust controls. Both aerial mapping methods are expensive, but would produce far greater certainty than other fixed monitoring technologies and would lead to a far more cost-effective system than simply placing dust control measures everywhere on the playa.

Several organizations and vendors have this capability, including NASA's Jet Propulsion Laboratory in Pasadena, California. An on-call contract would be necessary to ensure that aircraft can be deployed as needed during active dust storms.

3.1.1.6 Estimating Emissions on Active Areas

The PI-SWERL sampling and active area delineation will enable two types of emission estimates: maximum daily emissions (tpd for active source areas) and total annual emissions (tons per year [tpy] for all active source areas). Each is described below.

3.1.1.6.1 Maximum Daily Emissions

The PI-SWERL-measured emission potential is expected to vary over time depending on the surface type, climate conditions (e.g., temperature, wind speed, wind direction) and other factors. Similarly, the source areas active at any one time are also expected to vary by the same conditions. Accordingly, the maximum daily emissions will be computed by multiplying the maximum daily active area (in square

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meters) by the maximum emission potential (in grams of PM_{10} per square meter per day) *for each identified source type*. The sum of all the source types on the playa yields the maximum daily emissions for the entire playa (converted to tpd). Maximum daily emissions will be computed on a yearly basis.

3.1.1.6.2 TOTAL ANNUAL EMISSIONS

In similar fashion, the total annual emissions will be estimated by summing the product of the average active area per month (in square meters) by the average emission potential (in tons of PM_{10} per square meter per month) for all source types and months. The final units will be in tpy.

3.1.1.7 MODELING IMPACTS AT MONITORING STATIONS

The CALPUFF modeling system will be used to model the impact of the maximum daily emissions from exposed playa sources at monitoring stations located around Imperial and Riverside Counties. The purpose is to assess the relative contribution of exposed playa sources at the monitors. The difference between the observed PM_{10} concentrations at the monitors and the CALPUFF-predicted PM_{10} concentration is that the CALPUFF emission rates will be based on the maximum daily emission estimate (see Section 3.1.1.6.1).

3.1.2 NON-PLAYA SOURCES

This section describes the methods used to evaluate dust emissions from the open areas around the Salton Sea. This section also summarizes the methods used to compute total annual emissions and maximum daily emission rate by surface type within the area of interest (AOI). The approach, AOI, surface types, monitoring and estimation of emission rates are described below. Detailed technical information on the off-Sea inventory plan is provided in Appendix C.

3.1.2.1 APPROACH

Several lines of evidence will be used to establish the location, timing and magnitude of dust emissions from off-Sea areas, including: (1) "PM_{10} roses"[52] using data from the PM_{10} monitoring network on the west side of the Salton Sea; (2) a network of fixed sand motion monitoring instruments placed within various surface types; (3) video monitoring to provide visual evidence of dust emissions; and (4) PI-SWERL sampling to characterize the emission potential of various surface types.

This information will be used to confirm the location and timing of off-Sea emissions and to support an updated PM_{10} emission inventory that may be used for the revised Imperial County PM_{10} SIP (see Section 2.3.1).

3.1.2.2 AREA OF INTEREST

The off-Sea inventory AOI is a 5,805-square-mile area that encompasses the Salton Trough and portions of the surrounding mountain ranges (Figure 3-8). Its southern margin follows the Mexican-American border. It does not include the agricultural areas of the Imperial and Coachella Valleys, nor the Salton Sea. This AOI extent was chosen because it represents the majority of desert surfaces that account for open-area emissions in the Salton Sea Air Basin.

[52] PM_{10} roses are similar to wind roses; however, in the case of the former, the "petals" show the frequency, magnitude and direction of PM_{10} concentrations rather than wind speed.

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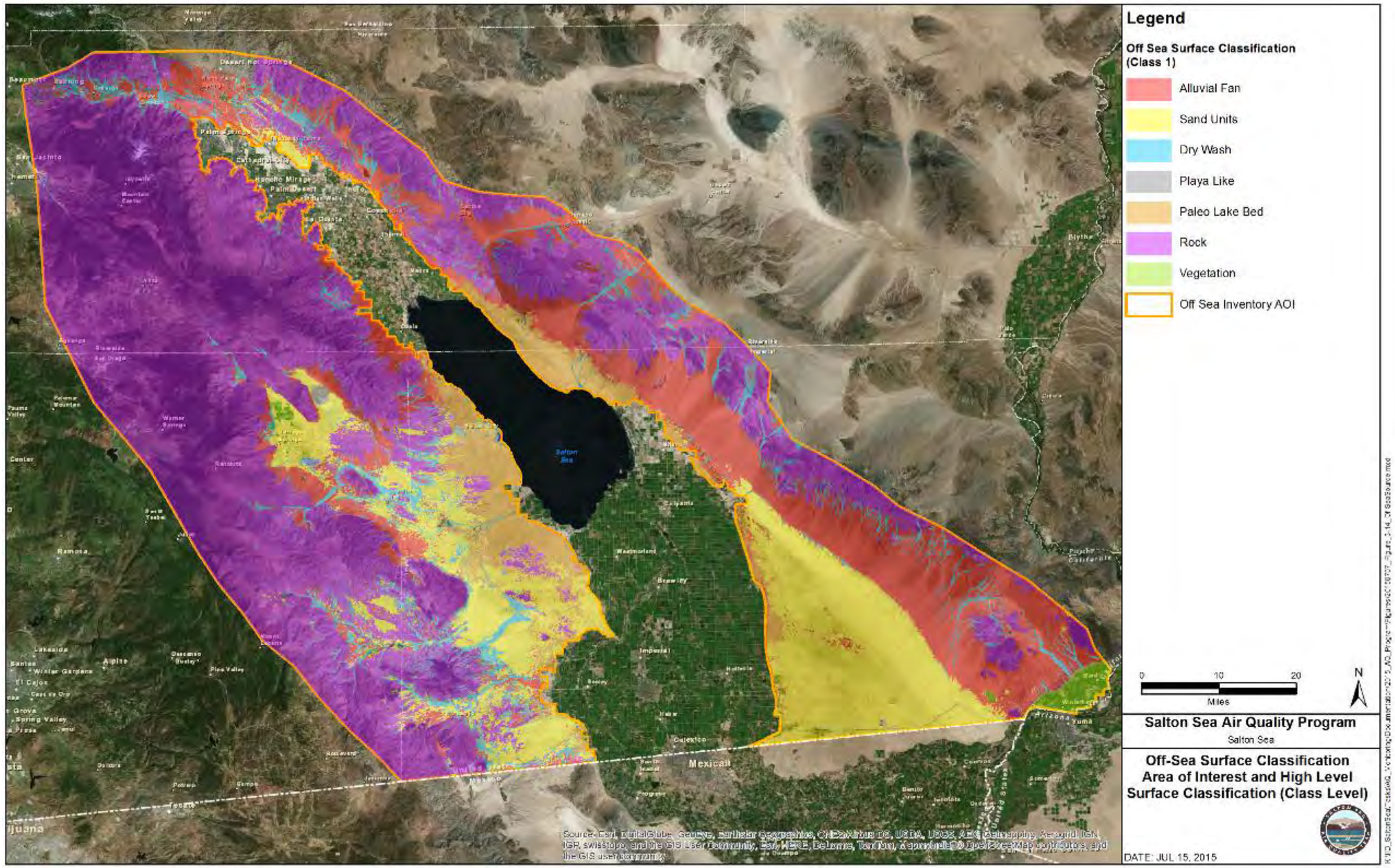
FIGURE 3-8. OFF-SEA SOURCE INVENTORY AREA OF INTEREST (AOI)

The extent of the off-Sea source inventory AOI encompasses the desert surface in the Salton Sea Air Basin contributing to open area emissions.



3.1.2.3 SURFACE TYPES

A surface type classification system was developed in order to quantify off-Sea dust sources. The classification system was created by researching the desert surfaces present in the region, targeted field investigations and the photointerpretation of satellite imagery. The surface types used in this classification system are detailed below (Table 3-4 and Figure 3-9, Figure 3-10, Figure 3-11 and Figure 3-12). Vegetative cover and surface armoring will be spatially mapped using remote sensing based imagery techniques.

TABLE 3-4. OFF-SEA SURFACE CLASSIFICATION LEGEND

Class	Sub-Class	Description	Erosion Risk
1-Dry Wash Units	Sand Dominated	Ephemeral drainage dominated by well sorted, fine to coarse grained sand.	High
	Silt Dominated	Ephemeral drainage dominated by silt. Undisturbed silt found in dry washes is often present as a fragile thin mud-cracked sheet.	High
	Gravel Dominated	Ephemeral drainage dominated by gravel.	Low
	Gravel and Sand	Ephemeral drainage consisting of gravel evenly distributed among a sandy matrix. Poor to moderately sorted. The upper surface often has been coarsened by wind erosion and/or OHV activity.	Medium
	Gravel and Silt	Ephemeral drainage consisting of gravel evenly distributed among a silty matrix. Poor to moderately sorted. The upper surface often has been coarsened by wind erosion and/or OHV activity.	Medium
2-Alluvial Fan Units	Sand Dominated	Alluvial fan deposits consisting of primarily sand. Typically located near the periphery of the fan.	High
	Sand and gravel	Alluvial sand capped by gravel lag. Typically located near the middle of the fan.	Medium
	Cobbles	Alluvial fan deposits consisting of sand, gravel and cobbles. Typically located near the top of the fan.	Low
3-Sand Units	Sand Dunes	Active aeolian dune and erosional interdune surface. Large asymmetrical, elongated Transerve dunes are the most common in this region. Dunes are > 1.5 M and typically fine to medium grained.	High
	Sand Sheet	Active aeolian deposit. Flat to low angle, uniform, expansive sand surface. Typically fine to medium grained.	High
	Sand over Alluvium	Sand sheets and coppice dunes < 1.5 m in height superimposed on alluvium. Coppice dunes are small vegetated sand mounds that form when a shrub impedes the flow of air and causes sand grains to settle out on the downwind side of the shrub.	High
4-Paleo Lakebed	Silt-Dominated	Well sorted lacustrine silt deposits from pre-historic Lake Cahuilla.	High
	Cobble over Silt	Large Cobbles regularly distributed among silt situated along the margin of pre-historic Lake Cahuilla. The cobbles serve as armory for the vulnerable underlying silt. The cobbles were deposited by wave action from Lake Cahuilla.	Medium
	Gravel and Sand	A mixture of gravel and sand present on old beach ridges formed by wave action.	Low
6-Rock Units	Sandstone	Highly friable, heavily eroded sandstone. Often taking the form of steep gullies.	Medium
	Bedrock	Undifferentiated bedrock. A consolidated hard surface that is not emissive.	Very Low

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Class	Sub-Class	Description	Erosion Risk
7-Offshore Playa Unit	Offshore Playa	Independent depressions that once held water and now have formed evaporites among very delicate mud-cracked silt. The underside of the mud cracks has a distinct micaceous sheen.	High

FIGURE 3-9. (A) SAND-DOMINATED DRY WASH WITH HEAVY OHV TRAFFIC AND (B) GRAVEL- AND SAND-DOMINATED ALLUVIAL FAN

A. Sand-Dominated Dry Wash with Heavy OHV Traffic



B. Gravel- and Sand-Dominated Alluvial Fan



FIGURE 3-10. (A) LARGE SAND SHEET AND (B) THE ALGODONES DUNE FIELD

A. Large Sand Sheet



B. The Algodones Dune Field



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FIGURE 3-11. (A) COBBLES DISTRIBUTED OVER SILT-DOMINATED PALEO LAKEBED AND (B) SILT-DOMINATED PALEO LAKEBED

A. Cobbles Distributed over Silt-Dominated Paleo Lakebed



B. Silt-Dominated Paleo Lakebed



FIGURE 3-12. (A) SANDSTONE BEDROCK AND (B) OFFSHORE PLAYA

A. Sandstone Bedrock



B. Offshore Playa



3.1.2.4 OFF-SEA / OPEN AREA LAND OWNERSHIP

The majority of the land within the off-Sea inventory AOI is owned by the federal government, the State of California and private landowners. In the east, the Algodones Dunes, the Chocolate Mountains and portions of the Mecca and Indio Hills are owned by the federal government. They also own the San Jacinto Mountains in the northwest and a large portion of the land south of the Superstition Hills. The State of California owns the Santa Rosa Mountains, Anza Borrego State Park and a large portion of the surrounding area in the west. Private land is interspersed throughout the AOI.

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3.1.2.5 Monitoring Components

The monitoring components needed to confirm the location and timing of off-Sea emissions and to support an updated PM_{10} emission inventory are discussed below. Appendix C contains a more detailed description of each component.

3.1.2.5.1 Ambient PM_{10} Concentrations

Since February 2010, five-minute- and one-hour-average ambient PM10 concentrations have been recorded continuously at six locations around the Salton Sea, including two on the west side of the Salton Sea: one at Salton City and the other at the Naval Test Station (Figure 3-13). All stations measure PM_{10} as well as particulate matter less than 2.5 microns in aerodynamic diameter, or $PM_{2.5}$ (Table 3-5). The PM coarse fraction is calculated as: $PM_{Coarse} = PM_{10} - PM_{2.5}$.

All six stations have all been in continuous operation since the start of the program. For the first two years, ICAPCD maintained the instruments and CARB conducted annual audits of the instruments. However, in July 2011, IID took over responsibility for operating and maintaining the PM_{10} network. IID is also responsible for operating and maintaining the meteorological instruments described in the next section.

Figure 3-13. Salton Sea PM10 Monitoring Locations

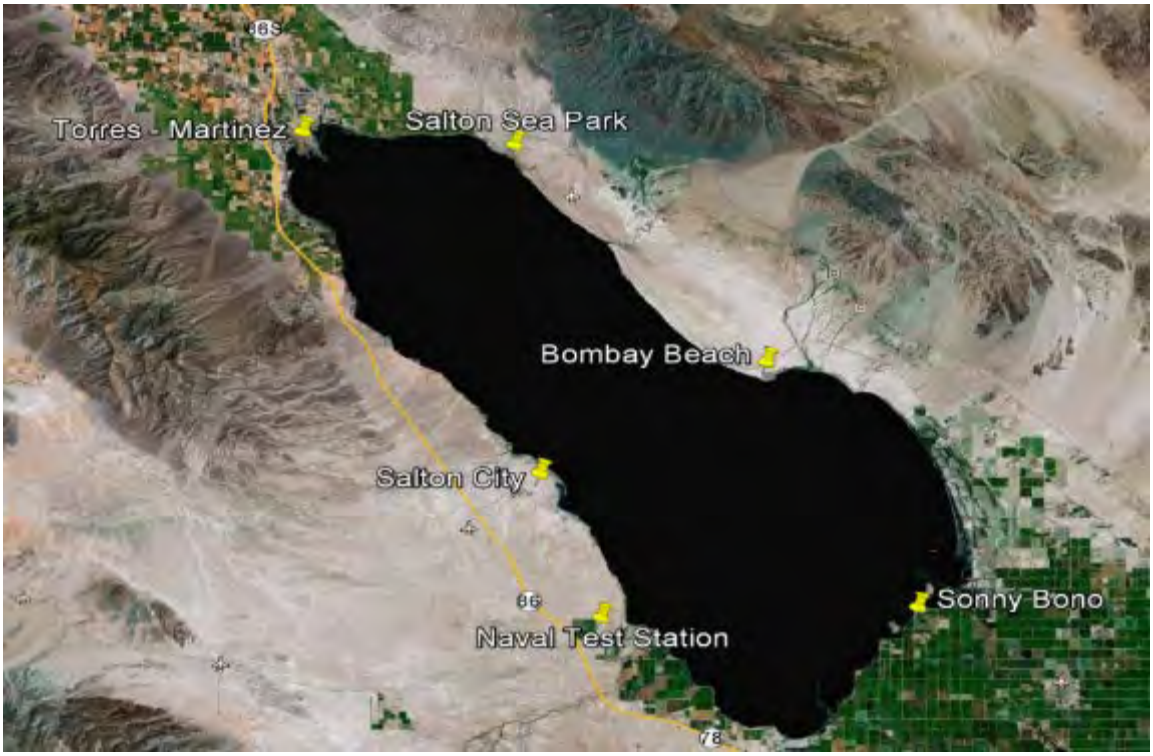

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TABLE 3-5. SALTON SEA AEROMETRIC MONITORING INSTRUMENTS

Parameter	Instrument	Comment
Particulate Matter Concentrations	Thermo Fisher Scientific TEOM 1405-D	Real-time measurements of PM_{10} and $PM_{2.5}$
3-Dimensional Wind Speed and Direction	R. M. Young Sonic Anemometer, Model 8100	10-meter height
Horizontal Wind Speed	R. M. Young Gill 3-Cup Anemometer, Model 12101	1-, 2- and 10- meter heights
Ambient Temperature	R. M. Young Platinum Temperature Probe, Model 41342VF	2-meter and 10-meter with aspirated radiation shields
Relative Humidity	R. M. Young Relative Humidity/Temperature Probe, Model 41382VF	2-meter with multi-plate radiation shield
Net Radiation	Met One Instruments Net Radiometer, Model 097	1-meter

The PM_{10} data, along with the meteorological data described in the next section, will be used to generate dust (or PM_{10}) roses for the west side of the Salton Sea. PM_{10} roses are especially useful because they are easy to interpret and reveal the frequency, magnitude and direction of dust sources affecting each PM_{10} monitor. An example set of PM_{10} roses is presented in Figure 3-14. Note that for the year 2014, significant dust sources existed in the desert area west of the Naval Test Station (NTS) monitor and west-southwest of the Salton City (SC) monitor. Appendix C contains a detailed description of the ambient PM_{10} monitoring protocol.

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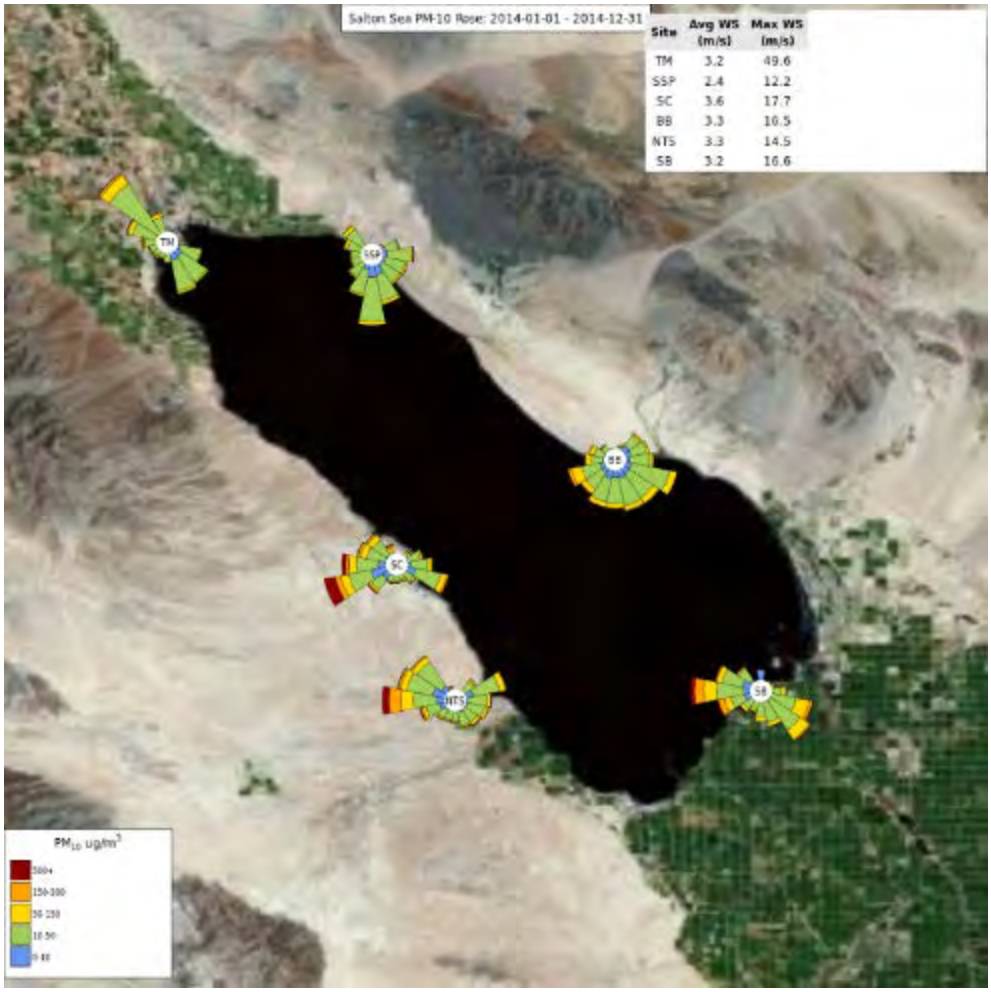
FIGURE 3-14. EXAMPLE SET OF PM10 ROSES FOR SALTON SEA, 2014



3.1.2.5.2 METEOROLOGY

The TEOMs described in Table 3-5 each have a co-located 10-meter-tall meteorological tower equipped with the instruments needed to calculate surface roughness length as well as to support standard regulatory air dispersion models (e.g., AERMOD and CALPUFF). The meteorological instruments mounted on each tower are summarized in Table 3-5. The three-dimensional sonic anemometer data are used to calculate five-minute and hourly wind directions.

3.1.2.5.3 SAND MOTION

Sand motion monitors, including Sensits and Cox Sand Catchers (CSC), will be used to establish real-time horizontal sand fluxes on the various off-Sea surface types identified within the AOI. Horizontal sand flux data, combined with surface-type-specific emission factors (either from published scientific literature or from the PI-SWERL), will be used to calculate vertical PM_{10} fluxes on the surfaces. The individual-area PM_{10} fluxes (in grams of PM_{10} per square meter per hour) will be summed to yield the area-wide PM_{10} emissions. Appendix D contains a detailed description of the sand motion monitoring protocol.

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3.1.2.5.4 PI-SWERL SAMPLING

PI-SWERL sampling will occur periodically on the surface types identified within the off-Sea inventory AOI. Appendix D contains a detailed description of the PI-SWERL sampling protocol.

3.1.2.5.5 VIDEO MONITORING

Portable video monitoring systems will be scattered around the AOI, focused primarily on the most active dust-producing areas west of the Salton Sea. Appendix D contains a detailed description of the video monitoring protocol.

3.1.2.6 ESTIMATING EMISSION RATES

The various types of monitoring and active area delineation will enable two types of emission estimates: maximum daily emissions (tpd for active source areas) and total annual emissions (tpy for active source areas).

3.1.2.6.1 MAXIMUM DAILY EMISSIONS

Maximum daily emissions will be computed by each of the following methods:

- Method 1: Worst-day measured horizontal sand fluxes coupled with PI-SWERL-generated emission factors.
- Method 2: PI-SWERL-generated vertical PM_{10} fluxes (varies with surface friction velocity, u_*) coupled with CALMET[53] estimates of surface friction velocity as a function of the worst-day meteorology.

Each of these methods will be applied to individual source areas identified using the methods described in Section 3.1.2.2, Area of Interest. The individual-area results will be totaled to yield the maximum daily emissions for the AOI. The results will be expressed in units of tpd.

3.1.2.6.2 TOTAL ANNUAL EMISSIONS

The total annual emissions will be calculated using the same methods outlined above in Section 3.1.2.6.1, except that the worst-day horizontal sand fluxes in Method 1 will be replaced with average daily horizontal sand fluxes (averaged over one year) and the PI-SWERL-generated vertical PM_{10} fluxes in Method 2 will be applied for each day of the year (i.e., using the meteorology from each day) and then summed. The results will be expressed in units of tpy.

3.1.3 UPDATES TO THE EMISSION INVENTORIES

The Salton Sea playa emission inventory described in Section 3.1.1 will be updated annually. Monitoring results related to the location and timing of playa exposure, salt crust surface characteristics and the

[53] CALMET, part of the CALPUFF modeling system, is a diagnostic meteorological model that reconstructs 3-dimensional wind and temperature fields starting from meteorological measurements, orography and land use data. http://www.arb.ca.gov/html/soft.htm

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associated emission potentials will be evaluated on an on-going basis and may be done in consultation with the Imperial County and ICAPCD. Results will be used to (1) identify and prioritize implementation of proactive DCMs on active source areas and (2) inform development of Annual Proactive Dust Control Plans (Section 3.2.1.2).

For purposes of this SS AQM Program, the off-Sea emission inventory described in Section 3.1.2 is currently planned to be performed only once unless and until it is necessary to perform this inventory again due to substantial changes in the off-Sea emission sources. However, Imperial County, ICAPCD and/or IID may choose to update the off-Sea emission inventory at any time for any reason or in the event the source characteristics change (either for better or worse). The updated inventories may consider the use of new technologies and methods as they become available.

3.2 DUST CONTROL STRATEGY

This section describes the dust control strategy for PM_{10} emissions from exposed Salton Sea playa. The main components of the dust control strategy will be collaboratively developed with the Imperial County and ICAPCD, and include the following:

- Develop and implement proactive dust control measures (DCMs) to prevent source areas from becoming a significant source of PM_{10} emissions. This includes development and testing of new DCMs that are specifically tailored to the climate and soil conditions on and around the Salton Sea playa.
- Develop a dust control strategy that can comply with the ICAPCD Regulation VIII rules to the maximum extent possible, utilizing opportunities for alternative BACM to be approved, and identify opportunities to establish new procedures and rules and/or improve existing procedures and rules to fully and successfully implement an effective dust control strategy.
- Develop and implement a playa traffic management plan focused on public outreach and education to prevent disturbance and erosion due to off-highway vehicle (OHV) traffic.

3.2.1 CONCEPTUAL PROACTIVE DUST CONTROL STRATEGY

The goal of proactive dust control is to prevent exposed Salton Sea playa from becoming a significant source of PM_{10} emissions, which will help protect the public health of the communities near and around the Sea. The proactive dust control strategy would be collaboratively developed with the Imperial County and ICAPCD. It will include broad-scale implementation of DCMs that are protective of air quality, but that are also adaptable given the unknowns regarding temporal exposure and the magnitude of future emissions. As playa is exposed, the surface characteristics and emission potential will be rigorously evaluated (see Section 3.1.1). Initially, results from these evaluations will be used to establish criteria to identify and prioritize areas of exposed playa that have high emission potential. Criteria will be developed for each playa evaluation method (e.g., PI-SWERL data, video monitoring), such that any individual line of evidence could be used to prioritize proactive control areas. Once the criteria are established, IID will use the monitoring results to develop and implement an Annual Proactive Dust Control Plan. Results from the active source delineations will be used to prioritize DCM implementation on an on-going basis. This process is illustrated in Figure ES-1.

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Each site would be monitored after DCM implementation to confirm that adequate surface stabilization is maintained. If the initial proactive DCM implementation on the site does not achieve a stabilized surface or if visible emissions occur, then the DCM would be further enhanced. This approach allows resources to be allocated efficiently and effectively, and in an expeditious manner to prevent significant sources of PM_{10} emissions.

The success of a proactive dust control strategy requires the development and testing of DCMs that can be quickly implemented, adequately maintain a stabilized surface and prevent the spread of emissive source areas as playa is exposed. Several DCMs have been field-tested and proven to be effective on playas, while other measures need additional research prior to use at the Salton Sea. Examples of proactive DCMs that could be used at the Salton Sea include surface stabilizers, soil roughening, water-efficient vegetation, vegetated swales, vegetation beach ridge enhancement and roughness elements, such as straw bales. Detailed descriptions of DCMs are included as Appendix E. Some of these measures require further pilot field testing to understand their effectiveness on Salton Sea playa (Section 3.2.1.1).

3.2.1.1 Pilot-Testing for New Dust Control Measures

The dust control strategy includes the development and testing of new DCMs for proactive control and/or for approval as BACM by the ICAPCD and the EPA. The DCMs will be specifically tailored to the climate and soil conditions on and around the Salton Sea playa and make efficient use of available resources. Some DCMs have been field-tested and proven to be effective and some DCMs need additional research prior to use at the Salton Sea. For the more novel and untested approaches, pilot field testing (pilot projects) will occur. The purpose of the pilot projects will be to perform field tests to understand DCM performance on the Salton Sea playa and to support ICAPCD and EPA approval of these DCMs as BACM.

As part of this SS AQM Program, IID is working cooperatively with Imperial County and ICAPCD on several DCM pilot projects. A surface stabilizer pilot project was completed in 2011 and surface roughening and plant community enhancement pilot projects were implemented in 2015. A vegetated swale pilot project is currently being planned. Pilot project sites were selected to represent the range of future playa surface and emission characteristics. Potential sites also were screened according to factors influencing their suitability, including, but not limited to: size, land ownership, permitting challenges, compatibility with anticipated operations and potential future land uses.

Pilot projects will allow IID, the Imperial County and ICAPCD to gain experience and understanding of novel, locally-adapted methods of DCMs and the site-specific factors that could affect their feasibility and cost. Pilot projects also are useful for determining the effectiveness of a DCM and refining design criteria for full-scale implementation. This helps develop efficient approaches for the design, construction and operation of DCMs on the playa.

3.2.1.2 Annual Proactive Dust Control Planning and Implementation

Results from the playa emissions inventory (Section 3.1) will be used to develop an Annual Proactive Dust Control Plan. The plans will be developed by IID in the first quarter of every year and may be done

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in consultation with the Imperial County and ICAPCD. They will include a synthesis of monitoring data for the prior year and will identify and prioritize areas for implementation of proactive DCMs. The plans may also incorporate considerations related to the transition of proactive dust control areas to alternative land uses, such as agriculture or habitat restoration.

3.2.2 ICAPCD Regulation VIII Rules for the Salton Sea Playa

IID intends to develop a proactive dust control strategy that complies with the regulatory requirements of ICAPCD and SCAQMD. However, IID recognizes that it may not be possible to maximize a proactive dust control strategy within existing rules and regulations. Therefore, there is a need to identify opportunities to establish new procedures and rules and/or improve existing procedures and rules to fully and successfully implement an effective dust control strategy to the maximum extent possible.

Exposed Salton Sea playa is subject to the ICAPCD Regulation VIII Rules related to the control of fugitive dust (see Section 2.3.2). Exposed Sea playa is currently subject to Rule 804 (see Section 2.3.2.2). There are several limitations in Rule 804 that would need to be addressed to allow maximum flexibility in implementing a proactive dust control strategy, including new DCMs specifically tailored to conditions on and around the Salton Sea playa.

The following list summarizes some of the limitations of Rule 804 and approaches for addressing them.

- Rule 804 applies to all persons who own or otherwise have jurisdiction or control over an open area. Landowners of exposed playa should have an opportunity to implement dust control in coordination with a responsible third party. While Rule 804 does not prohibit this from occurring, it does not specifically identify this opportunity and how it would work within the rule framework. Potential benefits for the ICAPCD include consolidated points of contact, improved coordination of dust mitigation (particularly for small, fragmented parcels) and consolidated responsible party resources.

- The existing definitions of a stabilized surface do not consider exposed playa surface characteristics and even though playa surfaces may be stable, they may not meet the definitions in Rule 800. A stabilized surface may be more appropriately defined by a broader set of performance standards and measurements, which could be verified through performance monitoring.

  For areas that do not meet the definition of a stabilized surface, the responsible parties should be able to proactively maintain or create a stabilized surface by any scientifically-based and tested reasonable means. The parties could monitor exposed playa to verify stability. In the event that the surface is not stabilized, then the parties would be required to augment the DCM to achieve stability with more intense control methods. This proactive dust control approach is described in more detail in Section 3.2.1.

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- Opacity observations are required to determine compliance with VDE standards, and must be conducted in accordance with the test procedures for "Visual Determination of Opacity" as described in Appendix A of Rule 800**.** Opacity observations to determine compliance with VDE standards are not an appropriate method to attribute dust plumes to specific source areas on such a vast land surface. Surfaces that meet the definition of stabilized surface should be considered adequately controlled. Furthermore, the air basin is designated as serious nonattainment for PM_{10} and isolated plumes are difficult to identify with standard opacity observations. This is a concern due to the significance of off-lake sources. According to the IC 2009 PM_{10} SIP (page 2-1):

> "The vast majority of PM_{10} emissions impacting Imperial County originate from natural, non-anthropogenic sources (for instance, fugitive dust from barren lands alone accounts for >55% of average daily emissions). During high winds, Imperial County's desert areas can produce PM10 emissions over 50 times greater than the emissions from any anthropogenic source, including agricultural crop land."

3.2.3 PLAYA TRAFFIC MANAGEMENT

The dust control strategy includes development and implementation of a playa traffic management plan. Extensive desert areas around the Salton Sea attract recreationalists and OHV traffic. OHV use is expected to expand onto the playa as the Salton Sea recedes. This activity will disturb the natural stability of playa crust and soil surfaces and increase erodibility and PM_{10} emissions. This is caused by the physical destruction of the fragile crusts by passes of vehicle tires. Tires pulverize the surface into sand-sized particles (Figure 3-15). These particles are then picked up by the wind, commencing saltation, and leading to loosening of many more particles downwind. This cascading effect increases erodibility on and around designated trails. The larger the footprint of vehicle use (through repeated passes), the larger the impact on the fragile playa crust.

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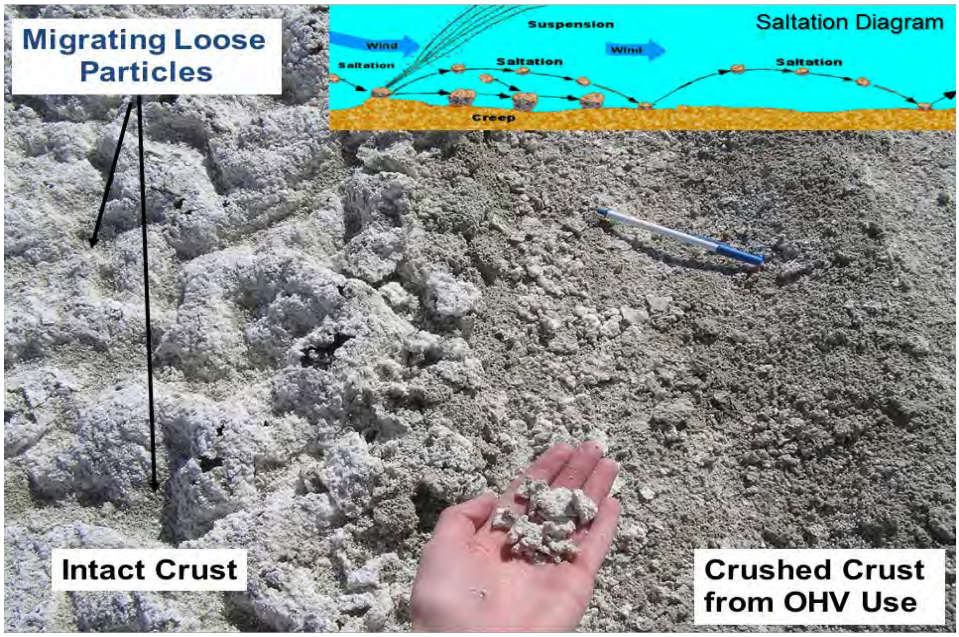

FIGURE 3-15. PHOTO OF SALT CRUST PULVERIZED BY OFF-HIGHWAY VEHICLE TRAFFIC

Prevention of vehicle related disturbances is the most important and cost-effective measure available to prevent and control emissions. Therefore, the playa traffic management plan will focus on limiting public access on fragile playa crusts to the extent legally and reasonably feasible. The ICAPCD, Bureau of Land Management (BLM) and California State Parks have found that approaches such as public outreach, education, sign posting, strategic fencing, gate installation and selectively closing or maintaining roads and trails are effective methods to control OHV activity. Therefore, rather than physical restriction of playa access, this SS AQM Program will focus on developing a plan that includes these approaches (Table 3-6).

TABLE 3-6. PLAYA TRAFFIC MANAGEMENT PLAN – PROGRAM ITEMS AND APPROACH

Program Item	Approach
Partnership and Educational Efforts	• Leverage partnerships relative to resource areas. Work cooperatively with partners to share resources and effectively manage OHV use around the Salton Sea. • Initiate public outreach effort which encourages OHV users to adopt a land use ethic that responsible OHV riders respect land resources and do not travel cross playa off roads and trails except in managed open areas. • Develop an education program in partnership with other federal and state agencies, counties, tribes, communities, OHV dealerships, user and other interest groups to teach the recreating public about the value of public land resources and how they can protect the environment while enjoying their recreation activities.
Land Use / Playa Planning	• Identify sensitive land resource and biological resource areas. • Determine appropriate use of these areas (if any). • Special emphasis on sensitive areas – Managing sensitive areas to ensure non-impairment.

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Program Item	Approach
Restrictive Orders and Monitoring	• Encourage the public to adopt a land use ethic that, except in managed open areas, cross country travel off roads and trails should no longer be considered a responsible use of vehicles. • Restrict vehicle use through signage, enforcement and education in: sensitive playa areas, mitigation facilities, habitat facilities, energy facilities, cultural sites, etc. • Ensure compliance through increased enforcement, posting signs, providing information and monitoring activities and impacts. Work to gain the cooperation and assistance of local government, private citizens and interest groups in completing these actions and obtaining voluntary compliance.
Adaptive Management	• Periodically look back at approach in place. Identify lessons learned and incorporate those into the revised management approach with partners. • Through monitoring results, identify if/where existing trails need to be augmented.

With the help of the basic framework outlined in Table 3-6, a Playa Traffic Management Plan will be more fully developed by IID in coordination with the Imperial County, ICAPCD, the resource agencies, California State Parks and other interested stakeholders. The plan will include an assessment element to gauge success of the plan and to determine whether modifications to the plan are necessary.

3.3 ESTIMATED PROGRAM COSTS

This section describes the rationale for estimating SS AQM Program costs. The cost estimates and assumptions described below should be considered "order of magnitude" because they were prepared without the benefit of site-specific dust control criteria or detailed designs necessary for more accurate cost estimation. Therefore, these estimates are for planning purposes only, derived from experience at Owens Lake and based on the assumptions outlined in the following sections.

3.3.1 COST ASSUMPTIONS

The following sections detail the assumptions used to develop long-term estimated program costs associated with implementing this SS AQM Program.

3.3.1.1 RATE OF PLAYA EXPOSURE

The timing and location of future playa exposure is a function of the hydrologic response of the Salton Sea to external forces, such as inflows, salt loads and evaporation rates. This cost estimate uses reasonable incremental playa exposure acreage estimates, which will be adjusted according to the results of the updated SALSA2 modeling that will be published in the hydrologic report anticipated to be released this summer. It is clear that actual playa exposure rates will affect the amount of playa that may become emissive and ultimately require dust control, thereby affecting the program costs.

For the purpose of estimating costs, a series of 6 construction phases between 2020 and 2045 were identified as dust control implementation periods. Yearly playa exposure estimates were then aggregated to these timeframes and considered in the cost estimate calculations (Table 3-7).

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TABLE 3-7 PLAYA EXPOSED FOR EACH CONSTRUCTION PHASE (ROUNDED TO THE NEAREST THOUSAND)

Year / Phase	Playa Exposed Per Phase (Acres)	Total Playa Exposed (Acres)
2020 / Phase 1	25,000	25,000
2025 / Phase 2	21,000	46,000
2030 / Phase 3	13,000	59,000
2035 / Phase 4	6,000	65,000
2040 / Phase 5	3,000	68,000
2045 / Phase 6	2,000	70,000

3.3.1.2 EMISSIVE CHARACTERISTICS OF THE PLAYA

The vast majority of the future exposed Salton Sea Playa is currently inundated. This makes it difficult to estimate the acreage of future playa that will be emissive (including the magnitude, timing and location of emissions) and require dust control. Restoration activities, including habitat projects and renewable energy development, on the future exposed playa are also uncertain with regard to location, size and timing. Additionally, other land management activities, which may or may not be included in the State's restoration activities, but may occur for other reasons are uncertain as well. Given these unknowns, the cost estimates assume 75 percent of the total playa exposure will be open, emissive and require some level of dust control. As a point of comparison, roughly 60 percent of the exposed Owens Lake playa is currently controlled.

3.3.1.3 DCMS APPROVED AS BACM

The types of DCMs available for implementation on future Salton Sea playa is an important component of the cost estimate. As described in Section 2.3.2.2, all exposed playa within the Imperial County is currently subject to ICAPCD Rule 804, Open Areas. Permissible BACM for open areas include: (1) applying water or chemical dust suppressants to all unvegetated areas, (2) establishing vegetation on previously disturbed areas, and (3) paving, applying and maintaining gravel, or applying and maintaining chemical dust suppressants. Additionally, alternative BACM may become permissible BACM once it has been approved by ICAPCD and the EPA according to the procedure outlined in Rule 804.

This SS AQM Program focuses on developing a proactive dust control strategy specific to the Salton Sea with DCMs that are science-based, practical, effective and feasible, and are anticipated to be approved as BACM for Salton Sea surfaces. While IID recognizes that air quality is ultimately regulated by the local air quality districts and the EPA and this program is structured to work with those agencies and within the applicable regulations, this program takes a broad and proactive approach that is not limited to currently approved BACM. This program anticipates further coordination with the local air quality districts and the EPA as described in Section 4. Nevertheless, an important step in that coordination is DCM pilot projects and studies, which will be a basis to expand the list of DCMs available for approval as BACM.

There are a significant amount of scientific and experience-based resources informing the development of this SS AQM Program. However, there are many unknowns that cannot be known for the Salton Sea until pilot-testing can be done on exposed Salton Sea playa with specific DCMs. DCM pilot projects are

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necessary to inform all interested parties of the broad range of technical issues associated with dust control implementation on the Sea playa. This includes factors such as hydrology, vegetative cover establishment, dust control effectiveness required, water supply planning, constructability and appropriate design criteria to meet dust control objectives.

For purposes of the program cost estimates provided in this SS AQM Program, Table 3-8 outlines the percentage breakdown of DCMs assumed for currently approved BACM under ICAPCD Rule 804 and, for comparison, DCMs anticipated to become approved BACM (both assume DCMs on 75 percent of total exposed playa). The assumptions made in Table 3-8 take the most cost-effective breakdown of DCMs under each scenario purely for informational purposes of providing a program cost estimate. In addition to estimated cost-effectiveness, the DCM percentage breakdown was developed using available surface soil texture information (Section 3.1.1.3). Approximately 42 percent of the future exposed playa will consist of fine textured soils suitable for surface roughening and/or moat and row; 36 percent medium textured soils potentially suitable for surface roughening, moat and row or vegetation establishment; and 22 percent coarse textured soils suitable for vegetation establishment. Table 3-8 is not a plan or proposal for specific DCMs to be implemented on exposed Salton Sea playa. The percentage of DCMs may be revised at any time and will be revised as actual exposed playa is mitigated by the implementation of specific DCMs. As discussed in this program, decisions regarding the type, location and timing of implementing DCMs on exposed playa are to be made on an annual basis as playa is exposed and analyzed to determine the dust control strategy needs of that playa and other contributing outside factors, such as available funding.

ICAPCD Rule 804 currently has only a limited number of approved BACM: water efficient vegetation (to achieve the 50 percent cover requirements), shallow flooding, chemical dust suppressants and gravel cover. This SS AQM Program takes a proactive approach that is not limited by approved BACM, but anticipates that all DCMs outlined in Appendix E will be approved as BACM as allowed under the alternative BACM process under Rule 804.

TABLE 3-8 ASSUMED DCM IMPLEMENTATION PERCENTAGES FOR APPROVED BACM UNDER ICAPCD RULE 804 AND ALL DCMS IDENTIFIED IN THIS PROGRAM

DCM	Rule 804 Approved BACM	All Identified DCMs
Surface Roughening	0%	42%
Moat and Row	0%	3%
Dust Suppressants	0%	0%
Veg. Enhancement	0%	35%
Veg. Swale	0%	10%
Water Efficient Vegetation	85%	7%
Shallow Flood	10%	2%
Brine Stabilization	0%	1%
Gravel Cover (2 inch thickness)	5%	0%
Gravel Cover (4 inch thickness)	0%	0%
Total	**100%**	**100%**

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3.3.1.4 DCM UNIT COST

A description of each DCM used in this cost estimate is provided in Appendix E. The estimated capital costs per DCM (Table 3-9) include construction costs plus engineering design, construction management and engineering services during construction. Operation and maintenance costs (Table 3-9) are based on an assumed percentage of construction cost. It is important to note that these cost estimates are reasonable and based on actual experience at the Salton Sea or Owens Lake, with the exception of dust suppressants, which involves a product that can be priced and purchased. However, air quality mitigation at Owens Lake is the only similar and comparable situation to that of the Salton Sea and that situation is very different from the Salton Sea in many respects including timing of implementation and the largely reactive approach that has been taken. There are no documented resources for costs specific to air quality mitigation associated with these DCMs implemented on a large-scale area of varying soil characteristics and other factors to be considered. Therefore, these cost estimates remain high-level estimates of DCMs that have largely not been performed at the Salton Sea to date and where design, construction and engineering costs may be greatly affected by the unique location, climate and other factors associated with this area. These cost estimates will be refined as this SS AQM Program is implemented.

TABLE 3-9 ESTIMATED DUST CONTROL MEASURE UNIT CAPITAL AND O&M COSTS (2014$)

Dust Control Measure	Capital (Per Acre)	Estimated O&M (% of Capital)	Information Source
Surface Roughening	$400	75.00%	IID AQ Program to date
Moat and Row	$14,000	10.00%	LADWP personal communication
Dust Suppressants	$2,000	100.00%	Cargill (Magnesium Chloride)
Vegetation Enhancement	$9,000	7.50%	IID AQ Program to date
Vegetative Swale	$17,000	7.50%	IID AQ Program to date
Managed Vegetation	$25,000	4.50%	LADWP personal communication
Shallow Flood	$25,000	2.00%	LADWP personal communication
Brine Stabilization	$21,000	0.25%	LADWP personal communication
Gravel Cover (2 inch thickness)	$36,000	0.25%	LADWP personal communication
Gravel Cover (4 inch thickness)	$48,000	0.25%	LADWP personal communication

Cost assumptions for water conveyance infrastructure (Table 3-10) were obtained from the Salton Sea Ecosystem Restoration Program, Draft Programmatic Environmental Impact Report (PEIR), Appendix H. Cost estimates from the PEIR were adjusted to 2014 dollars using the U.S. Department of Commerce, Bureau of Economic Analysis, Table 1.1.9. Implicit Price Deflators for Gross Domestic Product [Index numbers, 2009=100] seasonally adjusted values. It was assumed that costs for this infrastructure would begin two years prior to the first dust control construction phase. Water conveyance is likely required to facilitate irrigation of vegetation in certain areas, especially in locations where groundwater cannot be accessed, and potential water based DCMs on the playa as the Sea recedes.

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TABLE 3-10 CAPITAL COST ESTIMATES FOR CONVEYANCE INFRASTRUCTURE AS PRESENTED IN THE PEIR FOR AIR QUALITY MANAGEMENT

Infrastructure	PNA Estimates, Appendix H7 of PEIR ($ 2006)	Total Construction Costs ($ 2014)
Sedimentation Basin	40,776,000	46,741,835
Roads	689,000	789,806
Western AQM Canal (70 cfs, 42 mi)	30,224,000	34,645,998
Eastern AQM Canal (60 cfs, 40 mi)	25,845,000	29,626,318
Central AQM Canal (40 cfs, 10 mi)	4,555,000	5,221,431
Saltwater Conveyance for AQM	13,740,000	15,750,265
Pupfish Channels (30 mi)	9,110,000	10,442,861
Other Construction (5%)	6,246,950	7,160,926
Construction Subtotal	131,185,950	150,379,439
Contingency (30%)	39,355,785	45,113,832
Engineering, Legal, and Administration (12% of Construction Costs)	20,465,008	23,459,193
Total Capital Cost	**191,006,743**	**218,952,464**
Yearly O&M (3.5% of Construction)	**4,591,508**	**5,263,280**

Notes:

Values have been rounded and may not add directly

Values from the PEIR PNA, Appendix H7 are in 2006 dollars and have been escalated to 2014 dollars using U.S. Department of Commerce, Bureau of Economic Analysis, Table 1.1.9. Implicit Price Deflators for Gross Domestic Product [Index numbers, 2009=100] Seasonally adjusted

All values do include costs for land acquisition, easement, or taxes

AQM = Air Quality Management

3.3.2 ESTIMATED PROGRAM COSTS

Using the assumptions outlined in Section 3.3.1, a spreadsheet calculator was developed to estimate costs (using 2014 dollars) through 2076 for currently approved BACM under ICAPCD Rule 804 and the proactive dust strategy using all DCMs identified in this SS AQM Program. The spreadsheet calculator was developed to facilitate changes in assumptions outlined in Section 3.3.1 as more is learned through implementation of this SS AQM Program (e.g., dust control implementation schedule, emission characteristics of the playa, DCM costs, BACM approval, etc.). Table 3-11 provides a summarized version of the total cost on a five-year time step. Given the uncertainty associated with the assumptions outlined in Section 3.3.1, a -15% and +25% multiplier was applied to the final estimate to generate a cost range.

For implementation of the BACM currently approved under Rule 804, the total cost estimate in 2047 (timeframe of estimated maximum playa exposure) is $2.86BN, with a range of $2.43BN to $3.58BN. For implementation of the DCMs identified in this SS AQM Program regardless of approval as BACM, the total cost estimate in 2047 is $1.49BN, with a range of $1.27BN to $1.86BN. Estimated costs for

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implementation of the BACM currently approved under Rule 804 in 2076 (at the end of the water transfer) is $4.56BN, ranging from $3.88BN to $5.70BN. Estimated costs for implementation of the DCMs identified in this SS AQM Program regardless of approval as BACM for this same timeframe is $2.59BN, ranging from $2.11BN to $3.24BN. As discussed above, these are high-level estimates intended for informative purposes only and will be refined as this SS AQM Program is implemented and more is learned from this implementation.

As shown in Table 3-11, the estimated cost of implementing BACM currently approved under Rule 804 is nearly double the cost of the implementation of the DCMs identified in this SS AQM Program regardless of approval as BACM. This is mainly due to the limited amount of BACM currently available under Rule 804 as well as the 50% cover requirements for vegetation in Rule 804. This underscores the need for IID to to continue work with the Imperial County and ICAPCD immediately to seek approval of alternative BACM under Rule 804 and to identify opportunities to establish new procedures and rules and/or improve existing procedures and rules to fully and successfully implement this SS AQM Program. As stated previously, such opportunities should include new BACM performance measures (i.e., determining if the surface is adequately stabilized).

TABLE 3-11 Summary of Dust Control Total Costs (2014$)

	Rule 804 Approved BACM Estimated Cost ($BN)			All Identified DCM Estimated Cost ($BN)		
Year	Total Cost	Total Cost (-15%)	Total Cost (+25%)	Total Cost	Total Cost (-15%)	Total Cost (+25%)
2020	$0.60	$0.51	$0.75	$0.25	$0.22	$0.32
2025	$1.25	$1.06	$1.56	$0.59	$0.50	$0.74
2030	$1.72	$1.46	$2.14	$0.81	$0.69	$1.01
2035	$2.09	$1.77	$2.61	$1.02	$0.86	$1.27
2040	$2.42	$2.06	$3.03	$1.21	$1.03	$1.52
2047	$2.86	$2.43	$3.58	$1.49	$1.27	$1.86
2050	$3.04	$2.58	$3.80	$1.60	$1.36	$2.00
2055	$3.33	$2.83	$4.17	$1.79	$1.52	$2.24
2060	$3.63	$3.08	$4.53	$1.98	$1.69	$2.48
2065	$3.92	$3.33	$4.90	$2.18	$1.85	$2.72
2070	$4.21	$3.58	$5.26	$2.37	$2.01	$2.96
2076	$4.56	$3.88	$5.70	$2.59	$2.21	$3.24

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4 AGENCY COMMUNICATION, COORDINATION AND REPORTING

This section describes agency communication and coordination, as well as a summary of reporting.

4.1 AGENCY COMMUNICATION AND COORDINATION

As described in detail in this document, this SS AQM Program is focused on monitoring and mitigating dust emissions from exposed Salton Sea playa. Accordingly, communication and coordination with several local, state and federal agencies, as well as other stakeholders, will be essential to the success of this program. Different agencies will be involved in different aspects of this program. For instance, the Imperial County, ICAPCD, SCAQMD, CARB and EPA will need to be involved in efforts to expand approved BACM. IID will be communicating and coordinating with the Natural Resources Agency and other state agencies to ensure that the State's restoration activities are informed by and coordinated with the implementation of this program and that, likewise, air quality mitigation activities are informed by and coordinated with the State's restoration activities. Further, the QSA JPA and its member agencies will be involved for funding purposes according to the process described above (Section 2.1.2). IID will coordinate implementation of this SS AQM Program with these agencies and stakeholders as necessary and on an on-going basis. Additionally, IID anticipates that quarterly progress updates will be provided as appropriate and in a forum or format to be determined. IID will prepare an annual progress report that will document detailed aspects of implementation of this program on an annual basis.

4.2 SUMMARY OF REPORTING

A variety of documents will be prepared throughout implementation of this SS AQM Program. Documents may include: technical memoranda describing results of research and monitoring activities; Annual Proactive Dust Control Plans (Section 3.2.1.2); conceptual and final designs for DCMs; and outreach materials for the general public. Progress reports as described above will also be prepared to document progress and findings from implementation of this SS AQM Program. IID will ensure that final and complete materials will be available to the public and posted to the IID website.

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APPENDIX A – MASTER RESPONSE ON SALTON SEA AIR QUALITY MONITORING AND MITIGATION PLAN IN FINAL EIR/EIS

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AIR QUALITY

3.9 Master Response on Salton Sea Air Quality Monitoring and Mitigation Plan

3.9.1 Introduction

Commenters have requested additional discussion of measures that might be practical, available, and feasible for problem assessment and avoiding, minimizing, and mitigating potential dust and air quality impacts associated with exposed shoreline around the Salton Sea caused by the Project. This master response is intended to address those comments.

3.9.2 Difficulties Associated with Impact Assessment

Comments on the Air Quality Section of the Draft Environmental Impact Report/ Environmental Impact Statement (EIR/EIS) vary widely but tend to acknowledge that prediction of the scale or intensity of future dust impacts is not possible, given the limited available information on submerged areas and the variability of conditions that might promote or inhibit dust emissions at the Salton Sea. Notes from the Salton Sea Authority on the Salton Sea Air Quality Workshop held April 3, 2002, concluded, "At this time there is neither enough data nor enough exposed shoreline to predict with any credibility where, when, or how bad the emissions will be." As stated in the Draft EIR/EIS, several factors prevent any reasonable quantitative estimate of emissions and associated impacts from the exposed shoreline:

- Lack of data regarding sediment characteristics.
- Lack of data relating sediment characteristics to surface stability and actual emissions rates.
- Spatial variations in sediment characteristics and land surface erodibility.
- Temporal variations in wind conditions.
- Temporal variations in factors contributing to the formation of salt crusts and otherwise influencing the tendency of land surfaces to emit dust in high winds.

It is also not possible to perform modeling of potential impacts on ambient concentrations of PM10 (particulate matter with a diameter of less than 10 micrometers) in areas around the Sea without information on mass emission rates, location, or the areal extent of emissive land surfaces.

3.9.3 Similarities to and Differences from Owens Lake

Several comments pointed to similarities between exposure of sediments at Salton Sea and at Owens Lake, suggesting that similar dust emissions and air quality problems could ensue with lowering of the Salton Sea elevation. This response is based on available information and considerable experience at Owens Lake (where a large dust mitigation program is being implemented by the Los Angeles Department of Water and Power) and at the Salton Sea (where Imperial Irrigation District [IID] has operated for many decades).

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At the April 3, 2002 Air Quality Workshop held by the Salton Sea Authority, it was concluded that definitive data are lacking for prediction of PM10 emissions from exposed seabed sediments. However, several general observations regarding this comparison shed light on the level of risk of major dust emissions resulting from exposure of sediments at the Salton Sea.

Driving forces for dust emissions include wind and sand. Winds at the Salton Sea have been compared with those at Owens Lake in the Master Response on *Air Quality – Wind Conditions at the Salton Sea* in Section 3.16 of this Final EIR/EIS. Those data (Table 3.9-1) show that the frequency of high winds at the Salton Sea are much less frequent than at Owens Lake.

TABLE 3.9-1
Comparison of wind-speed frequency at 10 m above the ground surface for Salton Sea and Owens Lake

Site	>8.5 m/s (19 mph)	>11.0 m/s (25 mph)
Niland (near Salton Sea)	4.4%	1.4%
Tower N3 (Owens Lake)	18.9%	7.9%

Above a threshold wind velocity, sand if it is present on the surface, saltates (skips on the surface), and with each impact may break coherent soil crust and eject finer material upward into the airstream. So pronounced is the correlation of sand motion with PM10 emissions that, at Owens Lake, one of the primary tools for mapping dust emissions for mitigation is sand motion.

The sources of sand at Owens Lake are relatively steep-gradient streams feeding the lake, with few control structures to impede flow and cause sediment removal upstream of the lakebed. This has resulted in the following sand distribution at Owens Lake:

- A relatively continuous ring of sand dunes surrounding Owens Lake at its shoreline.
- Extensive areas of mobile sand (known locally as "sand sheets") on the lakebed surface.
- Extensive areas of lakebed with deep sand deposits mapped as the dominant soil type.

In contrast, there is very little sand to blow in the southeastern shore areas of the Salton Sea, where bathymetry suggests that sediments would be most extensively exposed. This is because of shallow gradients and extensive control on tributary rivers. Likewise, sand sources such as dunes are absent in this area. Where sand dunes do occur along the western side of the Sea, bathymetry suggests sediment exposure would be very limited. Therefore, the co-occurrence of sand sources and exposed lakebed, which is so widespread and problematic at Owens Lake, appears to be largely absent in this area of the Salton Sea.

Exposed soil surfaces are more resistant to wind erosion when they are roughened or covered with a stable crust. When saline sediments are exposed by lowered water levels, the crust that forms at the soil surface is cemented by salt, and its strength is largely dependent on the strength of this cementation. The salt chemistry at Owens Lake results in a high

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proportion of sodium-carbonate evaporite salts that change radically in degree of hydration and volume at temperature variations within the range commonly experienced at Owens Lake. This has the effect of softening the crust and increasing rates of breakage and emissions. Comparing the makeup of salts in the Salton Sea (Bertram Station) and at Owens Lake (subsurface drainage or aerated groundwater), the following observations can be made (see Figure 3.9-1):

- There is much more (26 percent) calcium and magnesium at the Salton Sea; cations at Owens Lake contain 97 percent sodium.
- Carbonate and bicarbonate are virtually absent at the Salton Sea; they make up about 29 percent of anions at Owens Lake.
- Sulfate levels at Salton Sea (29 percent) are more than twice Owens Lake levels (12 percent).

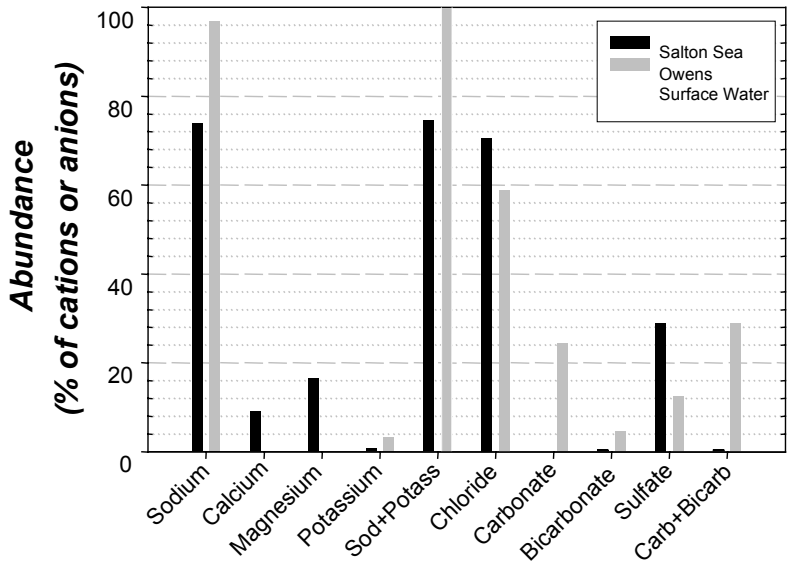

Figure 3.9-1

Relative abundance of major cations and anions at Salton Sea (Bertram Station, 1996-2001) and in subsurface drainage water at Owens Lake (Agrarian and Tree Rows sites, October 1998). Abundance for cations (sodium, calcium, magnesium, and potassium) is given as a percentage of the total cations, and for anions (chloride, carbonate, bicarbonate, and sulfate) as a percentage of total anions (milliequivalents/liter).

Further, the range of temperature variation at the Salton Sea is quite distinct from (generally warmer than) Owens Lake. The particular climatic interaction with salt minerals at Owens Lake influences dust emissions. This will also be the case at the Salton Sea. At the April 3 Air Quality Workshop, it was generally acknowledged that interactions between Salton Sea climate and minerals are undefined and constitute a pressing research need.

Sea levels have fluctuated over the period since the Sea filled during 1905 to 1907, resulting in periodic and extended exposure of significant Sea sediments. Such exposure at Owens

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and Mono Lakes generated unmistakable dust emissions. While there has been no systematic monitoring program at the Salton Sea, there does not appear to be any substantial anecdotal information that these areas have historically contributed observable dust emissions.

This is consistent with observations of soil crusts in the Salton Sea area. Crusts re-form when rain falls on these desert lakebeds and then progressively break apart over time; the extent and rate of breakage indicate the erosive forces to which the crusts are subjected, and, to some extent, the amount of wind erosion. Year-old crusts are generally heavily damaged in emissive areas at Owens Lake. Relatively old crusts (at least 18 months) generally show little damage at the Salton Sea.

In summary, weaker driving forces at Salton Sea, especially the absence of sand in potentially exposed areas, are consistent with observations suggesting that exposed sediments are not as emissive as they have been at Owens Lake.

3.9.4 Difficulties Associated with Specific Prescription of Mitigation

Without information on the nature and extent of the potential problem to be mitigated, it is unwise and impractical to propose or commit prematurely to costly dust control mitigation measures. Further, the dust control mitigation measures studied and under implementation at other lakebeds, such as Mono and Owens, may not be feasible or practical at the Salton Sea, given limitations on financial resources and the constraints on water availability for mitigation in this desert area. Nor would it be prudent to propose use of ratepayers' money to fund dust control measures for a problem that does not currently exist and may never materialize.

Under shoreline exposure scenarios, it is currently impossible to predict the extent and intensity of potential increases in dust emissions or the associated increases in ambient concentrations of the pollutant PM10 in excess of standards. The Draft EIR/EIS describes conditions at the Salton Sea that would naturally inhibit PM10 suspension, i.e., the combination of moisture present in the unsaturated zone beneath the exposed playa, the probable formation of dried algal mats and stable salt crusts consisting of chloride and sulfate salts, and the relatively low frequency of high wind events at the Salton Sea. In the best case, no problem would occur; in the worst case, a problem would emerge at some later date, after 2035, as the Sea's shoreline becomes exposed. Shoreline exposure caused by the Project will be delayed until that date because of implementation of the Salton Sea Habitat Conservation Strategy, which would provide mitigation water to the Sea to offset reductions in inflow caused by the Project. See the Master Response on *Biology – Approach to Salton Sea Habitat Conservation Strategy* in Section 3.5. IID would be responsible for impacts associated with implementation of the Proposed Project, apart from impacts associated with shoreline exposure anticipated from Baseline conditions.

3.9.5 Monitoring and Mitigation Plan

Rather than focusing on site-specific and costly dust control mitigation for an undefined and future potential problem, a phased approach is proposed to detect, locate, assess, and resolve this potentially significant impact. The following 4-step plan would be implemented

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to mitigate significant PM10 emissions and incremental health effects (if any) from Salton Sea sediments exposed by the Proposed Project:

(1) **Restrict Access.** Public access, especially off-highway vehicle access, would be limited, to the extent legally and practicably feasible, to minimize disturbance of natural crusts and soils surfaces in future exposed shoreline areas. Prevention of crust and soil disturbance is viewed as the most important and cost-effective measure available to avoid future dust impacts. IID or other governmental entities own or control most of the lands adjacent to and under the Salton Sea. Fencing and posting would be installed on these lands in areas adjacent to private lands or public areas to limit access.

(2) **Research and Monitoring.** A research and monitoring program would be implemented incrementally as the Sea recedes. The research phase would focus on development of information to help define the potential for problems to occur in the future as the Sea elevation is reduced slowly over time. Research would:

   (a) Study historical information on dust emissions from exposed shoreline areas.

   (b) Determine how much land would be exposed over time and who owns it.

   (c) Conduct sampling to determine the composition of "representative" shoreline sediments and the concentrations of ions and minerals in salt mixtures at the Sea. Review results from prior sampling efforts. Identify areas of future exposed shoreline with elevated concentrations of toxic substances relative to background.

   (d) Analyze to predict response of Salton Sea salt crusts and sediments to environmental conditions, such as rainfall, humidity, temperature, and wind.

   (e) Implement a meteorological, PM10, and toxic air contaminant monitoring program to begin under existing conditions and continue as the Proposed Project is implemented. Monitoring would take place both near the sources (exposed shoreline caused by the Project) and near the receptors (populated areas) in order to assess the source-receptor relationship. The goal of the monitoring program would be to observe PM10 problems or incremental increases in toxic air contaminant concentrations associated with the Proposed Project and to provide a basis for mitigation efforts.

   (f) If incremental increases in toxic air contaminants (such as arsenic or selenium, for example) are observed at the receptors and linked to emissions from exposed shoreline caused by the Project, conduct a health risk assessment to determine whether the increases exceed acceptable thresholds established by the governing air districts and represent a significant impact.

   (g) If potential PM10 or health effects problem areas are identified through research and monitoring and the conditions leading to PM10 emissions are defined, study potential dust control measures specific to the identified problems and the conditions at the Salton Sea.

(3) **Create or Purchase Offsetting Emission Reduction Credits.** This step would require negotiations with the local air pollution control districts to develop a long-term program for creating or purchasing offsetting PM10 emission reduction credits. Credits would be

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used to offset emissions caused by the Proposed Project, as determined by monitoring (see measure 2, above). IID proposes negotiation of an offset program that would allow purchase of credits available under banking programs, such as Imperial County Air Pollution Control District Rule 214 for agricultural burning. Other means of dust control and PM10 emissions reductions available for application to agricultural operations in the IID service area would also be pursued for credit banking opportunities (e.g., managing vacant lands, improving farming practices to reduce PM10, and paving roads). This step would not be used to mitigate toxic air contaminants (if any); Step 4 would be necessary if toxic air contaminants pose a significant health issue.

(4) **Direct emission reductions at the Sea.** If sufficient offsetting emission reduction credits are not available or feasible, Step 4 of this mitigation plan would be implemented. It would include either, or a combination of:

(a) Implementing feasible dust mitigation measures. This includes the potential implementation of new (and as yet unknown or unproven) dust control technologies that may be developed at any time during the term of the Proposed Project; and/or

(b) If feasible, supplying water to the Sea to re-wet emissive areas exposed by the Proposed Project, based on the research and monitoring program (Step 2 of this plan). This approach could use and extend the duration of the Salton Sea Habitat Conservation Strategy.

If, at any time during the Project term, feasible dust mitigation measures are identified, these could be implemented in lieu of other dust mitigation measures or the provision of mitigation water to the Sea. Thus, it is anticipated that the method or combination of methods could change from time to time over the Project term.

The success of the proposed plan is dependent on coordination and cooperation of the involved parties and the air quality regulatory agencies. Coordination, communication, staff commitment, and funding will be required in each phase of the proposed research, monitoring, and emissions reduction program.

3.9.6 Impact Assessment; Feasibility of Implementation

The Draft EIR/EIS concludes that windblown dust from exposed shoreline caused by the Proposed Project may result in potentially significant and unavoidable air quality impacts that could not be mitigated. This conclusion was based upon (1) uncertainty regarding the actual air quality impacts of Salton Sea shoreline exposure, because of the lack of sufficient records or research regarding emissive potential, and (2) uncertainty regarding the availability or feasibility of mitigation measures. This conclusion was intended to be conservative in view of the broad disclosure goals of the California Environmental Quality Act and the National Environmental Policy Act.

This master response is intended to propose a method for identifying the scope of actual air quality impacts caused by the Project and for identifying and implementing potentially feasible mitigation measures that could reduce those impacts. The proposed mitigation is potentially sufficient to avoid or suppress PM10 emissions to less than significant levels. However, a level of uncertainty remains regarding whether short-term and long-term impacts can be mitigated to a less-than-significant level, as described below. Therefore, the

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conservative conclusion that these impacts are potentially significant and cannot be mitigated has been retained in this Final EIR/EIS.

With the implementation of Salton Sea Habitat Conservation Strategy, shoreline exposure caused by the Project would not begin until some time after the year 2035. Up to an estimated 16,000 acres of shoreline would potentially be exposed between 2035 and end of the Project term as a result of full implementation of the Proposed Project. The mitigation plan described above works in concert with the Salton Sea Habitat Conservation Strategy and is expected to reduce air quality impacts and PM10-related health effects. However, problem assessment and mitigation implementation would occur subsequent to the development of potential dust emissions. Therefore, interim impacts could be significant.

It is uncertain what the conditions in the Salton Sea Air Basin will be as of 2035 when Project impacts may begin to occur. The Imperial Valley portion of the Salton Sea Air Basin is currently a moderate nonattainment area and the Riverside County/Coachella Valley portion is currently a serious nonattainment area for the National Ambient Air Quality Standard for PM10. The attainment status of the Basin in 2035 cannot be ascertained; however, the Clean Air Act requires a plan for attainment well in advance of that date.

Cost and water availability may affect the feasibility of certain dust mitigation measures and the proposed delivery of water to the Sea to re-wet emissive areas, as proposed under the mitigation plan described above. If mitigation water is generated by non-rotational fallowing within the IID water service area, this may result in significant impacts to agriculture, as described in Section 3.5 of the Draft EIR/EIS. Fallowing may also adversely affect the Imperial Valley economy, as described in Section 3.14 of the Draft EIR/EIS. Before approving the Project, the Lead Agencies must balance the benefits and impacts of the Project as well as the effects and feasibility of proposed mitigation measures.

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APPENDIX B – EXPOSED PLAYA PM_{10} INVENTORY

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B.1 Experimental Design

This section describes the experimental design of the PM_{10} (particulate matter less than 10 microns in diameter) emission inventory for exposed Salton Sea playa, including the inventory goal and objectives, approach, data collection and analysis, mapping and characterization of playa surfaces, collection of aerometric data, and delineation of active plume areas.

B.1.1 Goal and Objectives

The goal of the PM_{10} emission inventory for exposed Salton Sea playa is to develop an updated PM_{10} emission inventory for consideration in the 2016 Revised Imperial County PM_{10} State Implementation Plan (SIP). An accurate PM_{10} emission inventory is a critical aspect of preparing an effective dust control strategy and attainment demonstration modeling analysis.

The objectives of this emission inventory are four-fold:

1. To evaluate the PM_{10} emission *potential* of different exposed playa surfaces over time, with and without a protective surface crust.

2. To gain a better understanding of the length of the dust season on different exposed playa surfaces.

3. To develop methods for remotely observing and mapping active PM_{10} emission sources on exposed Salton Sea playa.

4. To use the information and data gathered to develop a refined estimate of exposed playa PM_{10} emissions.

The initial phase of the playa PM_{10} emission inventory will be completed in 2016. Follow-up inventory estimates will occur at roughly three-year intervals (next estimate in 2018) using updated equipment and methods, if available.

B.1.2 Approach

The approach for assessing PM_{10} emissions from current and future exposed Salton Sea playa is as follows:

1. Map the extent of exposed Salton Sea playa *by surface type* (e.g., coarse, intermediate, fine, barnacles, crusted vs. non-crusted, etc.) before the start of each playa *dust season*.[1]

2. Conduct PI-SWERL sampling to characterize the emission potential of each surface type over the course of the dust season.

[1] The period of time during which the playa is particularly susceptible to wind erosion (assumed to be January through February).

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3. Record the time and location of dust plumes or any other indications of dust emission activity.

4. Map active dust source areas using remote sensing methods.

5. Quantify maximum hourly and total annual emissions from active source areas.

6. Model dust emissions to evaluate potential impacts at PM_{10} compliance monitors.

Each of these items is discussed in more detail below.

B.1.3 Data Collection and Analysis

This section describes data collection and analysis for mapping and characterizing playa surfaces, for aerometric data, and for delineating active plume areas.

B.1.3.1 Mapping and Characterizing Playa Surfaces

This section describes the mapping and characterization of currently exposed playa surfaces and future exposed playa surfaces.

B.1.3.1.1 Current Exposed Playa

This section describes the objectives, methods, and reporting for mapping and characterizing current exposed playa surfaces.

B.1.3.1.1.1 Objectives

The objective is to map and characterize the surface types of exposed Salton Sea playa. Specifically, properties controlled by evaporate (water-soluble salt) mineral dynamics (e.g., surface type, surface crust thickness, and surface crust hardness) will be mapped and monitored because they are directly related to the spatial and temporal nature of PM_{10} dust emissions (Buck et al. 2011). A secondary objective is to better understand the range of conditions that may be reasonably expected as future playa surfaces are gradually exposed.

B.1.3.1.1.2 Methods

Extensive playa surface survey monitoring methodology originally developed for Owens Lake is being adapted for use at the Salton Sea. This includes monitoring protocols and methodology to accurately map playa exposure and playa surface characteristics (analogous to soil map units) using remotely sensed data resources and ground-based surface evaluations. In addition, mineralogy and groundwater chemistry will be evaluated. Each is described below.

Playa Exposure

Monitoring of the actual Sea surface elevation and associated playa exposure is important for understanding potential air quality impacts. This information will provide a real-time understanding of

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actual playa exposure as it occurs and will help to validate the SALSA2 model results. Two independent methods have been developed to quantify playa exposure.

- **USGS Sea Elevation.** Salton Sea elevation is monitored continuously by the USGS (USGS Site 10254005 Salton Sea NR Westmoreland CA). The monitored Sea elevation data provide the basis for extracting a shoreline from high-resolution bathymetric data. As discussed previously, all data from the USGS gauge are collected in NGVD29 and must be converted to NAVD88 using the standard conversion factor of 2.113 feet when using the bathymetric data or comparing to SALSA2 model results. GIS tools have been developed to provide near real-time estimates of shoreline location and therefore playa

- **Landsat Satellite Imagery:** The accuracy of the USGS gauge-based shoreline is a function of the Sea elevation data from the USGS as well as the precision of the underlying bathymetric data. Therefore, an independent method for assessing exposed playa was developed using satellite imagery. Specifically, the Landsat 5 (1984 to 2013), Landsat 7 (1999 to present), and Landsat 8 (2013 to present) satellites provide current and historic imagery on an 8-to-16-day basis for the Salton Sea. A spectral water index called the Modified Normalized Difference Water Index (MNDWI) (Equation 1) was used to identify standing water associated with the Salton Sea from Landsat imagery. MNDWI is based on the fact that water absorbs energy at shortwave-infrared (SWIR) wavelengths. The integration of the green band into the equation reduces noise associated with other land-based features (Zhang and Wylie 2009). A date-specific threshold of MNDWI was then established to isolate the Salton Sea water body and associated shoreline.

  EQUATION 1 – MNDWI

  $$MNDWI = \frac{\rho\ green - \rho\ SWIR}{\rho\ green + \rho\ SWIR}$$

Actual playa exposure acreage will continue to be monitored and reported on a quarterly basis using the Landsat imagery as well as the USGS Sea elevation approach. Results of the quarterly monitoring will be shared with Imperial County and ICAPCD.

Playa Surface Characteristics

Playa surface characteristics will include detailed characterization of surface properties at various locations, including each PI-SWERL sampling location (see Section B.1.3.2.1.2 for sampling locations). Surface properties are shown in Table B-1. Collector for ArcGIS will be used to record surface characterization data. Unit-defining crust types will be photographed with Collector and linked to the sampling location and associated surface characterization data. The predominant map unit will be described and mapped. The occurrence of significant amounts of surface sand also will be mapped because these features identify important depositional areas.

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The furthest extent of the Salton Sea is typically marked by beach ridges formed by Sea wave action. The intervening areas between beach ridges are generally consistent in terms of exposure time and duration of salt crust development. Thus, playa map units are expected to coincide with these areas. Several salt crust types may be mapped within each map unit due to topographic anomalies where water may have pooled longer or drained earlier than the surrounding area.

Table B-1. Surface Properties Collected During Surface Characterization Events

Surface Property	Description
Crust Type	Crust categories may include: smooth, botryoidal, weak botryoidal, hummocky, and networked. The dominant crust type of the observation area will be characterized, and if other types are present in smaller amounts, they will be noted as inclusions. Additional crust categories may be developed specifically for the Salton Sea playa.
Crust Thickness	Crust thickness is measured from the top of salt crust to the top of soil. In some places, the salt crust will be divided into two distinctly different layers: top-crust and sub-crust. Top-crust is usually a harder, salt-cemented crust that forms a shell over the surface. Sub-crust usually has weak structure (i.e., soft or crumbly) and extends from the bottom of the top-crust to the underlying, often looser soil. In some cases a top-crust will exist without a sub-crust and will be directly overlaying the soil. Total crust thickness is considered the sum of top-crust and sub-crust.
Crust Hardness	Crust hardness indicates the degree of erosion resistance. Crust hardness can be characterized by the amount of force necessary to crush the salt crust by hand according to United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) guidelines (Schoenenberger et al. 2002). On average, smooth and weak botryoidal crust types are the softest, while networked and hummocky crusts are harder. Hardness of both top-crust and sub-crust will be assessed if distinct surface and sub-crusts are present. In addition, the “ball drop method” will be used to evaluate crust hardness at each location using Rule 800 specifications.
Penetration Resistance	Penetration resistance can be measured with a penetrometer. A penetrometer will be inserted through the total crust depth to assess crust resistance. Local penetration resistance can vary substantially and will be measured at several points to calculate an average penetration resistance for a crust type. Penetration resistance readings will be recorded in pounds per square inch (psi). The penetrometer reads in tons per square foot, but the reading is easily converted to psi by multiplying the result by 13.89.
Surface Type and Boundary Type	The surface and boundary types are general field descriptions of the characterized site. The surface types may be classified as open water, saturated mineral soil, saturated salt crust, dry-low relief salt crust, and dry-high relief salt crust. The surface boundaries may be classified as diffuse, distinct, gradual, abrupt, and other.
Soil Moisture	Soil moisture will be qualitatively assessed for the first one to two inches of soil directly below the crust. Soil moisture can be classified based on USDA-NRCS classification parameters (Schoenenberger et al. 2002). Soils will usually range from slightly moist to saturated where crust exists, and dry to saturated where no crust exists.
Soil Texture	Soil texture will be qualitatively assessed for the first one to two inches of soil directly below the crust. Soil texture will be described as fine textured, moderately fine textured, medium textured, moderately coarse textured, coarse textured, or shell.
Free Surface Sand	Free surface sand will be visually determined by estimating the percentage of free, sand-sized particles in a square meter of playa surface. The amount of free sand can vary seasonally with crust development, because forming crusts can encapsulate surface sand as they harden. Free sand particles on the surface are often very fine and settle into very small depressions in crust surfaces.

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Surface Property	Description
Salt Efflorescence	Salt efflorescence is generally a white coating of salt on a surface. At the Salton Sea it is usually seen on top of thinly developed salt crusts. Salt efflorescence is a concern as it consists of extremely fine crystal mats which are very fragile and may be pulverized with the slightest touch.
Crust Relief	Crust relief will be measured to provide a more refined understanding of surface roughness. Roughness affects wind resistance and surface wind velocities, and is therefore useful in wind-erosion modeling. Crust relief will be determined by measuring the distance from the bottom of a crust depression to the top of a typical crust ridge. When applicable, macro- and micro-relief will be differentiated. Networked, botryoidal, and hummocky crusts usually have the greatest relief.
Surface Erosion and Deposition	Surface erosion is generally characterized as a percentage of total crust area that appears to have been eroded by wind. This can be done with visual or remote-sensing techniques. A qualitative description will also be provided using descriptors such as buffed, slightly buffed, scoured, sand shadows, dunes, etc.
Percentage Vegetation, Overflow, and Other Features	Percent surface area of vegetative cover, dune area, berm area, overflow area, and representative playa area will be estimated. These estimates will provide a distribution of small inclusions relative to the dominant mapped surface condition. These features also have implications for the formation of crusts and erodibility; percent overflow area and vegetative cover are probably the most influential of these features. The surface area assessment can be performed visually (from the ground) or using remote-sensing techniques.

Mineralogy

Salt mineralogy and crystal habit affect the vulnerability of various playa surfaces to wind erosion (Buck et al., 2011). The mineralogy of the dominant surfaces will be quantified using a portable X-Ray Diffraction (XRD) device known as the TERRA Portable XRD System. The XRD System bombards finely ground and homogenized samples with X-ray radiation, yielding bulk mineralogy. Bulk mineralogy is determined by measuring the angle and intensity of diffracted X-rays as they pass through the sample. Diffracted X-rays produce two dimensional diffraction patterns, each corresponding to different crystal orientations. Through Fourier Transforms, the two-dimensional diffraction patterns yield three-dimensional images of electron density within a crystalline sample, which further shows the positions and bond types of atoms in the sample. Every mineral has a unique chemical composition, or range of compositions, and the relationship of atoms (in terms of position and bond types) reveals its mineralogy. Figure B-1 is an example of typical output data from the XRD System.

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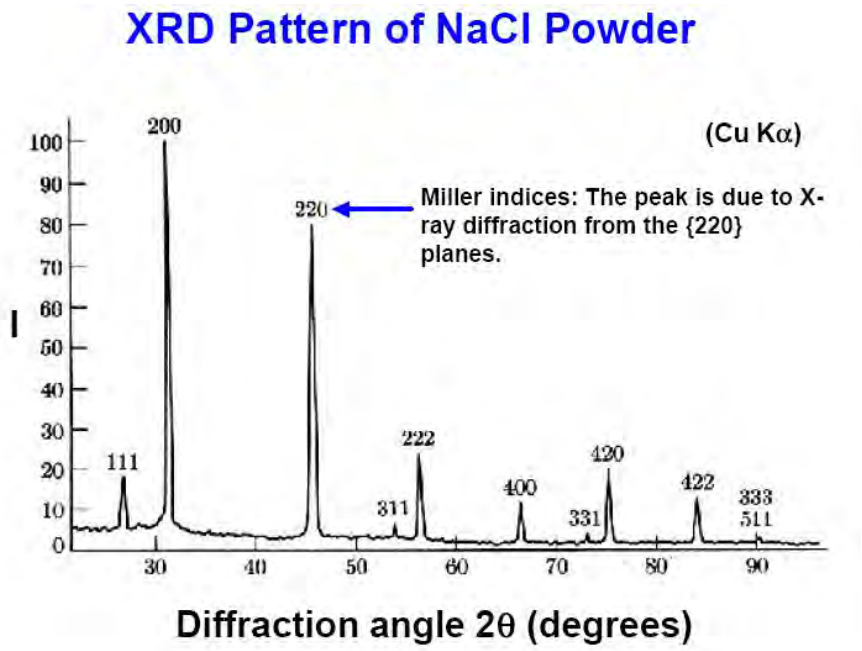
Figure B-1. Example Output from a TERRA Portable XRD System



Salt crust samples will be collected at PI-SWERL sampling locations (see Section B.1.3.2.1.2 for sampling locations). Samples will be collected with a stainless-steel hand trowel and gloved (nitrile) hands. Samples will be processed in the field by pulverizing the salt crust (with tools included with the XRD System) and placing the sample into the sample chamber for analysis with the XPowder software. Remaining sample material will be reserved for possible additional analysis, pending mineralogy results.

Analysis results will be compared to the American Mineralogist Crystal Structure Database (AMCSD) to determine mineralogy. The AMCSD is a crystal structure database that contains each mineral structure published in the American Mineralogist, The Canadian Mineralogist, the European Journal of Mineralogy and Physics and Chemistry of Minerals, as well as selected data sets from other journals (Downs and Wallace, 2003). The XRD System data will then be used to correlate salt mineralogy to potential PM_{10} emissivity based on the PI-SWERL results.

Groundwater Chemistry

Playa salt crust mineralogy characteristics are controlled by the evaporation of shallow groundwater (Buck et al., 2011). Specifically, loosely cemented sodium sulfate salts are known to have higher emission rates than sodium chloride salts (Buck et al., 2011). Therefore, shallow groundwater will be sampled and analyzed to quantify groundwater chemistry characteristics at each PI-SWERL sample location. Groundwater chemistry data will serve as the basis for predicting the minerals that will precipitate from solution as a result of evaporation. This analysis includes four main steps:

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1. **Sample Groundwater**. Representative groundwater samples will be collected at each of the five salt crust study sites, which include Bombay Beach, Alamo River, New River South, Poe Road and the Salton City Club House (Figure B-2). Groundwater will be sampled from one access tube installed in the near-surface aquifer system at each of the salt crust study sites. One round of groundwater samples will be conducted in 2016 in support of the emissions inventory. Additional sampling events at selected sites may be conducted, as needed.

   Prior to groundwater sampling, manual groundwater level measurements will be collected from the access tubes completed at the salt crust study sites. Groundwater samples and water level measurements will be collected in accordance with SOP No. 4, *Groundwater Sampling and Water Level Measurements* (Appendix D5). Groundwater will be sampled using a peristaltic pump and dedicated tubing unless the depth to water is too great in which case an alternative purge method will be used. Groundwater samples will be collected using one of the methods described in SOP No. 4, *Groundwater Sampling and Water Level Measurements* (Appendix D5). It is likely that the low-flow sampling method will be used. All non-dedicated sampling equipment will be decontaminated between each sample location in accordance with SOP No. 7, *Equipment Decontamination* (Appendix D6). Immediately following sample collection, samples will be appropriately labeled, placed in resealable plastic bags, and placed in a cooler with wet ice in accordance with SOP No. 2, *Sample Custody, Packaging and* Shipment (Appendix D7).

2. **Analyze Groundwater Samples**. Samples will be analyzed for laboratory and field parameters, including major minterals. Field water quality parameters include temperature, pH, specific conductance, dissolved oxygen (DO), and oxidation reduction potential (ORP). Field parameters will be measured in accordance with SOP No. 4, *Groundwater Sampling and Water Level Measurements* (Appendix D5). Prior to the collection of field water quality parameters, the water quality meters will be calibrated in accordance with SOP No. 31, *Water Quality Meter Calibration* (Appendix D8). All groundwater field parameters will be measured using a flow-through cell to ensure representative groundwater measurements from the aquifer.

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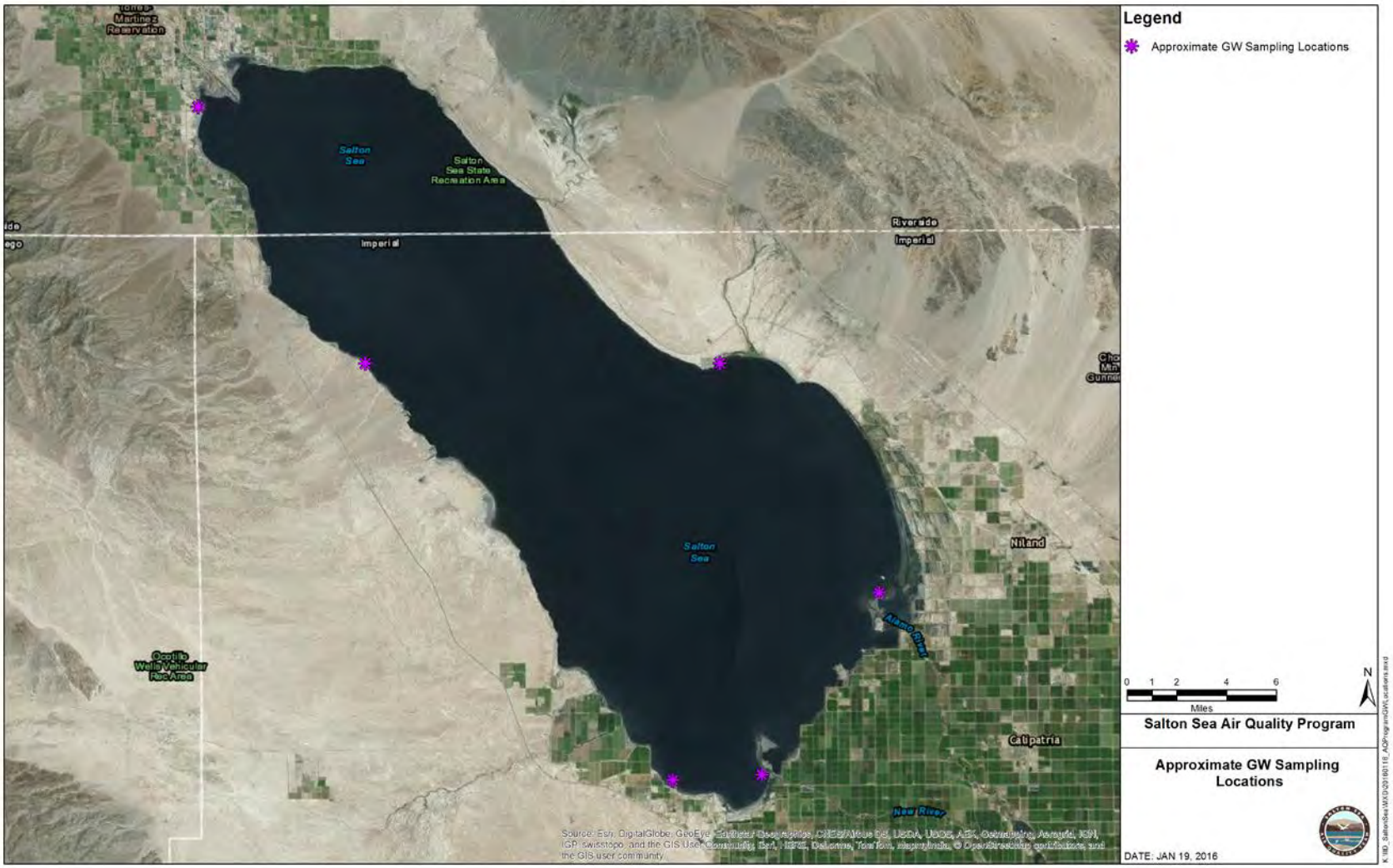

Figure B-2. Representative Groundwater Monitoring Locations

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3. **Review Lab Results**. A review of laboratory data quality indicators, including data completeness, quality and validation, will be performed upon receipt of the data reports prepared by the laboratory. Any data quality issues will be identified before the data are accepted for use in geochemical modeling.

4. **Simulate Evaporation and Mineral Precipitation Reactions**. Lab data will be used to develop aqueous complexation and chemical-reaction models. The aqueous models will be based on site-specific and empirical data. The Geochemist's Workbench® will be used to simulate evaporation and the resulting mineral precipitation reactions. Input data will be entered into The Geochemist's Workbench® computer code. The Geochemist's Workbench® can access thermodynamic data from a number of widely used databases, including the Lawrence Livermore National Laboratory (LLNL 1995) and MINTEQA2 (EPA 2006) databases. It also accomodates the Debye-Hückel and Harvie-Moller-Weare activity models to allow for modeling of solutions with a wide range of dissolved solids content.

   The resulting aqueous complexation models will be evaluated to identify the types of open-system reactions (e.g., mineral precipitation due to oversaturation in solution) that are predicted to take place in situ, as well as the potential for sorption of groundwater constituents to, or desorption from, aquifer solids. For the mineral solids that are predicted to precipitate from solution, their stability and solubility will be evaluated for the range of measured redox and pH conditions.

B.1.3.1.1.3 Reporting

Results of mapping and characterizing current exposed playa surfaces will be reported as outlined in Table B-2. Table B-2, Summary of Reporting for Playa Emissions Inventory, is located at the end of Appendix B.

B.1.3.1.2 Future Exposed Playa

This section describes the objectives, methods, and reporting for mapping and characterizing future exposed playa surfaces.

B.1.3.1.2.1 Objectives

The objective of this effort is to assess the physical characteristics of the inundated playa soils using available data sets and analyses related to Salton Sea floor bathymetry and sediment characteristics. This information will be used to quantify the types of soils and surfaces that will be exposed as the Sea recedes and develop "analoges" with playa already exposed. This information will also be used to stratify PI-SWERL sampling locations and then extrapolate that information to estimate the range in emissive conditions of the future exposed playa. In addition, results also provide insight into the types of dust control measures that may work well in specific regions of future exposed playa.

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B.1.3.1.2.2 Methods

Acoustic sonar data collected by the Bureau of Reclamation were analyzed to provide planning-level information on surface soil characteristics of the currently inundated playa. These data were combined with ground-truth data of soil sediment characteristics. The combination of these data sets was used to generate surface soil sediment characteristics on the playa. The resulting spatial maps predict surface sediment texture, soft sediment depth, surface roughness/complexity, and barnacle bed locations. The following sections detail the methods used to characterize the subsurface characteristics of the inundated Salton Sea playa.

Data Collection

Acoustic sonar data were collected on behalf of the Bureau of Reclamation by Quester Tangent (QTC) between October and December 2004. Simultaneously, surface grab samples were also collected by the Salton Sea Authority. A total of 24 survey days were required to collect all the data. Over 3 million 200 kHz echoes and over 3 million 50 kHz echoes were logged by each system. The systems digitally acquired each raw echo at a rate of approximately four per second and logged the waveform for post-processing. Both the full waveform (FWF) and envelope data were logged by the system. The sonar data were stored in a QTC proprietary format.

GPS navigation data were simultaneously logged as comma-delimited ASCII (American Standard Code for Information Interchange) records (as a National Marine Electronics Association Global Positioning System Fix Data [NMEA GPGGA] string). The GPS system was a CSI Wireless Inc. DGPS MAX, with an OmniSTAR subscription to improve positioning accuracy. OmniSTAR is a “sub-meter” level of service. A typical 24-hour sample of Virtual Base Station will show a 2-sigma (95 percent) of significantly less than 1-meter horizontal position error, and the 3-sigma (99 percent) horizontal error will be close to 1 meter. It operates in real time, and without the need for local base stations or telemetry links. In post-processing, the sonar and navigation records were merged based on a high-resolution time-stamp tagged to each record at the time of logging.

Classification and Processing

The amplitude and shape of an acoustic signal reflected from the sea floor is determined by the sea bottom roughness, the contrast in acoustic impedance between water and sea floor, and perturbations caused by inhomogeneities in the substrate’s volume. Remote seabed classification requires an acoustic data acquisition system, an algorithm set to analyze the data, an implementation method to determine the seabed type, and ground-truth data to relate the acoustic classification to seabed features.

The QTC VIEW seabed classification system by Quester Tangent was used to process the echo trace, and filtering algorithms were used to suppress noise. Echo description was accomplished using several algorithms to extract 166 echo shape features, known as full feature vectors (FFVs), from each trace. Multivariate statistical analysis then identified the best feature combinations to distinguish groups of

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echoes representing different seabed surface characteristics. The feature combinations are reduced to three primary values, known as Q-values, which describe each echo.

Echo classification is accomplished using the three Q-values; it is assumed that the acoustic response from like seabed surfaces will be similar. When Q1, Q2, and Q3 are plotted in orthogonal Q-space, seabed surfaces with similar acoustic responses will form clusters. An echo was classified using its position in Q-space with respect to the clusters generated from calibration data—the echo being classified the same as the closest cluster.

The echo classification in Q-space was done without prior knowledge of the sediment at the sites. Therefore, without a catalogue associating clusters to sediment type, unsupervised classification was used to statistically generate clusters from Q-values alone. Final Q-values for each frequency were appended to each echo location to generate a spatial point map of values.

Generation of Sediment Maps

Point Q-values for each frequency were further processed using geostatistical techniques to spatially interpolate between point values and create a spatially continuous map (Figure B-3). The sea floor depths calculated by the two different frequencies were also used to generate complexity calculations and soft sediment depth (Figure B-3).

Sediment grab samples collected by the Salton Sea Authority were statistically compared to the interpolated acoustic Q-values to create spatial maps of sediment depth, soil texture, surface roughness/complexity, and barnacle bed locations.

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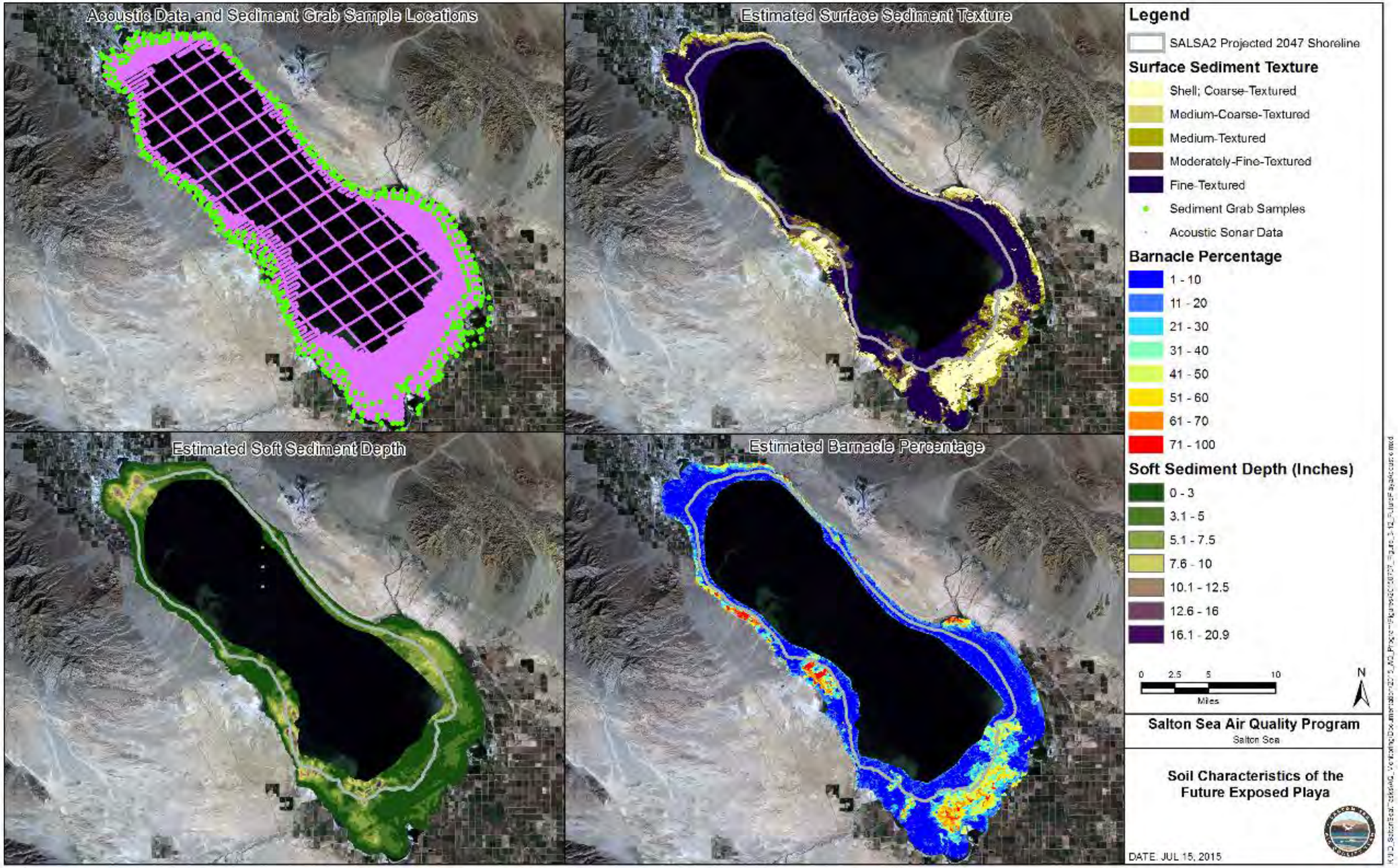
Figure B-3. Soil Characteristics of Future Exposed Playa from Acoustic Sonar Data



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Uncertainty

Due to the nature of the acoustic sonar and grab samples, there is significant uncertainty in the final sediment maps. In addition, wave action, currents, and other disturbances since the time of the acoustic survey could have significant impacts on the spatial structure of the sea floor sediments. That said, this layer provides the best available information for understanding the range of surface sediment characteristics of the future Salton Sea playa.

B.1.3.1.2.3 Reporting

Results of mapping and characterizing future exposed playa surfaces will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

B.1.3.2 Aerometric Data

This section describes the aerodynamic data collection activities that will occur as part of the design of the PM_{10} inventory for the exposed Salton Sea playa.

B.1.3.2.1 PI-SWERL Sampling

The PI-SWERL sampling objectives, locations and frequency, instrumentation, operation and maintenance procedures, analysis, and reporting activities for the exposed Salton Sea playa PM_{10} inventory are described in the following sections.

B.1.3.2.1.1 Objectives

The primary objective of PI-SWERL sampling is to characterize the PM_{10} emission potential for distinct surface types on exposed Salton Sea playa. A secondary objective is to gain a more complete understanding of the "dust season" on the playa (assumed to be January through February). The vulnerability of various playa surfaces to wind erosion is a function of salt mineralogy and crystal habit, both of which are influenced by climate variables: precipitation, relative humidity, and ambient temperature (Buck et al. 2011). For the remainder of the year (i.e., March through December), the playa surfaces are thought to have a more durable crust and are therefore more resistant to wind erosion and PM_{10} emissions. The PI-SWERL sampling will help to verify whether this is the case.

B.1.3.2.1.2 Sampling Locations and Frequency

PI-SWERL sampling will be performed on seven distinct surface types found around the Salton Sea (Section B.1.3.1.2). They are:

- Types 1-3, Coarse-textured soils with barnacles:
    - 0-30% barnacle cover
    - 31-60% barnacle cover

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- >60% barnacle cover

- Type 4, Medium-coarse-textured soils
- Type 5, Medium-textured soils
- Type 6, Moderately fine-textured soils
- Type 7, Fine-textured soils

Forty-two sampling sites will be selected in the field for the initial PI-SWERL investigation, including: seven surface types, two "treatments" (i.e., undisturbed crust and disturbed crust), and three replications for each combination of surface type and treatment (7 x 2 x 3 = 42 sampling sites). The sampling sites will be selected from within relatively large, uniform areas with the target surface conditions. However, much of the current exposed shoreline is a mosaic of various surface types. For these areas, emission potential will be assessed by taking the area-weighted average of the component types over a suitably large characteristic area; for example, 160 acres. Maps of preliminary sampling locations are shown in Figure B-4, Figure B-5, and Figure B-6.

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Figure B-4. Preliminary PI-SWERL Sampling Locations, Surface Type 1 (Torres-Martinez)

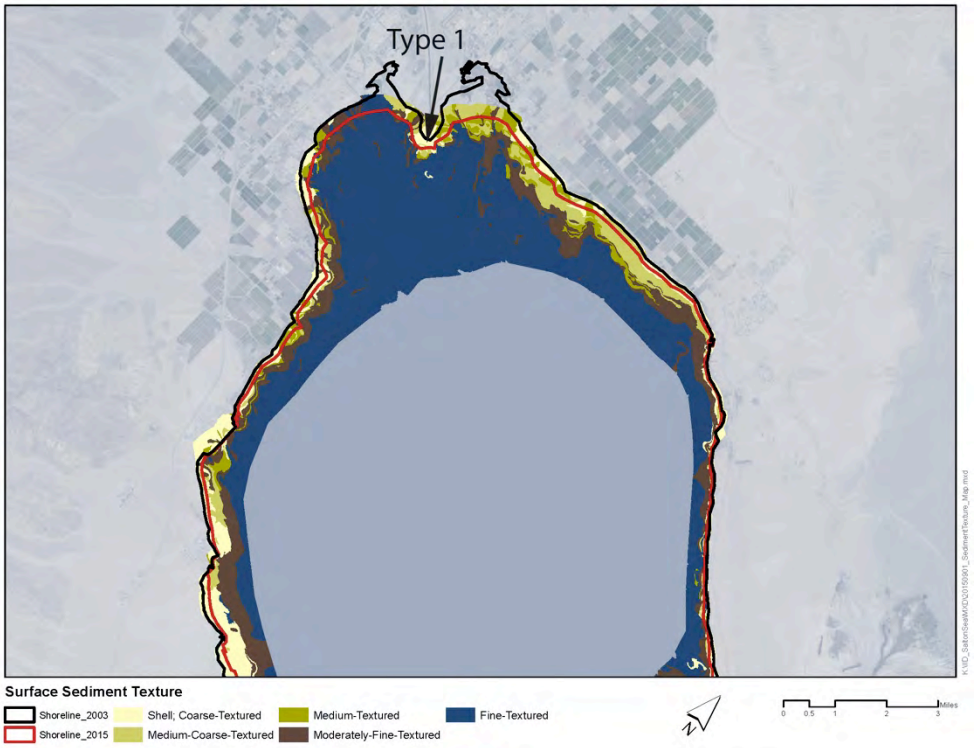

Figure B-5. Preliminary PI-SWERL Sampling Locations, Surface Types 2 and 3 (Bombay Beach) and Surface Types 4 and 5 (Salton City)

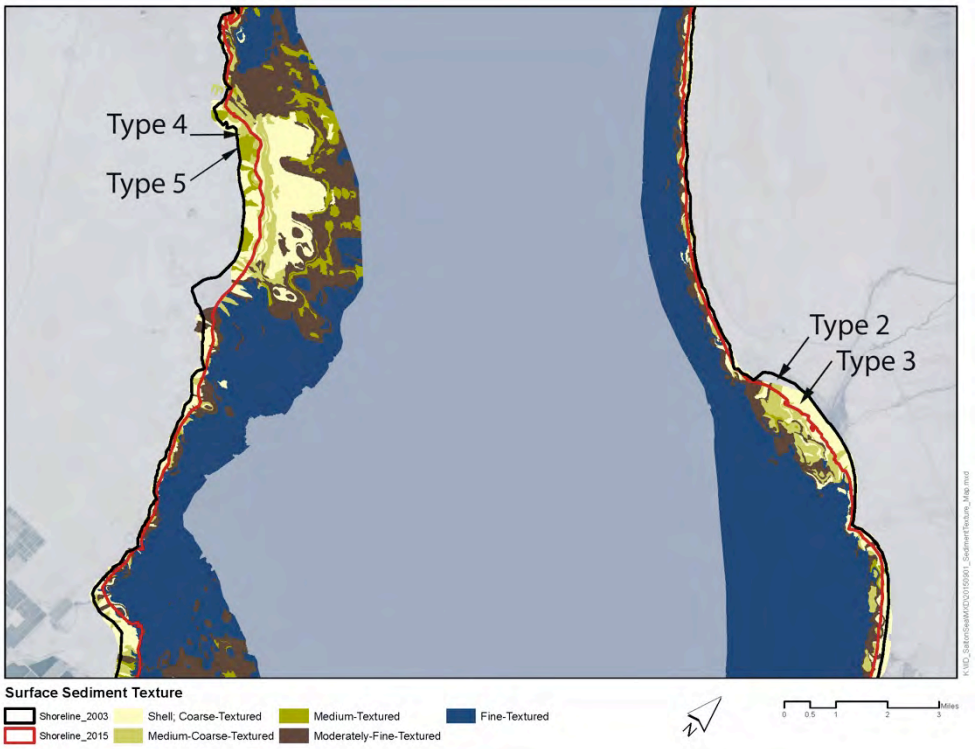

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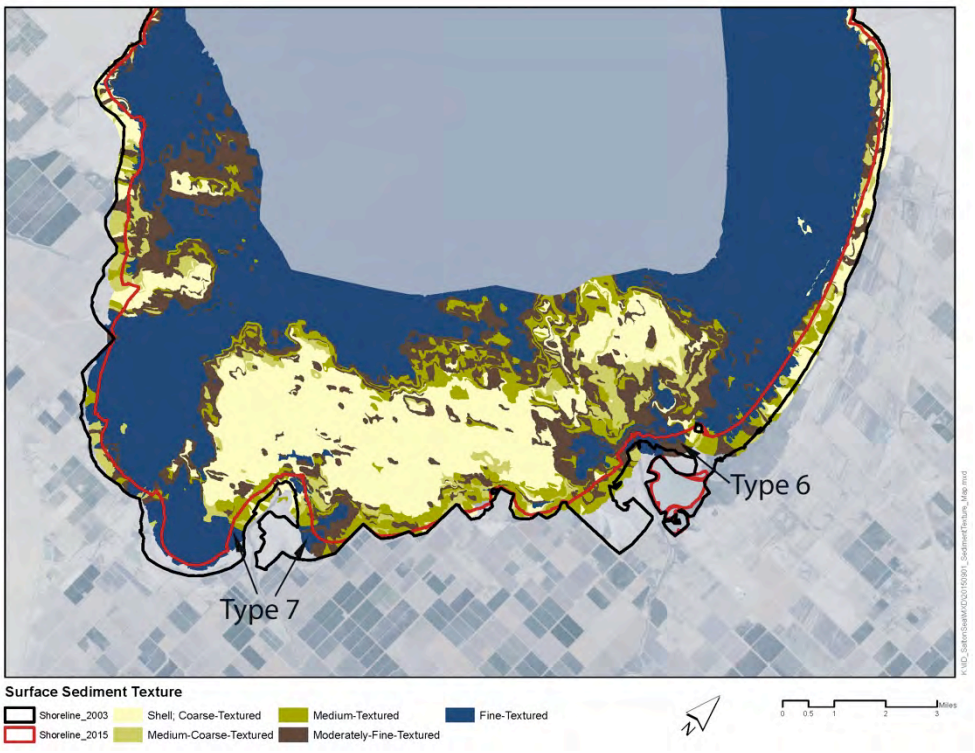
Figure B-6. Preliminary PI-SWERL Sampling Locations, Surface Types 6 and 7 (New River)



Eleven sampling times (events) are planned for the first year of operation. PI-SWERL sampling events are estimated for the following dates:

- Two events in November (1st and 15th, 2015)
- Two events in December (1st and 15th, 2015)
- Two events in January (1st and 15th, 2016)
- Two events in February (1st and 15th, 2016)
- Three events in March (1st, 15th, and 31st, 2016)

These sampling events bracket the assumed January-through-February dust season by at least one month. Bracketing will help to gain a better understanding of the true length of the dust season.

A soil scientist will accompany the PI-SWERL team to characterize the PI-SWERL sample locations as well as the surrounding playa. It is important to characterize the spatial variability of surface types because surfaces are not as uniform as they sometimes appear on maps.

Only the first six months of PI-SWERL sampling have been budgeted (November 2015 through April 2016). Future sampling events will be budgeted as needed. The timing and intensity of sampling events will be dictated by the areal extent of playa exposure and the desire to learn more about how the playa emission potential changes over time.

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B.1.3.2.1.3 Instrumentation

Required instrumentation includes the PI-SWERL apparatus, described below. Labeled diagrams of the PI-SWERL apparatus are found in Appendix D.1, Standard Operating Procedures: PI-SWERL.

Development of the PI-SWERL (Figure B-7) by Victor Etyemezian and others at the Desert Research Institute (DRI) in Reno, Nevada, was motivated by a need for a portable device to test and measure the potential for wind erosion and dust emissions from real-world surfaces. Large wind tunnels, the conventional mode of measurement prior to the PI-SWERL, required long setup times and often a team of people to operate. In comparison, the PI-SWERL is easy to move, requires minimal setup time, and can be operated by a single person.[2] A prototype was developed in 2000 and tested alongside the University of Guelph's large wind tunnel in Guelph, Ontario, Canada. This testing provided early indication of the feasibility of the PI-SWERL concept. Since then, several models have been used in many field investigations, including measuring emission potential on Owens Lake and Salton Sea playas.

Figure B-7. PI-SWERL Apparatus

The PI-SWERL uses a tri-wheeled buggy to transport the instrument and all supporting components. This photograph shows an Air Sciences Inc. crew member sampling surface emission potential at Area T23 on the Owens Lake playa, California.



The PI-SWERL comprises an open-bottomed, cylindrical chamber operated by a direct-current motor that spins an annular metal ring about 2.5 inches above and parallel to the soil surface. Principles of fluid mechanics allow simulation of high winds and ground-level turbulence that typically produce dust

[2] For safety and efficiency, two-person teams are recommended.

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emissions. The spinning ring creates known wind shear, lofting soil and dust particles and passing them through particulate monitors. The PI-SWERL electronically measures the number and size of entrained particles over the duration of a test cycle, typically less than 10 minutes. By controlling the speed of the ring to simulate varying wind speeds, the potential for a soil surface to produce PM_{10} dust emissions can be determined under a range of simulated wind conditions.

The PI-SWERL-derived PM_{10} and sand flux compared favorably to standard laboratory measurements in two separate calibration studies sponsored by the Los Angeles Department of Water and Power (LADWP). In 2011, the PI-SWERL PM_{10} flux using a DustTrak was calibrated against the gravimetric PM_{10} flux at DRI's laboratory in Reno, Nevada (Gillies and Zhou 2012). Overall, the DustTrak-to-gravimetric PM_{10} flux relationships were excellent with regression coefficients (R^2) between 0.85 and 0.99.

In a separate investigation in 2012, PI-SWERL particle counts based on an Optical Gate Sensor (OGS) were calibrated against the measured sediment flux at the University of Guelph's 1.2-meter wind tunnel (Nickling 2012). Very strong ($R^2 > 0.93$) linear relationships were found between the measured sediment flux and the OGS counts for laboratory sand and for two of the Owens Lake soils (located at Study Area 3 and Lizard Tail). A much lower ($R^2 = 0.4256$), but still statistically significant, linear relationship at the 95 percent confidence level was associated with Cottonwood soils.

B.1.3.2.1.4 Operation and Maintenance Procedures

Appendix D.1, Standard Operating Procedures: PI-SWERL, describes the PI-SWERL operation and maintenance activities (including precautions), start-up and operating procedures, periodic cleaning and maintenance procedures, and records management (including use of the SWERLView software).

B.1.3.2.1.5 Analysis

This section summarizes the process for transforming the PI-SWERL data to graphs and tables of PM_{10} emission flux versus surface friction velocity. These output graphs and tables are later used to calculate maximum hourly and annual PM_{10} emission rates (see Section B.2).

Data Output from PI-SWERL

Each PI-SWERL run will consist of a ten-minute cycle. Each cycle consists of a 60-second cleaning step at the onset of the test (friction velocity of zero) and five incremental steps with a constant friction velocity (Figure B-8). The cleaning step purges the test chamber from any residual particulate matter that might be left in the system from prior tests. The five incremental steps are based on stable blade rotations (RPM, or rotations per minute) and represent known friction velocities (through an internal instrument calibration) that can be compared to those observed in the meteorological monitoring network around the Sea (for example, Table B-3). Based on this comparison, the highest friction velocities evaluated in the PI-SWERL will be similar to or exceed those observed around the Salton Sea (depending on the location).

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Figure B-8. Example Output from PI-SWERL Test Cycle

Periods of constant (target) friction velocity, are indicated by the gray bars. The gold line represents surface friction velocity (m s^{-1}). The blue line is the normalized PM_{10} emission rate (dimensionless). The green line is the normalized horizontal sand motion (dimensionless).

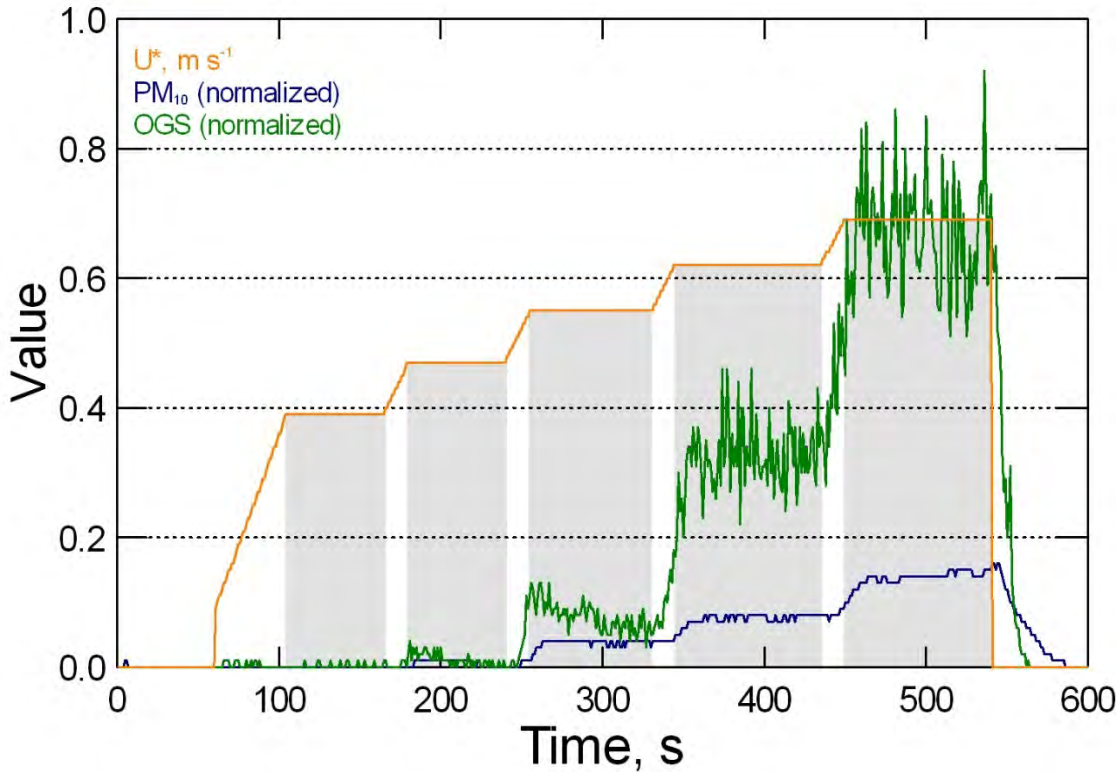

Table B-3. Meteorological Parameters Associated with Different PI-SWERL Rotation Rates

Rotation Rate (RPM)	Surface Friction Velocity (cm s^{-1})	Wind Speed at 10 Meters Above Ground † (m s^{-1})	(mph)
2000	39	11	25
2500	47	13	30
3000	55	15	34
3500	62	17	39
4000	69	19	43

† Assumes a roughness length (z_0) of 0.1 mm representative of smooth playa conditions

Over the course of each test, the PI-SWERL generates several data streams, which are electronically saved on a one-second basis. A portion of the output describes test characteristics (for example, test ID, GPS coordinates, etc.), another portion is primarily used in the data validation step (for example, air flow rate, actual versus targeted RPM), and a third portion of the data is used to characterize the emissions from the evaluated surface. Of the latter, the following data fields are used in the data analysis (see Figure B-8):

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- Friction velocity, u_*: Calculated from RPM, which varies stepwise within each test. The same RPM steps are used across all PI-SWERL tests.
- PM_{10}: Measured as a concentration (mg m^{-3}) but converted to vertical emission flux (μg m^{-2} s^{-1}).
- OGS: Measures the intensity of sand motion within the PI-SWERL chamber; expressed as number of particle counts per second.

Identification of Emission Flux "Regime"

Sand motion and PM_{10} emission profiles vary with soil type and surface conditions. This section summarizes five examples covering the range of surface conditions, from low sand motion/low PM_{10} emissions to high sand motion/ high PM_{10} emissions. An overview of the associated surface characteristics is given in Table B-4. Photographs are shown in Figure B-9. All of these examples are based on measurements on sandy soils at the Owens Lake playa (June 2015). A similar spectrum of soil and surface conditions can be found on exposed Salton Sea playa.

Table B-4. Representative Surface Types for Salton Sea

Representative Surfaces	Crust Moisture	Crust Condition	"Free" Surface Sand	PM_{10} Emission Potential	Sustained PM_{10} Emissions?
A	Dry	Undisturbed	Negligible	Low	No
B	Moist	Undisturbed	Negligible	Low	No
C	Dry	Undisturbed	Abundant	Intermediate	Yes, Intermediate
D	Dry	Disturbed	Minimal	Intermediate	No
E	Dry	Disturbed	Abundant	High	Yes, High

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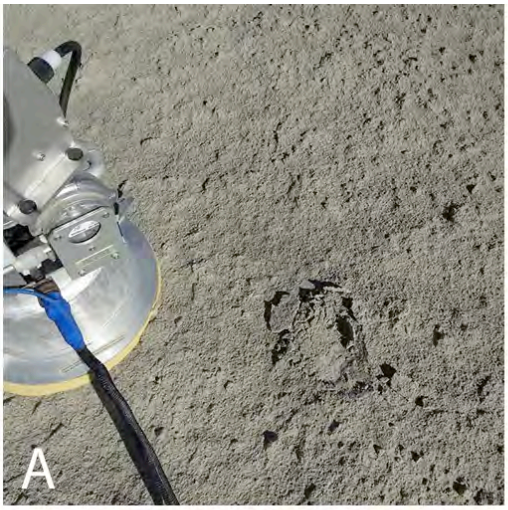
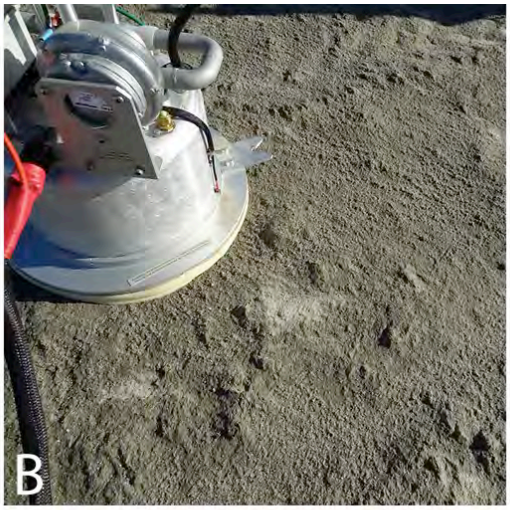
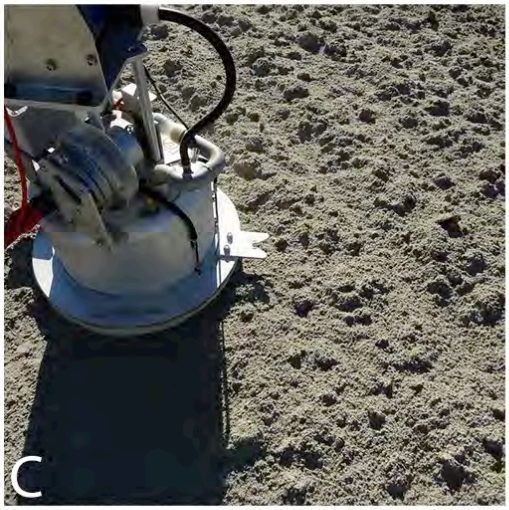
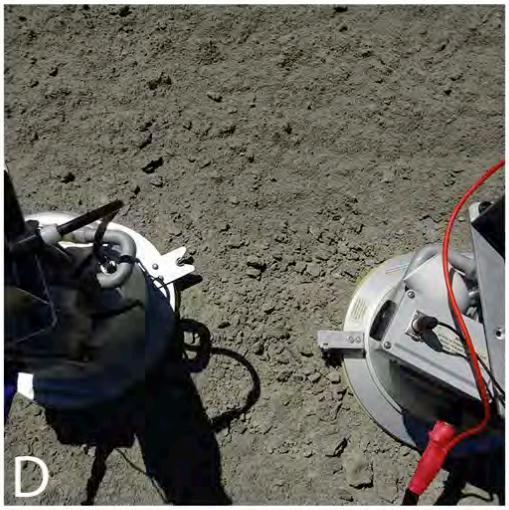
Figure B-9. Photographs of Representative Surface Types

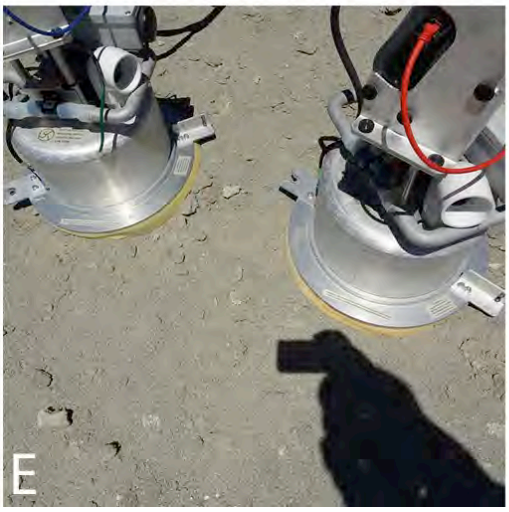
The identification letters (shown in lower left-hand corner of each panel) correspond to those used in Table B-4 and in later summary figures.











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Sand motion and PM_{10} flux profiles for each of the representative surfaces are presented in Figure B-10 through Figure B-14. Note that the sand motion and PM_{10} flux profiles are both normalized and therefore dimensionless.

Figure B-10 shows the sand motion and PM_{10} flux profiles for a dry, stable (that is, hard) salt crust (see Figure B-9, Surface Type A). Sand motion and PM_{10} flux are both low for this surface, with values lying close to the x-axis for all RPM levels. The OGS readings are within the instrument noise range, and the PM_{10} concentrations within the PI-SWERL chamber are at ambient levels.

A similar pattern exists on the surface characterized by a moist, stable salt crust (Figure B-11, Surface Type B). As with the dry salt crust example (Surface Type A), the OGS readings are within the instrument noise range, but in this case a small amount of superficial PM_{10} is available for entrainment at high RPMs. The PI-SWERL is capable of recording these low emission rates but they are insignificant in their contribution to the 24-hour average PM_{10} concentrations.

Surface Type C (Figure B-12) is an example of a dry salt crust with abundant free sand on the surface, generating sustained high sand motion with sustained intermediate PM_{10} emissions with increasing RPM.

Stable salt crusts have the potential to protect surfaces from erosion, especially if there is little to no erodible material on the surface to accelerate erosion and crust degradation. This was the case with Surface Types A, B, and C above. However, once the crust is broken, the PM_{10} emission rates increase significantly. In future PI-SWERL sampling events, sand motion and PM_{10} flux profiles will be generated for both disturbed and undisturbed salt crusts.

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Figure B-10. Example Surface Type A, Profile: Undisturbed Dry Crust, Negligible Free Sand, Low Sand Motion, Low PM_{10} Emissions

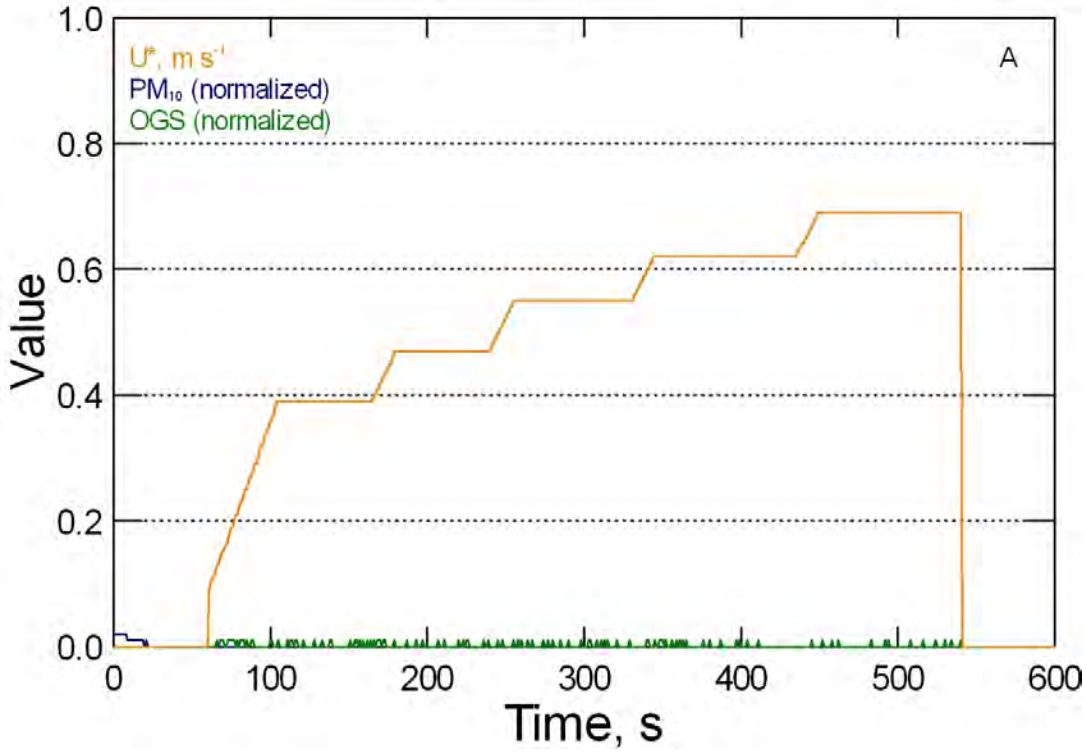

Figure B-11. Example Surface Type B, Profile: Undisturbed Moist Crust, Negligible Free Sand, Low Sand Motion, Low PM_{10} Emissions

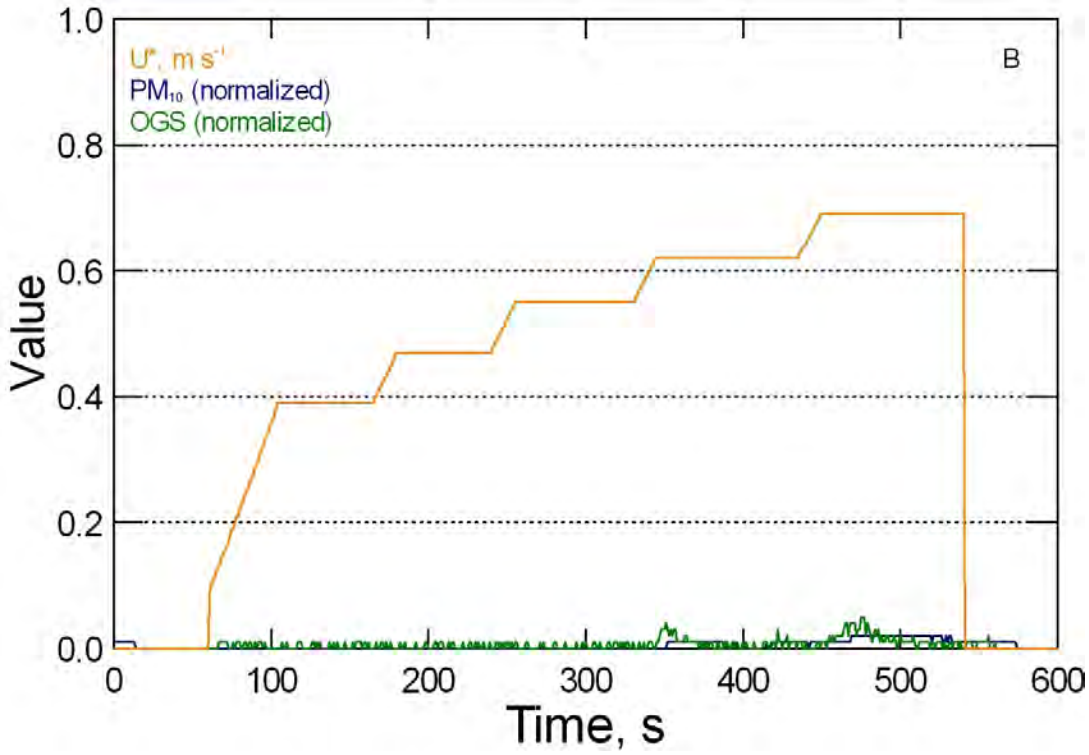

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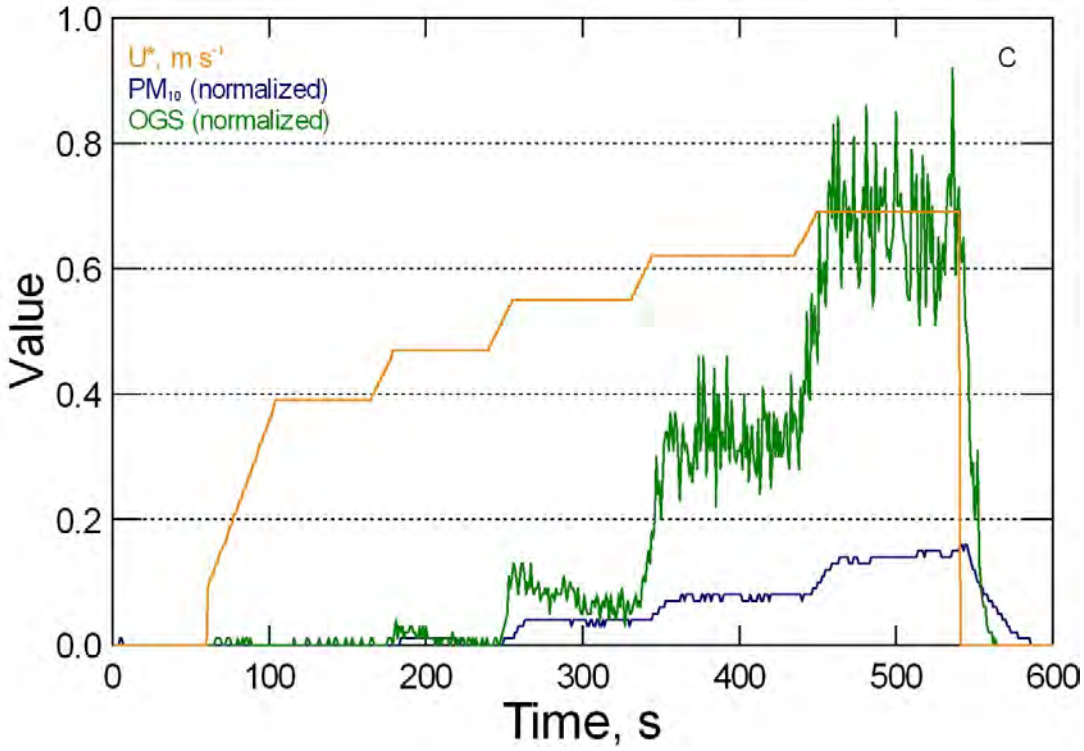
Figure B-12. Example Surface Type C, Profile: Undisturbed Dry Crust, Abundant Free Sand, High Sand Motion, Intermediate PM_{10} Emissions



Surface Type D (Figure B-13) is one with a disturbed crust, but little free sand on the surface to act as an abrasive agent. Sand motion and PM_{10} emissions both spiked at higher RPMs, but the increase lasted only about a minute before plummeting back to background levels. As with Surface Type C, the higher PM_{10} emissions are unlikely to contribute significantly to 24-hour PM_{10} concentrations.

Surface Type E (Figure B-14) is characterized by a disturbed crust with abundant free sand on the surface acting as an abrasion agent. The lack of durable crust produced a virtually unlimited supply of sand, causing sustained high sand motion with very high sustained PM_{10} emissions—the highest of any surface tested. Under this scenario, the higher PM_{10} emissions are expected to contribute significantly to ambient concentrations over extended periods of time (see discussion below regarding temporal and spatial averaging).

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Figure B-13. Example Surface Type D, Profile: Disturbed Dry Crust, Minimal Free Sand, Low Sand Motion, Spikes in PM_{10} Emissions

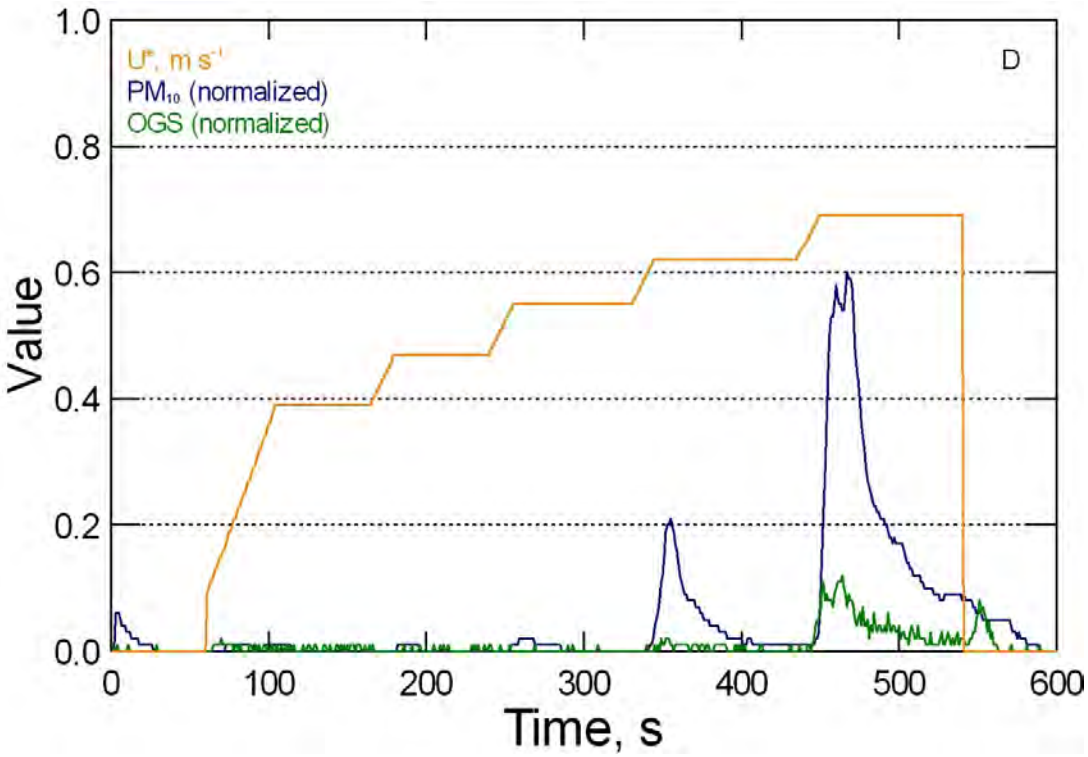
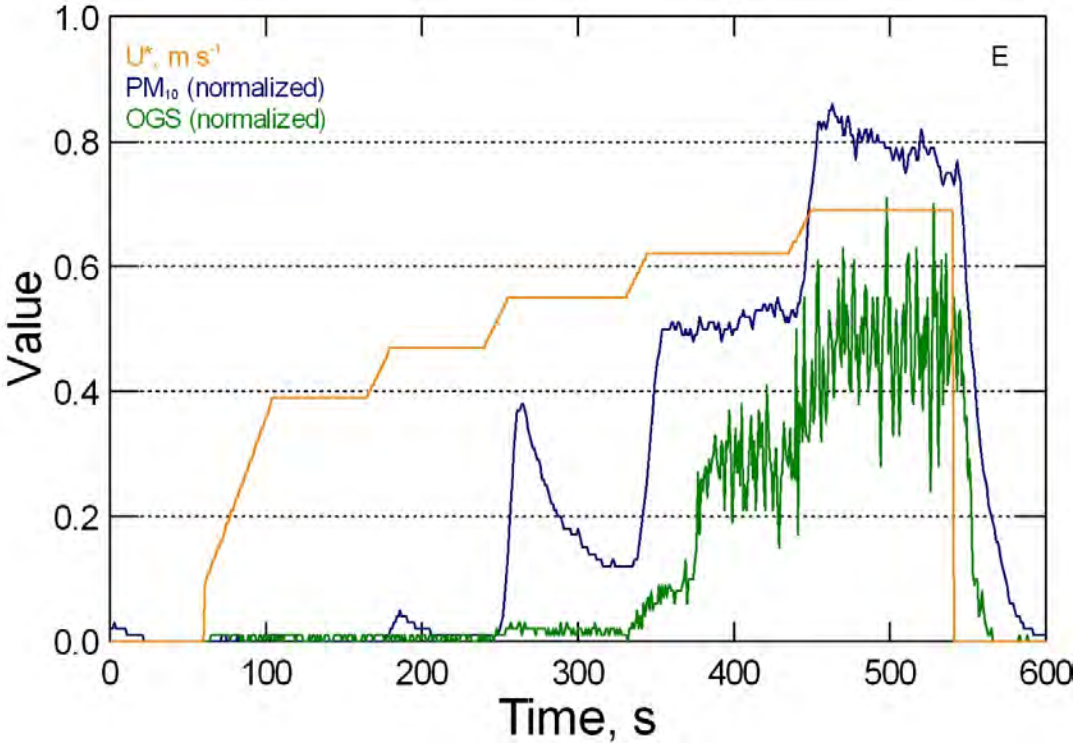


Figure B-14. Example Surface Type E, Profile: Disturbed Dry Crust, Abundant Free Sand, Sustained High Sand Motion, Sustained High PM_{10} Emissions



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Generation of Emission Flux Versus Friction Velocity Curves

In the next step, PM_{10} emissions and sand motion are expressed as a function of the surface friction velocity, allowing for estimating the potential PM_{10} emissions at a given wind speed in the field. The PM_{10} emission rates are geometrically averaged over each time step characterized by constant RPM (therefore, constant friction velocity; see Figure B-8), and then geometrically averaged over the replicate runs within a specific surface type (Figure B-15). Several features become apparent from these relationships:

1. PM_{10} emission rates vary strongly by u_* and surface type (top panel, Figure B-15).
2. Threshold friction velocities[3] vary by surface type (middle panel, Figure B-15).
3. K-factors[4] vary by u_* and surface type for all sand fluxes above background levels (surface types C and E) (bottom panel, Figure B-15).
4. Several surface types (A, B, D) have PM_{10} emissions rates and sand activity that do not exceed background (instrument noise) levels. These surfaces are considered non-emissive under all wind speeds that would occur under normal conditions on the Salton Sea playa.

Some of the surface types are characterized by PM_{10} emission rates that are above background levels (top panel, Figure B-15), but the PM_{10} emissions are short-lived (spikes) and not supported by sustained sand motion. Examples include surface types A, B, and D across all u_* values, and surface types C and E at low u_* values. In these cases, the surfaces are highly resistant and/or sand fluxes are not high enough to generate significant, sustained PM_{10} emissions (compare the middle panel of Figure B-15 with Figure B-10 through Figure B-14).

The duration of PM_{10} emissions is important when extrapolating the PI-SWERL emission rates to longer time periods; that is, 24 hours and above. For this reason, a persistence factor has been imposed to calculate longer-term PM_{10} emission rates:

$$ER_{LT} = \overline{ER_{ST}} \cdot PF \qquad \textbf{Equation B-1}$$

where ER_{LT} is the long-term average PM_{10} emission rate (g m^{-2} $event^{-1}$), $\overline{ER_{ST}}$ is the geometric-mean emission rate (g m^{-2} s^{-1}) for each RPM level within a PI-SWERL run, and PF is a persistence factor (s $event^{-1}$) defined as follows:

$$PF = \left(\frac{1}{60}\right)\left(\frac{1}{5}\right) = 3.3\ x\ 10^{-3} \qquad \textbf{Equation B-2}$$

[3] The friction velocity at which sand particles begin to move.

[4] Vertical PM_{10} flux divided by horizontal sand flux.

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This approach assumes that when PM_{10} fluxes are not stable but rather short-duration *spikes*, the spike duration is typically one minute in the PI-SWERL chamber (for example, see Figure B-13 and Figure B-14). Significant PM_{10} emissions, on the other hand, are generated by high-wind events lasting more than five hours.[5] The five-hour-equivalent PM_{10} emission rates in Equation B-1 are calculated by dividing the one-minute-average PI-SWERL PM_{10} emission rates by 60 s hr^{-1} to yield PM_{10} emissions per hour, and again by 5 hr $event^{-1}$ to yield PM_{10} emissions for a five-hour event.

The persistence factor is only applied to surface types and RPM levels that spike and drop to zero or near-zero within the one-minute to 90-second RPM run. The persistence factor is not applied to surface types and RPM levels with PM_{10} emission rates that do not drop to zero.

Adjusting all non-sustained emission rates in Figure B-15 by the five-hour persistence factor reduces most of the surface-type emissions to very low levels (Figure B-16; filled symbols), leaving only PM_{10} emissions sustained by sand motion as significant for longer-term emission calculations (Figure B-16; open symbols).

[5] Supported by analysis of high-wind events at Bombay Beach from 2010 to 2015.

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Figure B-15. Relationship between PM_{10} Emission Rate (Upper Panel) and Sand Motion (Lower Panel) versus Surface Friction Velocity [Log_{10}-transformed scale] by Surface Types (A-E)

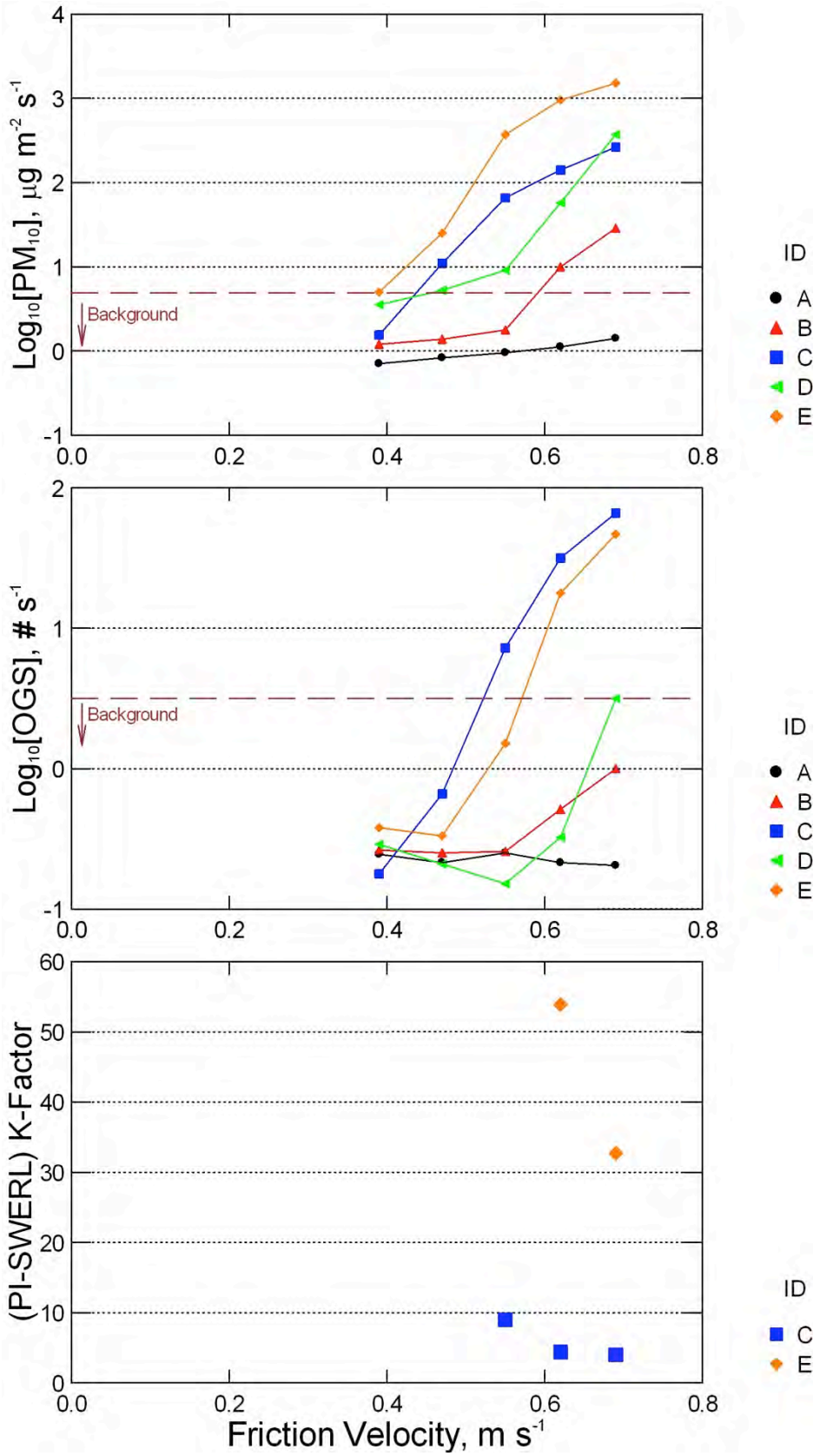

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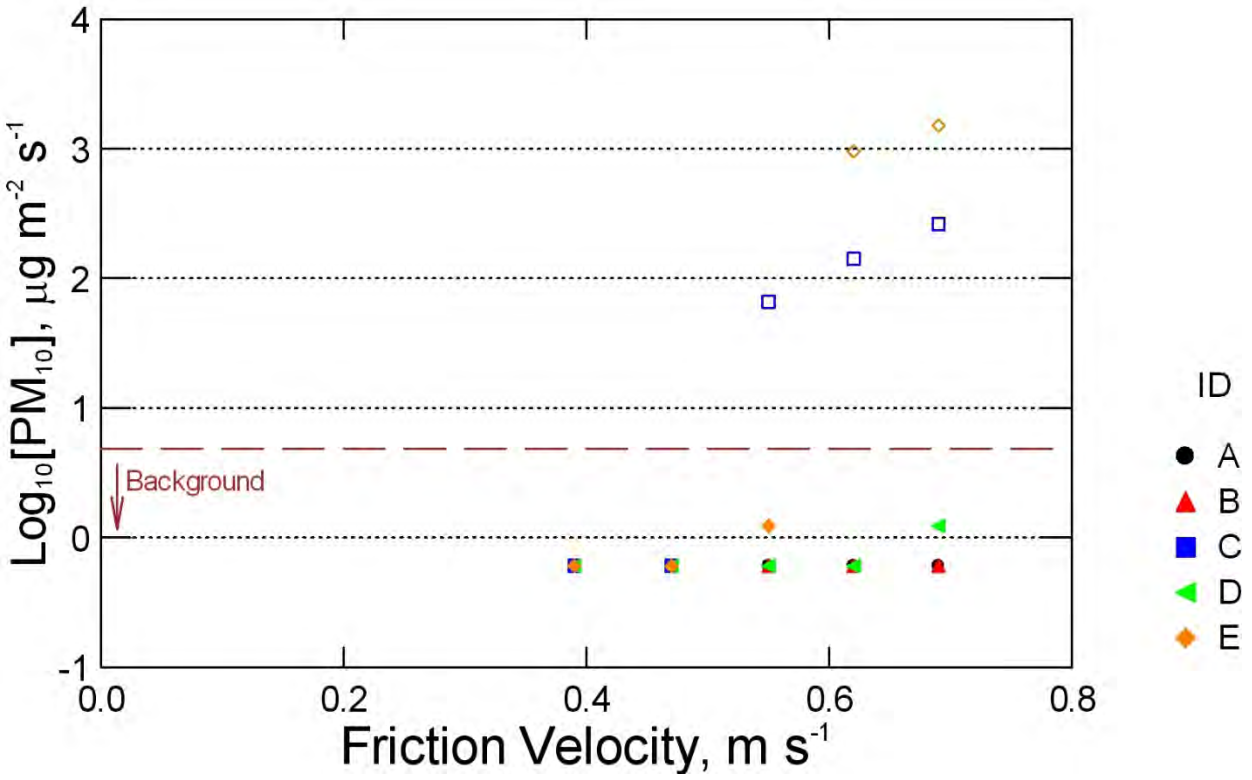
Figure B-16. Relationship between PM_{10} Emission Rate and Friction Velocity Adjusted for Persistence Factor in Equation B-2

Sustained and non-sustained (temporary) emissions are shown as open and filled symbols, respectively.



Generation of Mathematical Relationships between PM_{10} and Friction Velocity

Mathematical relationships between PM_{10} emission flux and u_* will be determined by fitting curves to the data points using SYSTAT 13 or equivalent statistical and graphical software. The form of the fitted equations is not yet known.

B.1.3.2.1.6 Reporting

PI--SWERL results will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

B.1.3.2.2 Meteorological Monitoring

This section describes the exposed Salton Sea playa emission inventory meteorological monitoring objectives, instrumentation, sampling locations and times, instrument operation and maintenance, analysis, and reporting.

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B.1.3.2.2.1 Objectives

Meteorological data will be used in the Salton Sea playa emission inventory in one of two ways: (1) estimating PI-SWERL-generated PM_{10} emission rates, with friction velocity as the independent variable, or (2) input to the CALMET meteorological modeling analysis, used in the CALPUFF dispersion modeling analysis to evaluate potential impacts at Salton Sea PM_{10} compliance monitors.

B.1.3.2.2.2 Instrumentation

Meteorological sensors will be mounted on a tripod with a 6-meter-tall mast (Figure B-17). Cup anemometers will be mounted on the mast at three heights above ground: at 1, 2, and 6 meters. Met One Instruments (Met One) model 014A mini wind speed sensors will be installed at the 1-meter height; standard Met One model 014A wind speed sensors will be installed at the 2- and 6-meter heights. A Met One 024A wind direction sensor will also be mounted at the 6-meter height. Other required instrumentation includes: a solar panel, a deep-cycle marine battery, a datalogger, a radio modem, radio antennae, and a grounding rod.

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Figure B-17. Salton Sea Portable Meteorological Tower with Cup Anemometers at 1, 2, and 6 Meters above Ground



B.1.3.2.2.3 Sampling Locations

A total of six meteorological monitoring locations will be chosen on the playa for assessing hourly values of surface friction velocity, u_*. The sampling locations will be distributed relatively evenly along the eastern, southern, and western portions of the playa as the Sea recedes. Sites will be chosen that are well away from any natural or human-made obstructions that would affect surface roughness, including fences, buildings, vegetation, and dunes.

Friction velocity is a *reference* wind velocity generally applied to motion near the ground where the *shear stress* (i.e., frictional force of wind acting parallel to the surface) is often assumed to be

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independent of height and approximately proportional to the square of the mean velocity (the "Square Law"):[6]

$$u_* \simeq \sqrt{shear\ stress} = \sqrt{\frac{\tau}{\rho}} \qquad \textbf{Equation B-3}$$

where τ is the Reynolds number and ρ is air density. Here, u_* is the velocity for which the Square Law applies.

B.1.3.2.2.4 Sampling Times

The portable meteorological stations will be operated continuously from November 2015 (planned commencement date of monitoring) through the end of project. Mean hourly wind speeds will be calculated by the datalogger for each sensor height at each site.

B.1.3.2.2.5 Operation and Maintenance Procedures

Operation and maintenance of the meteorological instruments are described in Appendix D.2, Standard Operating Procedures: Sand Flux and Meteorological Monitors. Appendix D.2 includes: site check and audit forms, data processing and quality assurance/quality control (QAQC) procedures, and calibration and audit procedures for the Met One 014A wind speed and Met One 024A wind direction sensors.

B.1.3.2.2.6 Analysis

Friction velocity (u_*) and roughness length (z_0) are derived by fitting the hourly average wind velocity (x axis) against height above ground (y axis) on a log-log scale. The slope of the line is u_*; the y-intercept is z_0.

As stated previously, hourly u_* values will be used to calculate hourly vertical PM_{10} emission fluxes using the relationship between PM_{10} emission flux and u_* derived from the PI-SWERL.

B.1.3.2.2.7 Reporting

Reports summarizing, among other things, hourly wind speed and wind direction data, and collection statistics and results of the quality control review will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

[6] Sutton, O. G. 1953. Micrometeorology. p. 76.

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B.1.3.2.3 Video Monitoring

This section describes the Salton Sea playa video monitoring objectives, equipment and monitoring locations, image collection rates, operation and maintenance procedures, image analysis procedures, and reporting.

B.1.3.2.3.1 Objectives

Video monitoring, in the form of time-lapse panoramic images from two locations at opposite ends of the Sea, serves several valuable purposes:

1. To document general visibility conditions within the Salton Sea airshed from vantage points located well above the sea elevation. Special focus will be given to days on which one or more Imperial Valley meteorological stations record wind speeds that are above the threshold required to generate dust.

2. To document the location, frequency, and relative intensity of dust plumes originating on exposed Salton Sea playa.

3. To document the location, frequency, and relative intensity of dust plumes traveling across the Salton Sea from sources *not* associated with the Salton Sea playa (including a mixture of playa and off-Sea emissions).

B.1.3.2.3.2 Equipment and Monitoring Locations

Two types of visual monitoring systems will be installed around the Salton Sea: a set of fixed-location, scanning cameras designed to provide high-resolution panoramic images of the Imperial Valley airshed, and a set of six portable video monitoring cameras deployed around playa emission *hotspots*.

The fixed location scanning sites will use Roundshot 360-degree panoramic scanning camera equipment (Figure B-18) and software with a Web interface for remote viewing.[7] The camera systems will be mounted in a camouflaged all-weather enclosure and surrounded by a 10-foot by 10-foot by 10-foot cyclone fence enclosure with a locking gate for added security.

Figure B-19 shows the proposed locations for the scanning cameras. The north camera location will be centered eastward and scan 195° between NNW and SSE to capture the north and western playas, as well as the easternmost off-Sea areas on the west side of the Sea. The south camera will be centered northwestward and scan 225° between SSW and ENE to capture the southern and western playas. A set of example time-lapse panoramic images (compressed horizontal scale) is presented in Figure B-20 to illustrate the output from the cameras.

[7] http://www.roundshot.com/xml_1/internet/de/intro.cfm

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Figure B-18. Roundshot Livecam D2 360° Scanning Equipment with Weatherproof Case



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Figure B-19. Proposed Sites for Roundshot Scanning Cameras

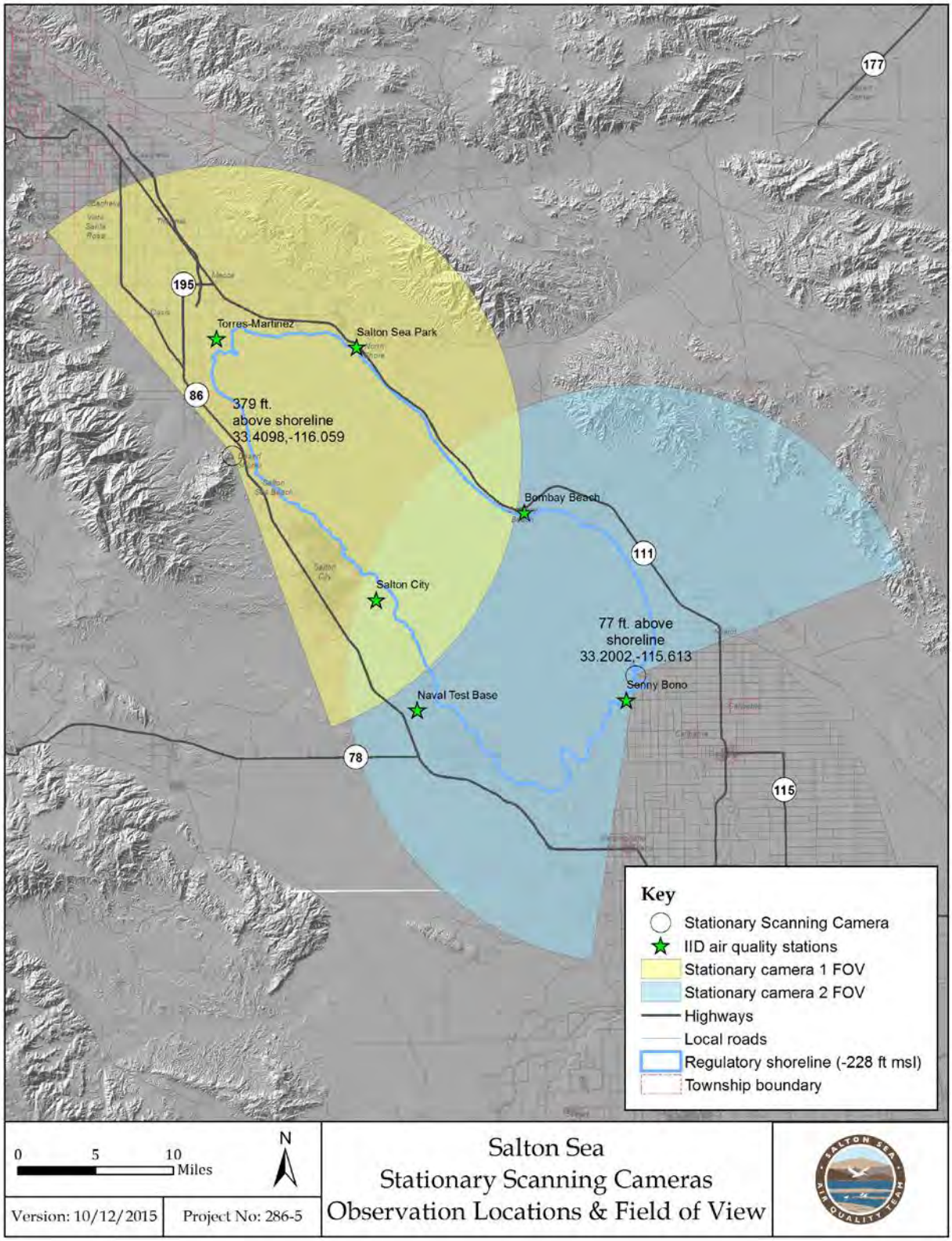

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Figure B-20. Time-Lapse Panoramic Images Taken with Roundshot Livecam D2 360° Scanning Camera (El Paradiso, St. Moritz, Switzerland)

The photographs have been compressed horizontally, producing a "fish eye" effect that doesn't exist in the original images.



The portable video camera systems will be equipped with the StarDot Corporation 10-megapixel (MP) H.264d Special Bundle, which includes a StarDot 10MP SC day/night camera (Figure B-21) with Dotworkz ST-BASE outdoor enclosure, a Veracity Power-over-Ethernet (PoE) injector, and a Tripp Lite outdoor-rated 100-foot patch cable.[8] In addition, each site will be equipped with an 8–48-millimeter vari-focal lens, providing a 4.5°–45° field of view (FOV) that may be adjusted according to specific site conditions. The StarDot camera will be mounted at the 2-meter height on a tripod (similar to the one shown in Figure B-17). Siting of the video camera stations will occur later, when and if dust emission hotspots are observed on the playa.

[8]http://californiapc.com/IP-Cameras-Enclosures-Lenses-Accs/StarDot-NetCam-Bundles/

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Figure B-21. StarDot Technologies SC H.264 Camera



B.1.3.2.3.3 Image Collection Rates

Both camera systems will operate continuously during daylight hours. The collection rate on the Roundshot scanning camera depends on the scanning angle and available bandwidth (a full 360° panorama is approximately 250 MB). The scan duration for a 180° panoramic image is on the order of three seconds. One Roundshot panoramic image and one StarDot still-frame image will be captured and stored at least every 15 minutes.

B.1.3.2.3.4 Operation and Maintenance Procedures

Operation and maintenance of the video monitoring stations are described in Appendix D.3, Standard Operating Procedures: Roundshot Livecam D2 and in Appendix D.4, Standard Operating Procedures: StarDot Technologies SC H.264. Each of these appendices includes installation and operation procedures, and site check forms, for the Roundshot camera system (fixed stations) and the StarDot camera system (portable stations), respectively.

B.1.3.2.3.5 Image Analysis Procedures

In the laboratory, the images will be filtered to include those taken on days when wind speeds exceed the threshold for dust generation (nominally, more than four hours with average wind speeds greater than 5 meters per second at a height of 10 meters above ground). All of the captured images will be securely stored, backed up, and available for viewing on a secure website.

Filtered images will be reviewed by an analyst to qualitatively identify and track areas of playa that display dust activity. This review will inform any subsequent decisions to site portable StarDot cameras near emissions hotspots.

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B.1.3.2.3.6 Reporting

Reports summarizing, among other things, days with 10-meter wind speeds above the threshold for dust generation, and a qualitative description of images showing evidence of dust plumes will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

B.1.3.3 Delineating Dust Plumes and Active Source Areas

This section describes the objectives, methods, and reporting for delineating dust plumes and active source areas on the currently exposed Salton Sea playa.

B.1.3.3.1 Objectives

The objective is to quickly and reliably map and delineate active dust plumes and source areas over the vast areas of exposed Salton Sea playa during the dust season.

B.1.3.3.2 Methods

A combination of visual monitoring, video monitoring, satellite imagery, and field investigations will be used to monitor dust plumes and identify source areas after high wind events. Visual monitoring and video monitoring will be used to identify dust plumes. Mapping and delineation of eroded and emissive sources areas will be completed using a combination of satellite imagery, ultra-high resolution Unmanned Aerial System (UAS) imagery and field investigations immediately after a high wind event. Detailed methods are listed as follows.

B.1.3.3.2.1 Plume Observations

Weather forecasts from the National Weather Service will be evaluated on a daily basis. An example weather forecast is provided in Figure B-22. During times of predicted high wind events, visual observers will be deployed around the playa to specific vantage points. This includes Red Hill Bay in the South, and the Santa Rosa Mountains in the North. Maps and mobile GIS tools will be used to track plumes and identify locations where emissions are occurring from the playa surface. In addition, video monitoring results will be evaluated after these events to help isolate playa locations where emissions occurred. Meteorological data will be evaluated from all available network locations to determine the magnitude of wind conditions around the playa.

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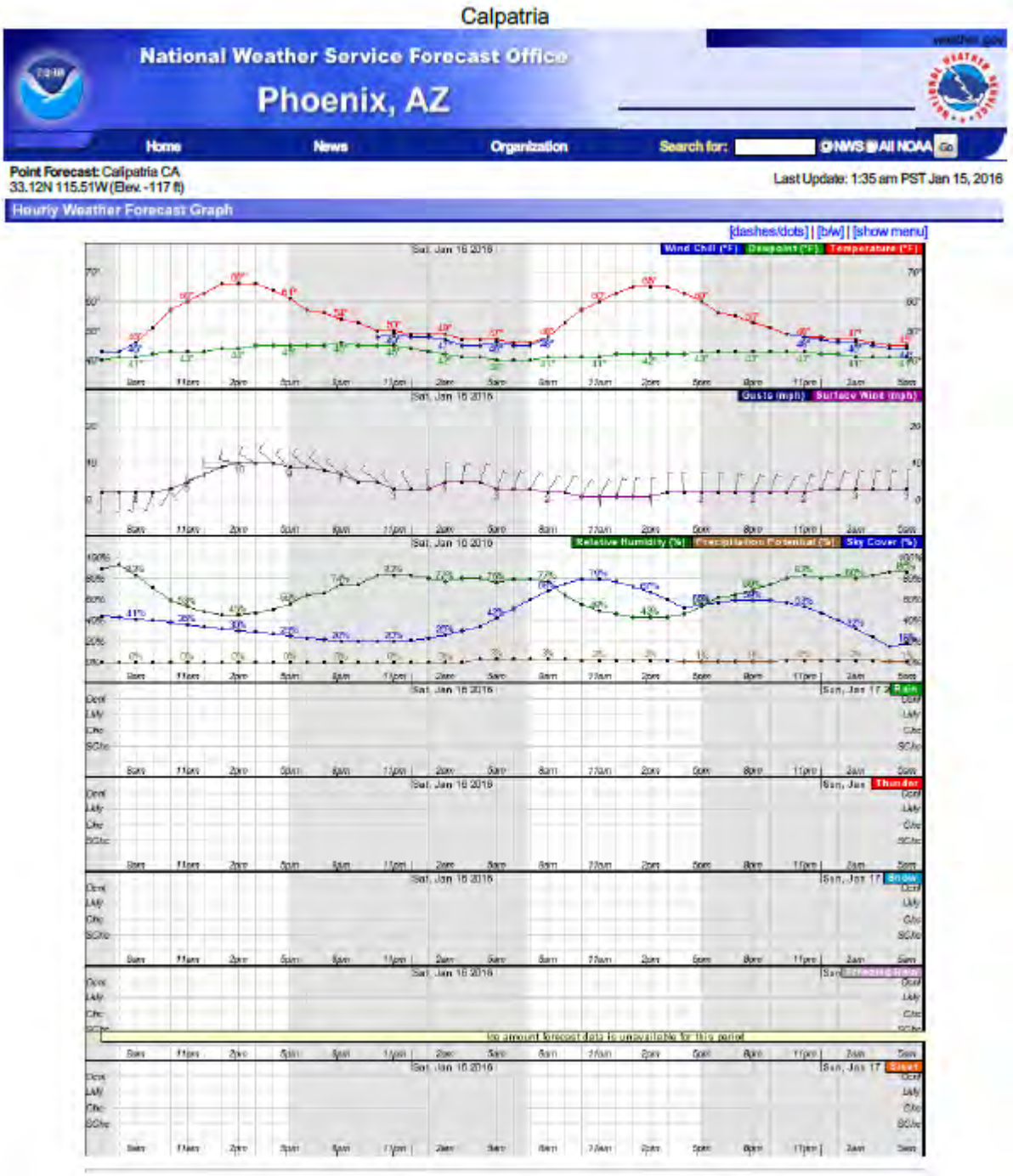
Figure B-22. Example Weather Forecast



B.1.3.3.2.2 Delineating Active Source Areas

Each wind event where visual plume observations occurred on the Playa would also trigger a high-resolution image collection for delineating active source areas. Mapping of specific source areas will be prioritized based on video and/or visual observations of identified plumes. Source areas will be

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identified primarily based on the presence of scoured areas. Scoured surfaces are usually denoted by a topographically low area (in the range of 1-7 cm below surrounding surfaces) with a hard surface.

Routine satellite or UAS imagery will be acquired after high wind events to aid in the field delineation of active source areas. Specifically, imagery will be used as a photo-interpretive base for delineating source areas on the playa. Maps of active source areas will be generated using Collector for ArcGIS with the recently collected imagery in the background. Salt crust units containing large scoured surfaces after high-wind events will be delineated and surface characterization data for those crust types will be recorded in Collector. The surface characterization include: crust type, top crust thickness, top crust hardness, penetration resistance, sub-crust thickness, sub-crust hardness, surface type, boundary type, soil moisture, soil texture, surface sand percent, salt efflorescence, macro-relief, micro-relief, surface erosion and deposition, and vegetative cover (see Table B-1). Photographic evidence will also be collected at each observation point and linked to the GPS location in Collector.

B.1.3.3.3 Reporting

Results of delineating dust plumes and active source areas on exposed playa surfaces will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

B.2 Quantifying PM_{10} Emissions on Exposed Salton Sea Playa

This section describes the procedures used to compute the maximum-day and annual PM_{10} emission estimates for exposed Salton Sea playa.

B.2.1 Maximum-Day PM_{10} Emissions

The Salton Sea playa maximum-day emissions will be computed as follows:

$$E_{Max-Day} = \sum_{n=1}^{N} \left(A_n \cdot \overline{F_{MaxDay,n}} \cdot 9.5\ x\ 10^{-2} \right) \qquad \textbf{Equation B-4}$$

where $E_{Max-Day}$ is the maximum-day mass emissions of PM_{10} (tons per day, tpd) summed for surface types *n=1* through *N* (the maximum number of surface types assigned), A_n is the total area (m^2) within each surface type n, $\overline{F_{MaxDay,n}}$ is an average maximum-day PI-SWERL-derived vertical PM_{10} emission flux (g m^{-2} s^{-1}) by surface type n, and 9.5 x 10^{-2} is a constant of proportionality to convert from seconds to days and from grams to tons of PM_{10}.

The $\overline{F_{MaxDay,n}}$ term in Equation B-4 is parameterized as follows:

1. PI-SWERL sampling is first used to define relationships between the vertical PM_{10} flux, *F*, and u_* for each surface type *n* represented on the exposed playa. The relationships will be determined with curve-fitting algorithms. The form of the equations is not yet known but expected to vary by surface type.

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2. Next, an array of portable, six-meter-tall meteorological stations will be used to produce an array of spatially averaged hourly u_* values by surface type *n* on the playa. The hourly u_* values are then used in the PI-SWERL relationships to derive spatially averaged hourly vertical emission fluxes:

$$\overline{F_{n,h}} = f\left(\overline{u_{*,n,h}}\right) \qquad \textbf{Equation B-5}$$

3. Next, the hourly vertical PM_{10} fluxes are averaged over successive 24-hour periods to produce daily average vertical PM_{10} fluxes by surface type *n* (day index denoted by subscript *d*):

$$\overline{F_{n,d}} = \frac{\sum_{h=1}^{24} \overline{F_{n,h}}}{24} \qquad \textbf{Equation B-6}$$

4. The array of daily vertical PM_{10} fluxes is then queried to identify the day *d* with the highest average vertical PM_{10} flux (i.e., the "maximum-day" flux) for each surface type *n*:

$$\overline{F_{MaxDay,n}} = max \begin{matrix} 365 \\ d = 1 \end{matrix} \Big| \overline{F_{n,d}} \qquad \textbf{Equation B-7}$$

5. These values are then used in Equation C-3 to express the maximum-day mass of PM_{10} emissions within the area of interest (AOI).

6. Maximum-day emissions will be computed using PI-SWERL and CALMET meteorological data collected during the period of investigation.

B.2.2 Annual PM_{10} Emissions

The annual mass of PM_{10} emissions from off-Sea sources is calculated as follows:

$$E_{Annual} = \sum_{n=1}^{N} \sum_{h=1}^{8760} \left(A_n \cdot \overline{F_{n,h}} \cdot 3.97\ x\ 10^{-3}\right) \qquad \textbf{Equation B-8}$$

where E_{Annual} is the annual mass emissions of PM_{10} (tons per year, tpy) for all hours in a year from *h*=1 through 8,760, and for all surface types represented on exposed Salton Sea playa from *n=1* through *N*. Here, A_n is the total area (m^2) for surface type n, $\overline{F_{n,h}}$ is the PI-SWERL-derived vertical PM_{10} emission flux (g m^{-2} s^{-1}) for hour *h* and surface type n, and 3.97 x 10^{-3} is a constant of proportionality to convert from seconds to hours and from grams to tons of PM_{10}.

The total area A_n within surface type *n* will be determined using Geographic Information System (GIS) mapping techniques.

The average hourly vertical emission flux, $\overline{F_{n,h}}$, in Equation B-8 is parameterized as follows:

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$\overline{F_{n,h}} = f\left(\overline{u_{*,n,h}}\right)$ for all *h* satisfying $u_{*,n,h} \geq u_{*t,n}$ **Equation B-9**

where $f\left(\overline{u_{*,n,h}}\right)$ is the PI-SWERL-derived relationship expressing vertical PM_{10} flux (g m^{-2} s^{-1}) as a function of surface friction velocity, u_*, and $u_{*t,n}$ is the threshold friction velocity for surface type *n*. $\overline{u_{*,n,h}}$ is the spatially averaged u_* values located within surface type *n*:

$$\overline{u_{*,n,h}} = \left.\frac{\sum_{s=1}^{S}(a_s \cdot u_{*s})}{\sum_{1}^{S} a_s}\right|_{n,h} \quad \textbf{Equation B-10}$$

where a_s and u_{*s} are the area and u_* values assigned to each portable meteorological station located within surface type *n*.

Annual emissions will be computed using PI-SWERL, u_*, u_{*t}, and active-area data collected during the period of investigation.

B.2.3 Future Emission Inventory Updates

The exposed Salton Sea playa emission inventory will be updated once every three years using the latest standards and best practices available at the time.

B.2.4 Reporting

Results of the emissions inventory will be reported as outlined in Table B-2, Summary of Reporting for Playa Emissions Inventory. Table B-2 is located at the end of Appendix B.

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Table B-2. Summary of Reporting for Playa Emissions Inventory

	Topic	Items to be Reported	Frequency
1	Mapping and Characterizing Playa Surfaces	Results of mapping and characterizing current exposed playa surfaces, and future exposed playa surfaces	Initial report due on or before June 1, 2016. In subsequent years, reports will be generated at the end of each dust season (by June 1st of each year).
2	PI-SWERL Sampling	Results of PI-SWERL monitoring	
3	Meteorological Monitoring	Report summarizing, among other things: hourly wind speed and wind direction data, and collection statistics and results of the quality control review	
4	Video Monitoring	Report summarizing, among other things: days with 10-meter wind speeds above the threshold for dust generation, and a qualitative description of images showing evidence of dust plumes	
5	Delineating Active Plume Areas	Results of active plume delineations	
6	Annual PM10 Emissions	Results summarizing maximum-day and annual PM_{10} emission estimates for exposed playa	

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APPENDIX C – OFF-SEA PM_{10} INVENTORY

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C.1 Experimental Design

This section describes the experimental design of the off-Salton-Sea (off-Sea) PM_{10} (particulate matter less than 10 microns in diameter) emission inventory, including the inventory goal and objectives, approach, data collection and analysis, mapping and characterization of off-Sea surfaces, collection of aerometric data, and delineation of active plume areas.

C.1.1 Goal and Objectives

Similar to the exposed playa PM_{10} emission inventory described in Appendix B, the goal of the off-Sea inventory is to develop a refined estimate of PM_{10} emissions for consideration in the 2016 Revised Imperial County PM_{10} State Implementation Plan (SIP).

The objectives of the off-Sea PM_{10} emission inventory are three-fold:

1. To characterize the magnitude, duration, and frequency of dust emissions from discrete surface strata within the Off-Sea Source Inventory Area of Interest (Off-Sea AOI) shown in Figure 3-14 (main body) of Salton Sea Air Quality Program. The Off-Sea AOI is a 5,805-square-mile area encompassing the Salton Trough and portions of the surrounding mountains, and extending as far south as the United States-Mexico border.
2. To provide greatest focus on the desert areas west of Salton City in and around the Ocotillo Wells State Vehicular Recreation Area (SVRA). PM_{10} roses[9] generated for the period from 2009-2013 show that the highest and most frequent hourly PM_{10} concentrations originate in the desert area west of the Sea. Other parts of the Off-Sea AOI are also important, but of lower priority for this initial inventory effort.
3. To develop a refined estimate of PM_{10} emissions for consideration in the 2016 Revised Imperial County PM_{10} State Implementation Plan (SIP).

Several lines of evidence will be used to establish the location, timing, and magnitude of dust emissions from off-Sea areas, including: (1) PM_{10} roses showing the frequency, magnitude, and direction of the highest PM_{10} concentrations originating in the desert areas west of the Sea; (2) a network of fixed sand motion monitoring instruments placed within various surface types to monitor activity there; (3) video monitoring to provide photographic evidence of dust emissions; and (4) PI-SWERL sampling to characterize the emission potential of various surface types. Element 1 is designed to provide corroborating evidence of emission activity within the Off-Sea AOI. Elements 2 through 4 will be incorporated directly into the maximum-day and annual PM_{10} emission estimates discussed below.

[9] PM_{10} roses are similar to wind roses but, in the case of the former, the "petals" show the frequency, magnitude, and direction of PM_{10} concentrations rather than wind speed.

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C.1.2 Approach

The approach for assessing PM_{10} emissions from current and future off-Sea desert lands is as follows:

1. Map and characterize the desert areas west of the Salton Sea by landform (e.g., sand dunes, alluvial fans, washes) and surface type (e.g., sand, rock-armored surfaces, Paleolithic lake sediments).
2. Sample with the PI-SWERL to characterize the emission potential of each surface stratum at the beginning and end of the investigation (around November 1, 2015, and May 1, 2016).
3. Prioritize the surface strata in terms of emission potential (from high to low) using the PI-SWERL data collected in step 2, above.
4. Install portable sand motion monitoring instruments (including meteorological instruments) on medium- and high-priority surface strata.
5. Deploy portable video monitoring stations around the highest priority surface strata to record the time and location of dust plumes and/or human activity.
6. Quantify maximum day and total annual emissions from active source areas.

Each of these items is discussed in more detail below.

C.1.3 Data Collection and Analysis

This section describes data collection and analysis for mapping and characterizing off-Sea surfaces, for aerometric data, and for delineating active plume areas.

C.1.3.1 Mapping and Characterizing Surfaces

This section describes the mapping and characterization of off-Sea surfaces.

C.1.3.1.1 Objectives

The objective of the off-sea mapping effort is to quantify the extent and characteristics of the landforms and surface types found within the desert areas west of the Salton Sea. This information will be used to guide and scale the PM_{10} emission potential of distinct landforms sampled with the PI-SWERL (see Section C2).

C.1.3.1.2 Methods

This section described the methods to characterize landform classes and to map landforms.

C.1.3.1.2.1 Landform Classes

A surface type classification system was developed in order to quantify the dominant Off-Sea landforms and their characteristics (surface, vegetation, and armoring). The classification system was created by researching the desert surfaces present in the region, targeted field investigations, and the photointerpretation of satellite imagery. The surface types used in this classification system are detailed in Table C-1 and Figures C-1 through C-4.

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Preliminary field data to develop the classification system was collected using the ESRI Collector App on a ruggedized tablet. Imagery and field domains were pre-loaded onto tablets before use. This interface allowed the seamless collection of geo-referenced field points, photos, and notes. Data collected using the Collector App was then synced to Arc GIS Online (AGOL) and is available to all Team members as documentation of ground truth for further mapping efforts.

Table C-1. Surface Types used to Characterize Off-Sea Landforms

Class	Sub-Class	Description	Erosion Risk
1-Dry Wash Units	Sand Dominated	Ephemeral drainage dominated by well sorted, fine to coarse grained sand.	High
	Silt Dominated	Ephemeral drainage dominated by silt. Undisturbed silt found in dry washes is often present as a fragile thin mud-cracked sheet.	High
	Gravel Dominated	Ephemeral drainage dominated by gravel.	Low
	Gravel and Sand	Ephemeral drainage consisting of gravel evenly distributed among a sandy matrix. Poor to moderately sorted. The upper surface often has been coarsened by wind erosion and/or OHV activity.	Medium
	Gravel and Silt	Ephemeral drainage consisting of gravel evenly distributed among a silty matrix. Poor to moderately sorted. The upper surface often has been coarsened by wind erosion and/or OHV activity.	Medium
2-Alluvial Fan Units	Sand Dominated	Alluvial fan deposits consisting of primarily sand. Typically located near the periphery of the fan.	High
	Sand and gravel	Alluvial sand capped by gravel lag. Typically located near the middle of the fan.	Medium
	Cobbles	Alluvial fan deposits consisting of sand, gravel, and cobbles. Typically located near the top of the fan.	Low
3-Sand Units	Sand Dunes	Active aeolian dune and erosional interdune surface. Large asymmetrical, elongated Transerve dunes are the most common in this region. Dunes are > 1.5 M and typically fine to medium grained.	High
	Sand Sheet	Active aeolian deposit. Flat to low angle, uniform, expansive sand surface. Typically fine to medium grained.	High
	Sand over Alluvium	Sand sheets and coppice dunes < 1.5 m in height superimposed on alluvium. Coppice dunes are small vegetated sand mounds that form when a shrub impedes the flow of air and causes sand grains to settle out on the downwind side of the shrub.	High
4-Paleo Lakebed	Silt-Dominated	Well sorted lacustrine silt deposits from pre-historic Lake Cahuilla.	High
	Cobble over Silt	Large Cobbles regularly distributed among silt situated along the margin of pre-historic Lake Cahuilla. The cobbles serve as armory for the vulnerable underlying silt. The cobbles were deposited by wave action from Lake Cahuilla.	Medium
	Gravel and Sand	A mixture of gravel and sand present on old beach ridges formed by wave action.	Low
6-Rock Units	Sandstone	Highly friable, heavily eroded sandstone. Often taking the form of steep gulleys.	Medium
	Bedrock	Undifferentiated bedrock. A consolidated hard surface that is not emissive.	Very Low

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Class	Sub-Class	Description	Erosion Risk
7-Offshore Playa Unit	Offshore Playa	Independent depressions that once held water and now have formed evaporites among very delicate mud-cracked silt. The underside of the mud cracks has a distinct micaceous sheen.	High

Figure C-1. (A) Sand-Dominated Dry Wash with Heavy OHV Traffic, and (B) Gravel- and Sand-Dominated Alluvial Fan

A. Sand-Dominated Dry Wash with Heavy OHV Traffic



B. Gravel- and Sand-Dominated Alluvial Fan



Figure C-2. (A) Large Sand Sheet, and (B) The Algodones Dune Field

A. Large Sand Sheet



B. The Algodones Dune Field



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Figure C-3. (A) Cobbles Distributed Over Silt-Dominated Paleo Lakebed, and (B) Silt-Dominated Paleo Lakebed

A. Cobbles Distributed over Silt-Dominated Paleo Lakebed



B. Silt-Dominated Paleo Lakebed



Figure C-4. (A) Sandstone Bedrock, and (B) Offshore Playa

A. Sandstone Bedrock



B. Offshore Playa



C.1.3.1.2.2 Landform Mapping

Landforms will be spatially quantified/mapped using a mixture of the field ground truth data mentioned above, photo-interpretation of satellite imagery, and Object Based Imagery Analysis techniques (OBIA). NAIP satellite imagery will be segmented using Trimble eCognition. Pixels within the imagery that share common characteristics will be bundled together to create objects that delineate the landforms. Using the ground truth data, samples will be selected from these objects and classified according to their landform classification (Table C-1). This will be accomplished by consulting the imagery, a Digital Elevetion Model (DEM), and the field ground truth data. Once a reasonable distribution of samples have been collected across the different landforms, they will then be used as training data to inform the random forest data mining classification. The output of the random forest data mining classification is a spatial map depicting the major landforms. This output will be manually reviwed for quality control and

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additional ground data will be collected to determine the accuracy / uncertainty associated with the final mapping product.

Vegetative cover within the off-sea area will be extracted from a natural color, 1 foot spatial resolution aerial imagery collected in 2011. This will be combined with NAIP high resolution 4 band aerial imagery collected in 2012. The NAIP imagery provides additional detail in the Near Infrared region (which is sensitive to vegetation photosynthesis), while the 1 foot natural color imagery will be used to delineate the edges of the vegetation structure. An example of the vegetation extraction for a portion of the off-sea area is provided in (Figure C-5). Results of the vegetation extraction process will be aggregated to a 1 acre grid to calculate an area weighted average percent cover on a conitinuous scale.

Final results of the landform mapping will be summarized in the final off-Sea inventory documentation.

C.1.3.1.3 Reporting

Results of mapping and characterizing off-Sea surfaces will be computed and reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

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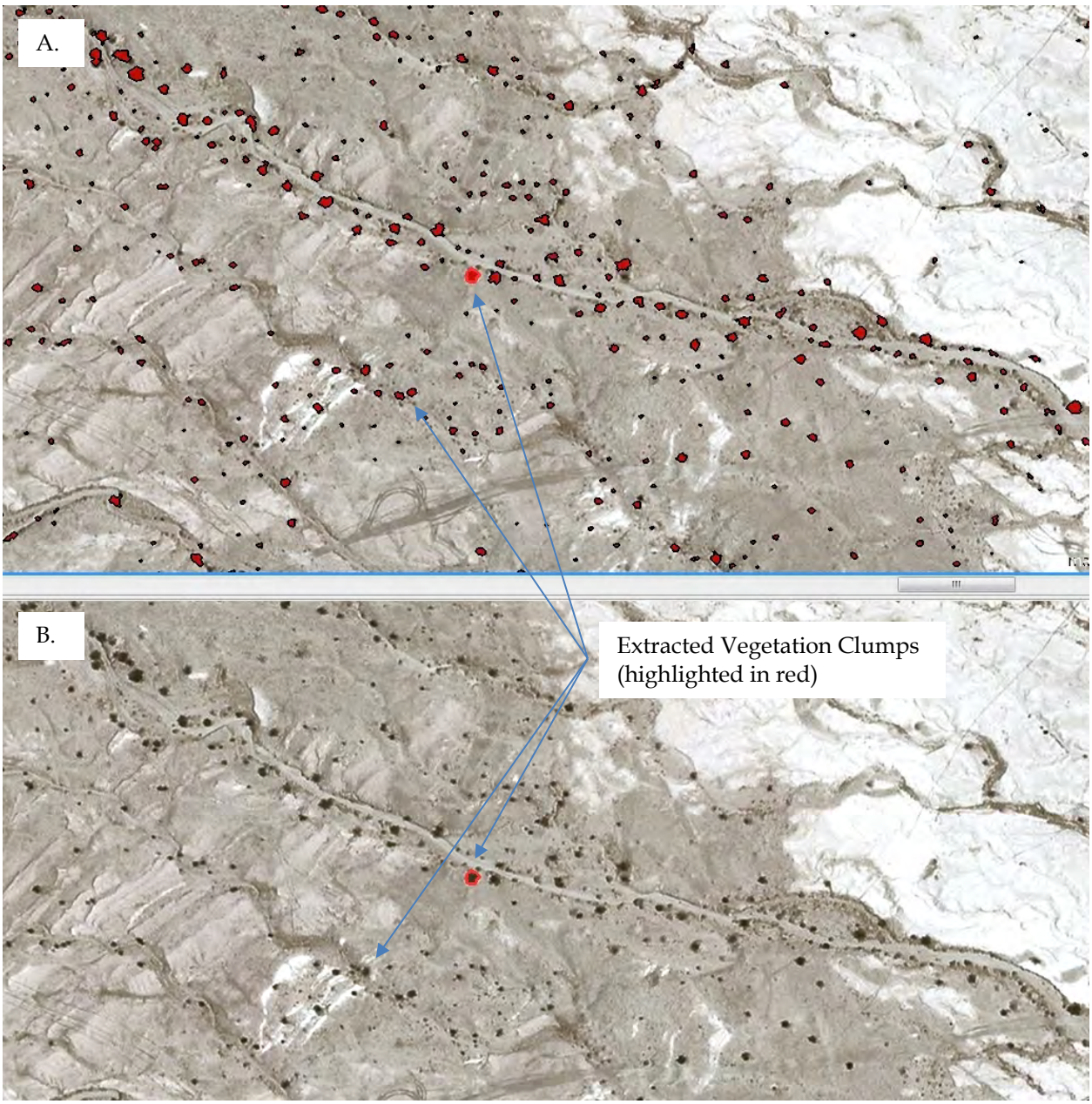
Figure C-5. Example Vegetation Extraction for a Portion of the Off-Sea Area



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C.1.3.2 Aerometric Data

This section describes the aerodynamic data collection activities that will occur as part of the PM_{10} inventory for off-Sea sources.

C.1.3.2.1 PI-SWERL Sampling

The PI-SWERL sampling objectives, sampling locations and frequency, instrumentation, operation and maintenance procedures, analysis, and reporting activities are described in the following sections.

C.1.3.2.1.1 Objectives

The objective of PI-SWERL sampling is to characterize the PM_{10} emission potential of distinct landforms and surface types found within the desert areas west of the Salton Sea. These surfaces include, but are not limited to: alluvial fans with flood silt channels and deposits, stably vegetated sand dunes, actively migrating sand dunes, and sand sheets with various degrees of rock armoring, among others. The vulnerability of desert surfaces to wind erosion is not expected to change seasonally, at least not to the extent expected on exposed playa surfaces where salt mineralogy and crystal habit is being influenced by changing temperature and moisture conditions (Buck et al. 2011). Modest seasonal differences may be observed on desert surfaces, particularly after flash flood events on the alluvial fans and flood silt deposition areas, but even in these cases the emission potential is expected to return to earlier, roughly equilibrium conditions after a relatively short period of drying.

The results of the PM_{10} sampling will be used to assign the emission potential of various surfaces. Surfaces with medium to high emission potential will then be targeted for more extensive sand flux and meteorological monitoring.

C.1.3.2.1.2 Sampling Locations and Frequency

PI-SWERL sampling will be performed on up to 17 distinct surface types found in the desert areas west of the Salton Sea. These are presented below in Table C-2 (condensed version of Table 3-4 in the main body of the Salton Sea Air Quality Program).

Of these major surface types, four are considered to be non-emissive and as such will be excluded from the PI-SWERL sampling. The exclusions apply to: Types 3, 8, 14, and 16. These sites are gravel-, cobble-, or bedrock-dominated surfaces with low overall erosion risk. The 13 remaining surface types have a significant component of sand and silt and will be included in the PI-SWERL sampling.

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Table C-2. Major Surface Types Found in Desert Area West of the Salton Sea

Type Number	Description	Erosion Risk*
1	Dry wash, sand dominated	High
2	Dry wash, silt dominated	High
*3***	*Dry wash, gravel dominated*	*Low*
4	Dry wash, gravel and sand	Medium
5	Dry wash, gravel and silt	Medium
6	Alluvial fan, sand dominated	High
7	Alluvial fan, sand and gravel	Medium
*8***	*Alluvial fan, cobbles*	*Low*
9	Sand dunes	High
10	Sand sheet	High
11	Sand over alluvium	High
12	Paleo lakebed sediments, silt dominated	High
13	Paleo lakebed sediments, cobble over silt	Medium
*14***	*Paleo lakebed sediments, gravel and sand*	*Low*
15	Rock, sandstone	Medium
*16***	*Rock, bedrock*	*Very Low*
17	Offshore playa	High

* Overall risk of erosion from wind and water combined with vehicular traffic. This is not the same as the "emission potential" being evaluated with the PI-SWERL.
** Excluded from PI-SWERL sampling because of low expected emission potential.

A total of 130 PI-SWERL sampling sites will be selected in the field for the initial PI-SWERL investigation, including: 13 surface types, 2 separate geographic locations, and 3-5 replications for each combination of surface type and location (13 surface types x 2 locations x 5 replications = 130 samples per event). The estimated sampling time in the field is 40 hours, including site-to-site travel time and assuming a production rate of 36 PI-SWERL samples per day. Individual sampling sites will be selected from relatively large, uniform areas characterized by each of the targeted surface types.

PI-SWERL sampling will be performed twice during the initial study phase: once in November 2015, and again in March 2016.

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C.1.3.2.1.3 Instrumentation

Required instrumentation includes the PI-SWERL apparatus, described below. Labeled diagrams of the PI-SWERL apparatus are found in Appendix D.1, Standard Operating Procedures: PI-SWERL.

Development of the PI-SWERL (Figure C-6) by Victor Etyemezian and others at the Desert Research Institute (DRI) in Reno, Nevada, was motivated by a need for a portable device to test and measure the potential for wind erosion and dust emissions from real-world surfaces. Large wind tunnels, the conventional mode of measurement prior to the PI-SWERL, required long setup times and often a team of people to operate. In comparison, the PI-SWERL is easy to move, requires minimal setup time, and can be operated by a single person.[10] A prototype was developed in 2000 and tested alongside the University of Guelph's large wind tunnel in Guelph, Ontario, Canada. This testing provided early indication of the feasibility of the PI-SWERL concept. Since then, several models have been used in many field investigations, including measuring emission potential on Owens Lake and Salton Sea playas.

Figure C-6. PI-SWERL Apparatus

The PI-SWERL uses a tri-wheeled buggy to transport the instrument and all supporting components. This photograph shows an Air Sciences Inc. crew member sampling surface emission potential at Area T23 on the Owens Lake playa, California.



[10] For safety and efficiency, two-person teams are recommended.

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The PI-SWERL comprises an open-bottomed, cylindrical chamber operated by a direct-current motor that spins an annular metal ring about 2.5 inches above and parallel to the soil surface. Principles of fluid mechanics allow simulation of high winds and ground-level turbulence that typically produce dust emissions. The spinning ring creates known wind shear, lofting soil and dust particles and passing them through particulate monitors. The PI-SWERL electronically measures the number and size of entrained particles over the duration of a test cycle, typically less than 10 minutes. By controlling the speed of the ring to simulate varying wind speeds, the potential for a soil surface to produce PM_{10} dust emissions can be determined under a range of simulated wind conditions.

The PI-SWERL-derived PM_{10} and sand flux compared favorably to standard laboratory measurements in two separate calibration studies sponsored by the Los Angeles Department of Water and Power (LADWP). In 2011, the PI-SWERL PM_{10} flux using a DustTrak was calibrated against the gravimetric PM_{10} flux at DRI's laboratory in Reno, Nevada (Gillies and Zhou 2012). Overall, the DustTrak-to-gravimetric PM_{10} flux relationships were excellent with regression coefficients (R^2) between 0.85 and 0.99.

In a separate investigation in 2012, PI-SWERL particle counts based on an Optical Gate Sensor (OGS) were calibrated against the measured sediment flux at the University of Guelph's 1.2-meter wind tunnel (Nickling 2012). Very strong ($R^2 > 0.93$) linear relationships were found between the measured sediment flux and the OGS counts for laboratory sand and for two of the Owens Lake soils (located at Study Area 3 and Lizard Tail). A much lower ($R^2 = 0.4256$), but still statistically significant, linear relationship at the 95 percent confidence level was associated with Cottonwood soils.

C.1.3.2.1.4 Operations and Maintenance Procedures

Appendix D.1, Standard Operating Procedures: PI-SWERL, describes the PI-SWERL operation and maintenance activities (including precautions), start-up and operating procedures, periodic cleaning and maintenance procedures, and records management (including use of the SWERLView software).

C.1.3.2.1.5 Analysis

The analysis procedures for the off-Sea PI-SWERL data are the same as those described earlier in Appendix B for exposed playa surfaces (see Section B.1.3.2.1.5). The relationships developed between vertical PM_{10} flux and surface friction velocity are used in Section C.2 to calculate maximum day and annual PM_{10} emission rates.

C.1.3.2.1.6 Reporting

PI-SWERL results will be computed and reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

C.1.3.2.2 Sand Flux Monitoring

The sand flux monitoring objectives, sampling locations and frequency, instrumentation, operation and maintenance procedures, analysis, and reporting activities are described in the following sections.

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C.1.3.2.2.1 Objectives

Sand flux data will be used in the off-Sea emission inventory to compute the vertical PM_{10} emission rates based on measured horizontal sand fluxes and PI-SWERL-generated K-factors[11] (see Sections C.2.1.1 and C.2.2.1 of this document).

C.1.3.2.2.2 Sampling Locations and Frequency

The numbers and locations of sand flux monitoring sites will be determined after the initial PI-SWERL sampling is complete and the various surfaces have been prioritized in terms of emission potential. For planning purposes, 18 off-Sea sand flux monitoring sites have been budgeted. Once installed, the sand flux instruments will be operated continuously for the duration of the project.

C.1.3.2.2.3 Instrumentation

Sand flux will be estimated using a combination of Cox Sand Catchers (CSCs) and Sensits. CSCs are passive collection instruments that capture windblown sand and sand-sized particles. The CSC is composed of a 6-cm-diameter PVC tube mounted vertically in the ground (Figure C-7 and Figure C-8). CSCs were designed and constructed by the Great Basin Unified Air Pollution Control District as a simple, easy-to-use instrument capable of withstanding the harsh conditions on Owens Lake. CSCs have no moving parts and can collect sand for a month or more without overloading its storage capacity. Field personnel visit CSC sites to measure the mass of the collected sand catch.

[11] $K = F/Q$, where F is the vertical PM_{10} emission flux (g cm^{-2} s^{-1}) and Q is the horizontal sand flux (g cm^{-2} s^{-1}).

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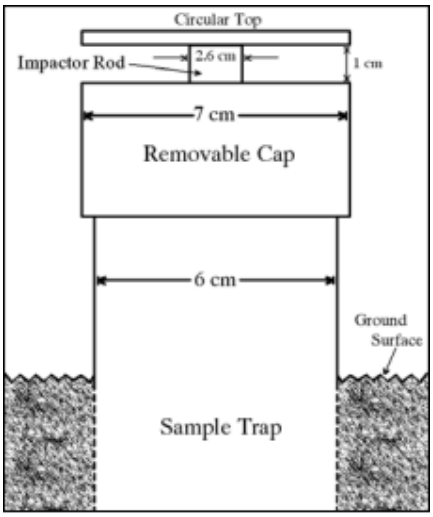
Figure C-7. Schematic Diagram of Cox Sand Catcher



Courtesy of Great Basin Unified Air Pollution Control District

Figure C-8. Photograph of Cox Sand Catcher



Courtesy of Great Basin Unified Air Pollution Control District

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Sensits are passive, real-time electronic sensors that measure the kinetic energy or the particle counts of sand-sized particles as they *saltate*, or leap, across the surface under high winds. Sensits are used to time-resolve the CSC mass (g collection period^{-1}) into estimates of hourly sand flux (g cm^{-2} hr^{-1}). The Sensit collection surface is a highly sensitive piezoelectric ring that records striking particles in one of two ways: as a particle count (PC; total number of particle strikers per unit time), or as kinetic energy (KE; cumulative kinetic energy of striking particles per unit time). In general, PC is more stable and therefore more useful than KE because its signal does not saturate as readily as KE under very high saltation sand masses. For this reason, PC will be the primary basis for apportioning the CSC sand masses into one-hour sand fluxes. KE will be used only if the PC data are not of sufficient quantity to correctly apportion the masses. Several quality control graphs will be generated, including: (1) $\log_{10}$(PC) versus $\log_{10}$(KE); (2) $\log_{10}$(PC) and $\log_{10}$(KE) as a function of time; and (3) $\log_{10}$(PC) and $\log_{10}$(KE) as a function of wind speed.

CSCs and Sensits will be co-located at each site and positioned with their sensing surfaces at 15 cm above the local ground level. This is designed to record the movement of high-energy soil particles moving across the soil surface during high-wind events.

Figure C-9 shows a Sensit suspended above the ground on the right, and a CSC mounted in the ground on the left. A datalogger will record 5-minute Sensit data during active saltation periods. Data collection will be triggered by particle count activity and will continue until particle counts are zero for an hourly period. Each datalogger will have a radio transmitter that will send Sensit data to the IID's field office once a day to provide updates on erosion activity at each site. These daily updates will be used to alert field personnel to active source areas for possible Global Positioning System (GPS) mapping and inspection. Daily transmission of the data may be temporarily suspended if the solar battery power is low due to extended days of cloud cover.

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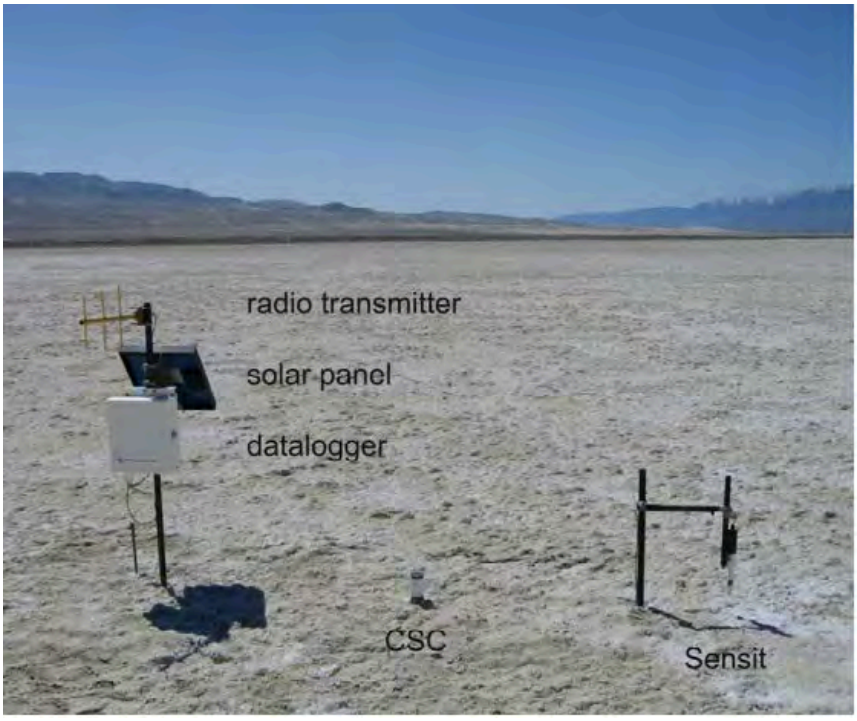
Figure C-9. Example of Sand Flux Monitoring Site



C.1.3.2.2.4 Operation and Maintenance Procedures

Operation and maintenance of the sand flux instruments is described in Appendix D.2, Standard Operating Procedures: Sand Flux and Meteorological Monitors. Topics in Appendix D.2 include: principles of operation, safety precautions, sampling interferences, site location and installation, CSC sample collection procedure, and others.

Sand will be collected from the CSC tubes at least once a month. Additional collections will be made after larger wind events if Sensit activity indicates that the CSC might be close to full.

The tubes will be labeled with the site ID number and date and transported to the IID's Salton City Field Office for drying, weighing, and recording. IID will make the sand mass data available to ICAPCD (or other interested agencies) if requested.

Each Sensit's own datalogger will record sand flux data as one-hour totals via electronic signal. The Sensit dataloggers will be programmed using IID's customized script and equipped with radio modems linked to IID's Salton City Field Office. Within a geographic area, individual Sensits will transmit to a single radio relay modem, which in turn will transmit to the IID field office. At the same time the sand masses are collected, the data from the associated Sensits will be downloaded in the field to a laptop computer. The laptop data will be then uploaded and stored on IID and Air Sciences servers for later quality control checks and data analysis. The raw (i.e., pre-quality control) Sensit data collected during the manual download will be provided to IID as part of the monthly reporting.

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C.1.3.2.2.5 Analysis

Hourly sand fluxes will be calculated for each Sensit/CSC site by multiplying the collection-period ratio of sand mass to Sensit response by the hourly Sensit response (either PC or KE).

If PC is used to time-apportion the CSC sand masses, the hourly sand fluxes (g cm^{-2} hr^{-1}) at site *n* and hour *t* will be calculated as follows:

$$q_{n,t} = \left(S'_{n,t}\right) \cdot \left[\frac{CSC_{n,p}}{\sum_{t=1}^{N}\left(S'_{n,t}\right)}\right] \cdot \frac{1}{1.2} \qquad \textbf{Equation C-1}$$

where

$S'_{n,t}$ = Sensit total PC for site *n* and hour *t* (dimensionless)

$CSC_{n,p}$ = CSC mass for site *n* and collection period *p* (grams)

N = Total number of hours in CSC collection period *p*

Note that the hourly sand flux is divided by 1.2 cm^2, which is the CSC equivalent inlet opening size for flux calculation purposes.

If KE is used to time-apportion the CSC sand masses, the hourly sand fluxes (g cm^{-2} hr^{-1}) at site *n* and hour *t* will be calculated as follows:

$$q_{n,t} = \left(S_{n,t} - S_{n,bg}\right) \cdot \left[\frac{CSC_{n,p}}{\sum_{t=1}^{N}\left(\left(S_{n,t} - S_{n,bg}\right)\right)}\right] \cdot \frac{1}{1.2} \qquad \textbf{Equation C-2}$$

where

$S_{n,t}$ = Sensit total KE reading for site *n* and hour *t* (dimensionless)

$S_{n,bg}$ = Sensit KE background reading for site *n* (dimensionless)

C.1.3.2.2.6 Reporting

Reports summarizing, among other things, the CSC sand mass and Sensit response data, collection statistics and results of the quality control inspection, and calculated hourly sand flux will be reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

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C.1.3.2.3 Meteorological Monitoring

This section describes the off-Sea emission inventory meteorological monitoring objectives, instrumentation, sampling locations and times, instrument operation and maintenance procedures, analysis, and reporting.

C.1.3.2.3.1 Objectives

Meteorological data will be used in the off-Sea emission inventory in two ways: (1) as input data for the CALMET meteorological modeling analysis used to estimate vertical PM_{10} flux as a function of surface friction velocity, and (2) as input data for the CALPUFF dispersion modeling analysis to evaluate "hotspot" impacts at Salton Sea PM_{10} compliance monitors.

C.1.3.2.3.2 Instrumentation

The meteorological instrumentation is the same as that described in Appendix B, Section B.1.3.2.2.2.

C.1.3.2.3.3 Sampling Locations and Frequency

One 6-meter-tall meteorological tower will be installed at each of the 18 proposed off-Sea sand flux monitoring sites described in Section C.1.3.2.2.2 above. The sites will be determined later, after the initial PI-SWERL sampling and subsequent prioritization of surfaces by emission potential is complete.

C.1.3.2.3.4 Operation and Maintenance Procedures

Operation and maintenance of the meteorological instruments is described in Appendix D.2, Standard Operating Procedures: Sand Flux and Meteorological Monitors. Appendix D.2 includes: site check and audit forms, data processing and quality assurance/quality control (QAQC) procedures, and calibration and audit procedures for the Met One 014A wind speed and Met One 024A wind direction sensors.

C.1.3.2.3.5 Analysis

For the playa inventory, the meteorological data will be used to calculate the hourly surface friction velocity (u_*) and roughness length (z_0) by fitting the hourly average wind velocity (x axis) against height above ground (y axis) on a log-log scale. The slope of the line is u_* and the y-intercept is z_0. For the off-Sea inventory, however, the hourly wind speed and wind direction data will be used in the CALMET meteorological model[12] to produce gridded fields of surface friction velocity with inputs of fixed-point meteorological data and gridded inputs of terrain elevation, land use category, and (optionally) surface roughness length, albedo, and vegetation leaf area index, among others.

As discussed later, the gridded hourly u_* values will be used to calculate hourly vertical PM_{10} emission fluxes using the relationships between PM_{10} emission flux and u_* derived from PI-SWERL sampling (see Sections C.2.1.1 and C.2.2.1).

12 http://www.src.com/calpuff/download/CALMET_UsersGuide.pdf

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C.1.3.2.3.6 Reporting

Reports summarizing, among other things, hourly wind speed and wind direction data, collection statistics, and results of the quality control review will be reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

C.1.3.2.4 Video Monitoring

This section describes the off-Sea desert area video monitoring objectives, equipment and monitoring locations, image collection rates, operation and maintenance procedures, image analysis procedures, and reporting.

C.1.3.2.4.1 Objectives

Video monitoring serves several useful purposes:

1. To document the locations of active dust sources in the desert areas west of the Salton Sea.

2. To document the location, frequency, and relative intensity of dust plumes originating at those locations.

3. To document the frequency and relative intensity of dust plumes traveling into and across the off-Sea desert area from sources farther upwind.

C.1.3.2.4.2 Equipment and Monitoring Locations

Video monitoring in the off-Sea desert areas will be performed with a network of 8 portable camera systems scattered around the desert area west of the Salton Sea. The cameras will be sited such that each AOI is observed by at least two cameras with fields of view (FOV) perpendicular to each other to facilitate qualitative analysis of plume activity. Historical wind patterns will be employed to ensure that the cameras are sited upwind of the most frequent wind directions with average wind speeds greater than 5 meters per second at a height of 10 meters above ground.

The portable video camera systems will be equipped with the StarDot Corporation 10-megapixel (MP) H.264d Special Bundle, which includes a StarDot 10MP SC day/night camera (see Figure B-21) with Dotworkz ST-BASE outdoor enclosure, Veracity Power-over-Ethernet (PoE) injector, and Tripp Lite outdoor-rated 100-foot patch cable.[13] In addition, each site will be equipped with an 8–48-millimeter vari-focal lens, providing a 4.5°–45° FOV that may be adjusted according to specific site conditions. As many as possible of the 8 cameras will be installed on 30-meter cellular towers to minimize equipment costs. The remaining cameras will be mounted above the permiter fence on a tripod (similar to the 6-meter-tall tower shown in Figure B-17).

For added security, each video monitoring station not mounted on a cellular tower may be surrounded by a 10-foot-square by 10-foot-tall cyclone fence enclosure with a locking gate.

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[13] http://californiapc.com/IP-Cameras-Enclosures-Lenses-Accs/StarDot-NetCam-Bundles/

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C.1.3.2.4.3 Image Collection Rates

The StarDot cameras will be operated during daylight hours only. One still-frame image will be captured and stored every 15 minutes, with all cameras on the same collection schedule to facilitate analysis.

C.1.3.2.4.4 Operation and Maintenance Procedures

Operation and maintenance of the video monitoring stations are described in Appendix D.3, Standard Operating Procedures: Roundshot Livecam D2 and in Appendix D.4, Standard Operating Procedures: StarDot Technologies SC H.264. Each of these appendices includes installation and operation procedures, and site check forms, for the Roundshot camera system (fixed stations) and the StarDot camera system (portable stations), respectively.

C.1.3.2.4.5 Image Analysis Procedures

In the laboratory, the folder of still images will be filtered to include those taken on days when wind speeds exceed the threshold for dust generation (nominally, more than four hours with average wind speeds greater than 5 meters per second at a height of 10 meters above ground). The filtered images will then be used to qualitatively assess the location, frequency, and magnitude of dust plumes originating in the desert area west of the Salton Sea.

Since the AOIs will be covered by at least two cameras with perpendicular FOV capturing images simultaneously, an estimate of plume location and height can be determined with triangulation. An azimuth/elevation angle grid will be developed for each camera FOV. An analyst will review an image of interest to determine the azimuth angles of both sides of plumes in the image; the same will be done for an image viewing the same AOI from a different angle. The intersection of the plume extent "rays" from both images will identify the approximate locations and sizes of the plumes. Once the triangulated position is determined, the height of each plume can be determined using the elevation angle.

C.1.3.2.4.6 Reporting

Reports summarizing, among other things, days with 10-meter wind speeds above the threshold for dust generation, and a qualitative description of images showing evidence of dust plumes will be reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

C.2 Quantifying PM_{10} Emissions from Off-Sea Desert Areas

This section describes the procedures used to compute the maximum-day and annual PM_{10} emission estimates for source areas located in the off-Sea desert areas located west of the Salton Sea.

C.2.1 Maximum-Day PM_{10} Emissions

Maximum-day emissions will be computed by one of two methods: surface friction velocity, and horizontal sand flux. Each of these methods is described below.

For both methods, the maximum-day PM_{10} emissions will be computed using the following equation:

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$$E_{Max-Day} = \sum_{n=1}^{N} \left(A_n \cdot \overline{F_{MaxDay,n}} \cdot 9.5\ x\ 10^{-2} \right)$$ **Equation C-3**

where $E_{Max-Day}$ is the maximum-day mass emissions of PM_{10} (tons per day, tpd) summed for surface types *n=1* through *N* (the maximum number of surface types assigned), A_n is the total area (m^2) with each surface type n, $\overline{F_{MaxDay,n}}$ is an average maximum-day PI-SWERL-derived vertical PM_{10} emission flux (g m^{-2} s^{-1}) by surface type n, and 9.5 x 10^{-2} is a constant of proportionality to convert from seconds to days and from grams to tons of PM_{10}.

The two methods differ in how $\overline{F_{MaxDay,n}}$ is parameterized. The surface friction velocity method uses CALMET meteorological modeling to generate gridded u_* estimates across the meteorological domain in conjunction with PI-SWERL-derived relationships expressing vertical PM_{10} emission flux as a function of u_*. The horizontal sand flux method uses PI-SWERL-generated *K*-factors[14] for various surfaces of interest, multiplied by location-specific horizontal sand flux, *Q*, to compute location-specific vertical PM_{10} fluxes.

With either method, the hourly PM_{10} fluxes are summed over time and space to estimate the maximum-day emission estimates for the off-Sea AOI.

C.2.1.1 Surface Friction Velocity Method

The procedure for parameterizing $\overline{F_{MaxDay,n}}$ in Equation C-3 is as follows. First, PI-SWERL sampling is used to define the relationship between *F* and u_* for each of the surface types *n* represented in the AOI. The relationships will be determined later with curve fitting algorithms.

The CALMET meteorological model is then used to produce a three-dimensional array (two spatial variables plus time) of gridded hourly u_* values within the off-Sea AOI. The gridded u_* values are subsequently aggregated by surface type *n* and averaged to produce a two-dimensional array (surface type and time) of $\overline{u_{*,n,h}}$ values. The spatially averaged u_* values are then used in the PI-SWERL relationships to derive spatially averaged hourly vertical emission fluxes:

$$\overline{F_{n,h}} = f\left(\overline{u_{*,n,h}}\right)$$ **Equation C-4**

In the final steps, the hourly values are averaged over successive 24-hour periods to produce daily average vertical PM_{10} fluxes by surface type *n* (day index denoted by subscript *d*):

$$\overline{F_{n,d}} = \frac{\sum_{h=1}^{24} \overline{F_{n,h}}}{24}$$ **Equation C-5**

The array of daily vertical PM_{10} fluxes is then queried to identify the day *d* with the highest average vertical PM_{10} flux (i.e., the "maximum-day" flux) for each surface type *n*:

[14] *K = F/Q*, where *F* is the vertical PM_{10} emission flux (g cm^{-2} s^{-1}) and *Q* is the horizontal sand flux (g cm^{-2} s^{-1}).

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$$\overline{F_{MaxDay,n}} = max_{d=1}^{365} \left| \overline{F_{n,d}} \right| \qquad \textbf{Equation C-6}$$

These values are then used in Equation C-3 to express the maximum-day mass of PM_{10} emissions within the AOI.

Maximum-day emissions will be computed using PI-SWERL and CALMET meteorological input data for a one-year period.

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C.2.1.2 Horizontal Sand Flux Method

With the horizontal sand flux method, the spatially averaged hourly vertical emission flux, $\overline{F}$, is the product of the spatially averaged hourly horizontal sand flux, $\overline{Q}$, and the PI-SWERL-derived K-factor,[15] K_f , for each surface type *n* and hour *h*:

$$\overline{F_{n,h}} = \overline{Q_{n,h}} \cdot \overline{K_{f,n}} \qquad \textbf{Equation C-7}$$

Here, $\overline{Q_{n,h}}$ is the spatially averaged hourly horizontal sand flux for all sand motion monitoring stations within surface type *n* (g m^{-2} s^{-1}), and $\overline{K_{f,n}}$ is the spatially averaged K_f for all PI-SWERL monitoring sites within surface type *n*.

The hourly values are then averaged over successive 24-hour periods to produce daily average (denoted by subscript *d*) vertical PM_{10} fluxes by surface type *n*:

$$\overline{F_{n,d}} = \frac{\sum_{h=1}^{24} \overline{F_{n,h}}}{24} \qquad \textbf{Equation C-8}$$

The maximum-day vertical emission flux, $\overline{F_{MaxDay,n}}$, is then computed by scanning all days to find the maximum value of $\overline{F_{n,d}}$. This procedure will be performed for all days of the year, from *d* = 1 through 365:

$$\overline{F_{Max-Day,n}} = max_{d=1}^{365} \left| \overline{F_{n,d}} \right. \qquad \textbf{Equation C-9}$$

The total area within surface type *n* will be determined using Geographic Information System (GIS) mapping techniques.

C.2.2 Annual PM_{10} Emissions

Annual emissions will be computed using the same two methods described in the previous section: the surface friction velocity method, and the horizontal sand flux method.

For both methods, the equation used to compute the annual mass of PM_{10} emissions from off-Sea sources is as follows:

$$E_{Annual} = \sum_{n=1}^{N} \sum_{h=1}^{8760} \left(A_n \cdot \overline{F_{n,h}} \cdot 3.97\ x\ 10^{-3} \right) \qquad \textbf{Equation C-10}$$

where E_{Annual} is the annual mass emissions of PM_{10} (tpy) for all hours in a year from *h*=1 through 8,760, and for all surface types represented with the AOI from *n=1* through *N*. Here, A_n is the total area (m^2)

[15] Wind tunnel calibrations of *F* and *Q* reported in: Nickling, W. G. 2012. 2011 PI-SWERL Research Study, Final Report, Owens Lake Dust Mitigation Program, Agreement No. 300-1-SUB7, Task Order No. 300-10. Prepared for Air Sciences Inc., Golden, CO, by W. G. Nickling, Nickling Environmental Ltd., Cambridge, ON, Canada. 58 pp.

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for surface type n, $\overline{F_{n,h}}$ is the PI-SWERL-derived vertical PM_{10} emission flux (g m^{-2} s^{-1}) for hour *h* and surface type n, and 3.97 x 10^{-3} is a constant of proportionality to convert from seconds to hours and from grams to tons of PM_{10}.

The total area A_n for each surface type *n* will be determined using GIS mapping techniques. For the off-Sea desert region, the A_n values are not expected to change significantly over time but will be periodically updated as necessary.

C.2.2.1 Surface Friction Velocity Method

With the surface friction velocity method, the average hourly vertical emission flux, $\overline{F_{n,h}}$, in Equation C-10 is parameterized as follows:

$$\overline{F_{n,h}} = f\left(\overline{u_{*,n,h}}\right) \text{ for all } h \text{ satisfying } u_{*,n,h} \geq u_{*t,n} \qquad \textbf{Equation C-11}$$

where $f\left(\overline{u_{*,n,h}}\right)$ is the PI-SWERL-derived relationship expressing vertical PM_{10} flux (g m^{-2} s^{-1}) as a function of surface friction velocity, u_*, and u_{*t} is the threshold friction velocity for surface type *n*. $\overline{u_{*,n,h}}$ is the area-weighted average of the CALMET gridded u_* values within each surface type *n*:

$$\overline{u_{*,n,h}} = \left.\frac{\sum_{s=1}^{S}(a_s \cdot u_{*s})}{\sum_{1}^{S} a_s}\right|_{n,h} \qquad \textbf{Equation C-12}$$

where a_s and u_{*s} are the area and u_* values assigned to CALMET grid cell *s*.

Annual emissions will be computed using PI-SWERL, u_{*t} , and CALMET meteorological data collected during the period of investigation.

C.2.2.2 Horizontal Sand Flux Method

With the horizontal sand flux method, the average hourly vertical emission flux, $\overline{F_{n,h}}$, in Equation C-10 is parameterized as follows:

$$\overline{F_{n,h}} = \overline{Q_{n,h}} \cdot \overline{K_{f,n}} \qquad \textbf{Equation C-13}$$

where $\overline{Q_{n,h}}$ is the spatially averaged hourly horizontal sand flux for all sand motion monitoring stations within surface type *n* (g m^{-2} s^{-1}), and $\overline{K_{f,n}}$ is the spatially averaged K-factor for all PI-SWERL monitoring sites located within surface type *n*.

Annual emissions will be computed using PI-SWERL and sand flux monitoring data collected during the period of investigation.

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C.2.3 Future Inventory Updates

The off-Sea emission inventory will be updated as needed based on changes in conditions

C.2.4 Reporting

Results of the emission inventory will be reported as outlined in Table C-3, Summary of Reporting for Off-Sea Emissions Inventory. Table C-3 is located at the end of Appendix C.

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Table C-3. Summary of Reporting for Off-Sea Emissions Inventory

	Topic	Items to be Reported	Frequency
1	Mapping and Characterizing Off-Sea Surfaces	Results of mapping and characterizing current off-sea surfaces	Initial report due on or before June 1, 2016. In subsequent years, reports will be generated as needed.
2	PI-SWERL Sampling	Results of PI-SWERL monitoring	
3	Sand Flux Monitoring	Report summarizing, among other things: the CSC sand mass and Sensit response data, collection statistics and results of the quality control inspection, and calculated hourly sand fluxes	
4	Meteorological Monitoring	Report summarizing, among other things: hourly wind speed and wind direction data, and collection statistics and results of the quality control review	
5	Video Monitoring	Report summarizing, among other things: days with 10-meter wind speeds above the threshold for dust generation, and a qualitative description of images showing evidence of dust plumes	
6	Emissions Inventory	Report summarizing off-Sea emissions inventory results and supporting data (items 1 through 5, above)	

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APPENDIX D – STANDARD OPERATING PROCEDURES

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APPENDIX D.1.
STANDARD OPERATING PROCEDURES:
PI-SWERL

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Standard Operating Procedure
Miniature
PI-SWERL with DustTrak Ver. 1.3a
Dust Monitoring
Revision 3

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1.0 SCOPE AND APPLICABILITY

This document provides procedures for properly operating and maintaining the miniature PI-SWERL with DustTrak. The PI-SWERL is a portable instrument that is used to measure the potential for soil wind erosion and dust suspension (Users Guide Version 1.3a, 2011). It is designed with the intention that minimal personnel can operate it. It should be noted that the description of the standard operating procedures (SOP) are not intended as a comprehensive guide to use of the PI-SWERL. Anyone using the instrument should become sufficiently familiar with the PI-and DustTrak user manuals (see reference section), in order to operate these instrument correctly and safely.

1.1 Principals of Operation

Section 1.2 Overview of the PI-SWERL. Additional information in the instrument can be found in the User's Guide. Figures 1 and 2 provide visual images of the instrument.

Figure 1. PI-SWERL Unit and Carrier



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Figure 2. PI-SERL Unit Details

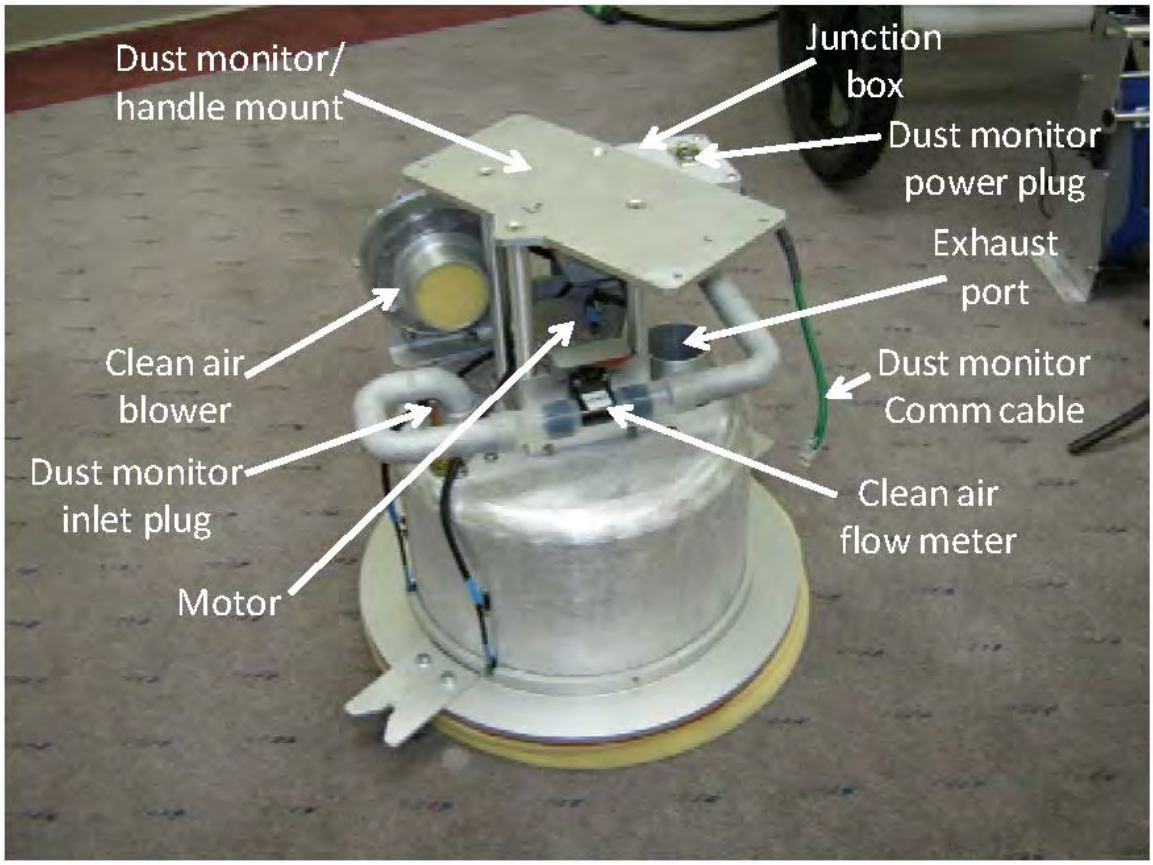
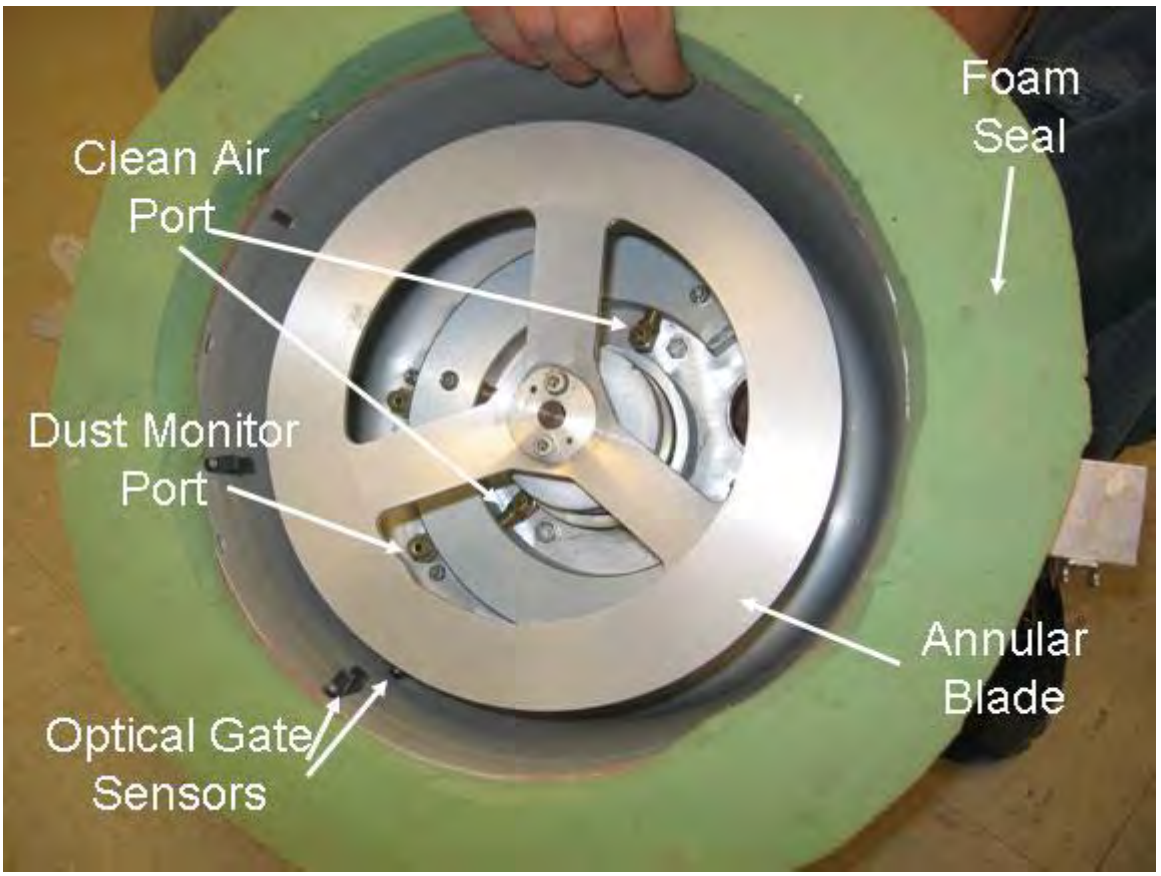


Figure 3. View Inside PI-SWERL Chamber



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1.2 Safety Precautions

Normal precautions should be taken to avoid electrical shock and/or dismemberment of body parts. Disconnect power before working with electrical components. Ensure that all moving parts have come to a complete stop before moving or handling instrument.

Use caution when working on elevated surfaces as to not damage the instrument or risk personal injury (due to loosened objects from fast spinning blade).

1.3 Sampling Interferences/Precautions

- Areas with visible moisture should be avoided.
- Sampler should rest on smoothest part of surface with minimal gaps under foam.
- Sampling surfaces should not be disrupted.
- Vegetation should be cut down if anticipated to interfere with rotating blade, but not completely removed.
- Avoid large rocks that could damage instrument.

1.4 Equipment and Supplies

- DustTrak with holder
- Battery pack and backup battery
- Control and backup cables (10 or 20 foot)
- Trimble (GPS unit)
- Garden shovel
- Air tank with air
- PI-SWERL
- Cart
- Site map

1.5 Sampling Locations

Locations will be selected by the Project and Site Manager. Methods of site selection will depend on type of sampling effort. For repeated systematic sampling efforts the sites to be sampled will be selected prior to sampling, loaded onto the Trimble, and reviewed by field staff at least one day prior to sampling. For exploratory surveys the general areas to be sampled, as well as surface types of interest will be identified by the Project and Site Manager. However, actual sampling locations will be determined in the field.

1.6 Operational Procedures

1.6.1 Introduction

The PI-SWERL and DustTrak units need be checked and cleaned regularly as part of the quality control (QC) program. The DustTrak is used to measure particulate concentrations, specifically,

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particulate matter with an aerodynamic diameter ten micron or less (PM_{10}), in the PI-SWERL chamber. The Optical Gate Sensors (OGS) are a set of four sensors (two sensors at two heights above the surface) that provide a measure of sand motion within the chamber. At this time the PI-SWERL is not an EPA certified instrument, and therefore there are no required calibration protocols. Per recommendation by the manufacturer, the DustTrak will be factory cleaned and calibrated annually by TSI. In addition, if two PI-SWERL units are available on site, periodic co-located testing is recommended to verify that both DustTrak units track each other (and one unit is not systematically skewed up or down).

1.6.2 Initial setup of sampler

Confirm the following before leaving the shop:

1. PI-SWERL will turn on.
2. DustTrak is connecting with the PI-SWERL software.
3. Battery is fully charged.
4. Foam on PI-SWERL is secure.
5. Extra control cable and battery are present.
6. The zero calibration on the DustTrak (DustTrak manual, page 19) has been run.

1.6.3 Steps to be performed to start sampling

1. Locate sampling site and travel to sampling site
    - Use truck to transport PI-SWERL to reasonably close walking distance to sampling location. For safety it recommended to transport the carrier (transport cart) strapped down in the pickup bed, and the actual PI-SWERL instrument in the cab of the pickup.
    - Load PI-SWERL unit onto cart, and locate first sampling location using the coordinate file uploaded onto the Trimble
    - Depending on site access and travel distance to sampling site, the PI-SWERL can be transported to test site using one of two methods:
        - Using the cart that PI-SWERL unit is mounted on
        - Using ATV and trailer, where PI-SWERL and cart securely strapped into cart
2. Turn on the PI-SWERL unit once at sampling site

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- Ensure that the control cable linking the PI-SWERL to the control unit is properly connected and secure at each end. A red LED on the switch will light up to indicate that the power is on.
    - Note: Control cable must be securely connected before the PI-SWERL unit is turned on.
- Ensure that the communications cable linking the monitor to the control unit is properly connected and secure at the control unit.
    - Note: Communications cable must be securely connected before the PI-SWERL unit is turned on.
- Ensure that the battery power cable is properly connected and secure, located inside the control unit housing.
    - Note: Power cable must be securely connected before the PI-SWERL unit is turned on.
- Toggle the main power switch to 'ON' (located at the rear of the control unit).
- Toggle the computer monitor's momentary switch to 'ON' (located below the monitor, facing downward) and confirm that the green LED is illuminated above the monitor screen.
    - Note: Occasionally the cursor will appear to dart wildly about the monitor upon initial start-up. This is a known glitch in the system and is best corrected by briefly pressing the monitor's momentary power switch to reboot the system.

3. Select program a sampling event

Program the sampler to run first test

- From the desktop, double click, SwerlView.
- The Test Specification Panel will appear. Choose the program you wish to run.
    - Note: Evaluation to be run can vary by test and will be coordinated by Project and Site Manager. If new program is developed, onsite staff will verify that test specifications are transferred correctly to PI-SWERL Software.
- The Test Description Panel will appear. Input the Test Description and Comment (for example):

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- Test Description: Bombay Beach
- Comment: Site 45

- Select Run at the bottom. Important: Once Run is selected the test will begin. Ensure that the sampler is properly placed before selecting Run.
- Document site conditions using digital camera, as well as surface information. Surface information forms can either be loaded onto the Trimble, field tablet, or, hardcopy if needed. In addition, maintain brief written field log to aid in data QC.

4. Movement from one site to the next
   - Ensure that the test has been completed.
   - Confirm that the annular blade has been turned off and stopped running.
   - Place sampler on the docking plate.
   - Coil control cable around sampler, make sure not to twist it.
   - Note: If control cable becomes too twisted, disconnection of the cable and untwisting may need to be performed
     - Note: Do not disconnect the control cable until the monitor has been shut down and the control unit powered off
   - Latch toggle clamp on front of docking plate.
     - Note: toggle clamp might come loose during travel. During travel check occasionally to make sure that clamp is still attached. The tension on the clamp may need to be adjusted over time.
   - If traveling short distances on the playa (~10 minutes between sites) it is not necessary to power down the PI-SWERL or computer if using the field cart to transport the instrument.
5. Setting up at new sampling site
   - Unlatch toggle clamp.
   - Uncoil control cable.
   - Place sampler onto test area.

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6. If unit was left running, repeat starting step 3 (program should go to prior test by default, if new test desired a different test needs to be selected). If unit was turned off for travel or "uncoiling" the cable, repeat starting step 1.

1.6.4 Cleaning and Maintenance of PI-SWERL and DustTrak

The following procedures are to be performed at end of each sampling day.

1. Cleaning of the PI-SWERL

   - Make sure all power is off on the PI-SWERL. Remove the DustTrak holder. Tilt the PI-SWERL so that it is at a 45˚ or greater angle. Using the air tank and a pressure nozzle blow out the inside of the PI-SWERL. Avoid blowing air directly into the Clean Air Ports.
   - Blow out the exhaust port, and outside of PI-SWERL.
   - Remove air intake filter, and blow out.
   - Wipe computer screen with clean cloth or recommended monitor cleanser.

2. Cleaning of the DustTrak

   - Wipe display screen with clean cloth or recommended monitor cleanser.
   - Blow any visible dust off with air tank.

3. General Instrument Maintenance

   - A description of general maintenance tasks and the recommended frequency is provided in the table 1-1.

Table 1-1. Instrument Maintenance Tasks

Frequency	Maintenance Item
Every Sample Day	Inspect all cables for cracks or abnormal wear. Confirm full charge on batteries. Re-zero DustTrak at the beginning of each sampling day, prior to first measurement
Every 20 sampling events, or as necessary	Run zero flush program. When necessary clean out sampler with compressed air.
After every 2 full days of field use	Clean DustTrak monitor (see DustTrak manual for details)
Every 1 month	Repeat steps from Sample Day.

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Frequency	Maintenance Item
Every 1 to 3 months	Clean DustTrak inlet filter: monthly during dust season,; every 2 to 3 months during non-dust season Vacuum dust and sand particles from battery section of control box, vacuum lid.
Long-term PI-SWERL care	Carefully vacuum electrical connectors. Remove dust from field cart using hand brush or handheld vacuum.

1.7 Data Records and Management

STEPS TO DOWNLOAD RUN DATA:

- Turn on the PI-SWERL unit following the procedures in section 1.6.3.
- Insert a flash drive into one of the open USB ports located below the monitor, facing downward.
- Open the 'Shortcut to Swirlerdata' folder located on the control screen desktop. Alternatively, using Windows Explorer, open folder used to store the data (c:/Swirlerdata/) and find folder with results for that day (for example, all files for June 7, 2011 will be stored in folder named "20110607."
- Select the appropriate files, named for the date of the test event, right-click, and copy over to the flash drive.
- Remove the flash drive from the monitor following safe removal practices, shut down the monitor, then switch the control unit power off.

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2.0 REFERENCES

Dust-Quant LLC. User's Guide for the Miniature Portable In-Situ Wind ERosion Lab (PI-SWERL). Model 8530/8532 DustTrak™ II Aerosol Monitor: Operation and Service Manual. PN6001893, Revision F (January 2011)

Environmental Protection Agency. 2007. Guidance for Preparing Standard Operating Procedures (SOPs). EPA/600/B-07/001. April 2007. Accessed August 27, 2015. http://www.epa.gov/QUALITY/qs-docs/g6-final.pdf.

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APPENDIX D.2.
STANDARD OPERATING PROCEDURES:
SAND FLUX AND METEOROLOGICAL MONITORS

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Standard Operating Procedure
Sand Flux/Meteorological Monitoring Station Installation and Operation at Salton Sea

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Appendix D: Sample CSC Weigh Data Sheets
Appendix E: Wind Speed and Direction Audit Forms

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1.0 INTRODUCTION

This document describes the procedures for properly locating, installing, and operating a sand flux and meteorological monitoring station for use in the Salton Sea Air Basin. The station is designed to be adaptable, so that any combination of sand flux and meteorological instruments can be used, depending on the measurement scenario. The station consists of a Sensit, Cox Sand Catcher (CSC), three levels of wind speed measurements, a single level of wind direction, a solar power system, and data storage and telemetry equipment. This document has been written specifically for application to Salton Sea project and may not be applicable to other jobsite locations.

This document is in accordance with the Environmental Protection Agency's *Guidance for Preparing Standard Operating Procedures (SOPs)* (EPA 2007).

1.1 Principles of Operation

Windblown dust emissions occur when the force of wind becomes sufficiently strong to initiate the movement of soil particles across an erodible surface, generating particulate matter less than 10 microns in diameter (PM_{10}) from the surface. As the wind speed increases, sand sized particles are lifted by fluid drag force and start hopping across the surface in a process known as saltation (Bagnold, 1941; Shao, 2008). As the sand strikes the surface, it frees fine particles which are entrained into the air stream and are carried downwind. The amount of PM_{10} released is a complex function of environmental conditions (e.g. wind, precipitation, and temperature), soil properties (e.g. soil texture, composition, and aggregation), and land-surface characteristics (e.g. topography, surface disturbance, vegetation cover, and/or other non-erodible elements). It is assumed that the vertical PM_{10} emission rate is proportional to the horizontal sand flux, which is measured at a reference height of 15 cm using a CSC and electronic Sensit. The CSC is a passive sampling device used to collect sand and sand-sized particles being transported across the site by the wind. The Sensit is a cylindrical electronic device that records particle count and kinetic energy of the sand particles that strike the sensing surface. The Sensit data are used to time-resolve the sand mass collected by the CSC, resulting in a horizontal sand flux measurement.

Wind speeds are measured at 6-m, 2-m, and near the ground to resolve the vertical wind profile and provide an estimate of the surface friction velocity at the site. The wind speeds are measured using a Met One 014A anemometer or Met One 014A mini anemometer. These anemometers consist of three aluminum cups mounted on a cup assembly hub and shaft. The shaft includes a magnetic assembly to open and close a reed switch, generating a pulse signal with a frequency that is linear with the wind speed.

The wind direction is measured at 6-m using a Met One 024A Wind Vane. This sensor measures wind direction from 0 to 360 degrees with a 5-degree accuracy specification. The wind vane assembly consists of a counterweighted aluminum arm and vertical air foil mounted to an aluminum hub. The hub is attached to a stainless steel shaft which is connected to a potentiometer. When the shaft is rotated, the

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potentiometer varies the sensor resistance in relation to wind direction, resulting in a linear change in output voltage with wind direction.

1.2 Safety Precautions

- All field staff should carry a working cell phone and wear the appropriate Personal Protective Equipment (PPE).
- Disconnect power before working with electrical components.
- Take normal precautions to avoid electrical shock.

1.3 Sampling Interferences/Precautions

- Check the forecast to ensure safe weather and environmental conditions before visiting a sand flux/meteorological station. Site visits and maintenance should only occur under low wind conditions to avoid operator interferences in the data signal.
- Ensure proper grounding for good performance.
- Avoid using a field vehicle to access the monitoring site. If vehicle access is necessary and unavoidable, the field vehicle must always be parked at a minimum of 10 meters away from the monitoring site.
- All access to the monitoring site should be from the direction that has the lowest frequency of high winds to avoid disturbing the surface upwind of the sensors. At Salton Sea, high winds from the east are extremely rare; therefore, access should be from the east.
- All data should be collected using Pacific Standard Time (PST). Configure all field laptops and tablets devices using PST to prevent accidental datalogger clock updates to Pacific Daylight Savings Time (PDT).
- The site operator needs to confirm that a datalogger program is appropriately configured with the monitoring site ID and the Sensit serial number. Database problems are likely to occur if either the site ID or Sensit serial number is incorrect.

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2.0 SITE LOCATION AND INSTALLATION

2.1 Equipment and Supplies

- CSC assembly and empty sand collection tube
- Sensit Assembly:
    - Sensit model H14-LIN
    - 1″ diameter iron pipe (lengths of ~5′, ~2′, and ~1′) and two 1″x1″ Nurail fittings
    - 1-foot foam pipe insulation
    - PVC tape and cable ties
- One Met-One 024A Wind Vane
- Two Met-One 014A anemometers with 6-m and 3-m cable heights.
- One Met-One 014A mini anemometer with cable
- Two 4-foot cross-arms with support brackets
- Either one 8-foot 1″ pipe or one 10″ support stand for the 014 Mini
- Four 1″x3/4″ Nurail fittings
- Logger and battery enclosure (BBA3):
    - Back plate
    - CR6 Datalogger
    - SunSaver 10 charge regulator
    - 110ah external storage battery
    - Power-Over-Ethernet (POE) Adaptor
- 90 W solar panel with mounting bracket
- NanoBridge M5 Ethernet radio with antenna
- 20 foot tripod with anchors and guy wire kit
- Grounding package, including 6′ copper grounding rod, clamp, cable, and lightning rod
- Various U-bolts
- Portable GPS unit with monitoring site location file pre-loaded
- T-post pounder
- Packing putty
- Soil coring auger (4″ diameter)
- Small straight-bladed screwdriver
- Large Allen keys

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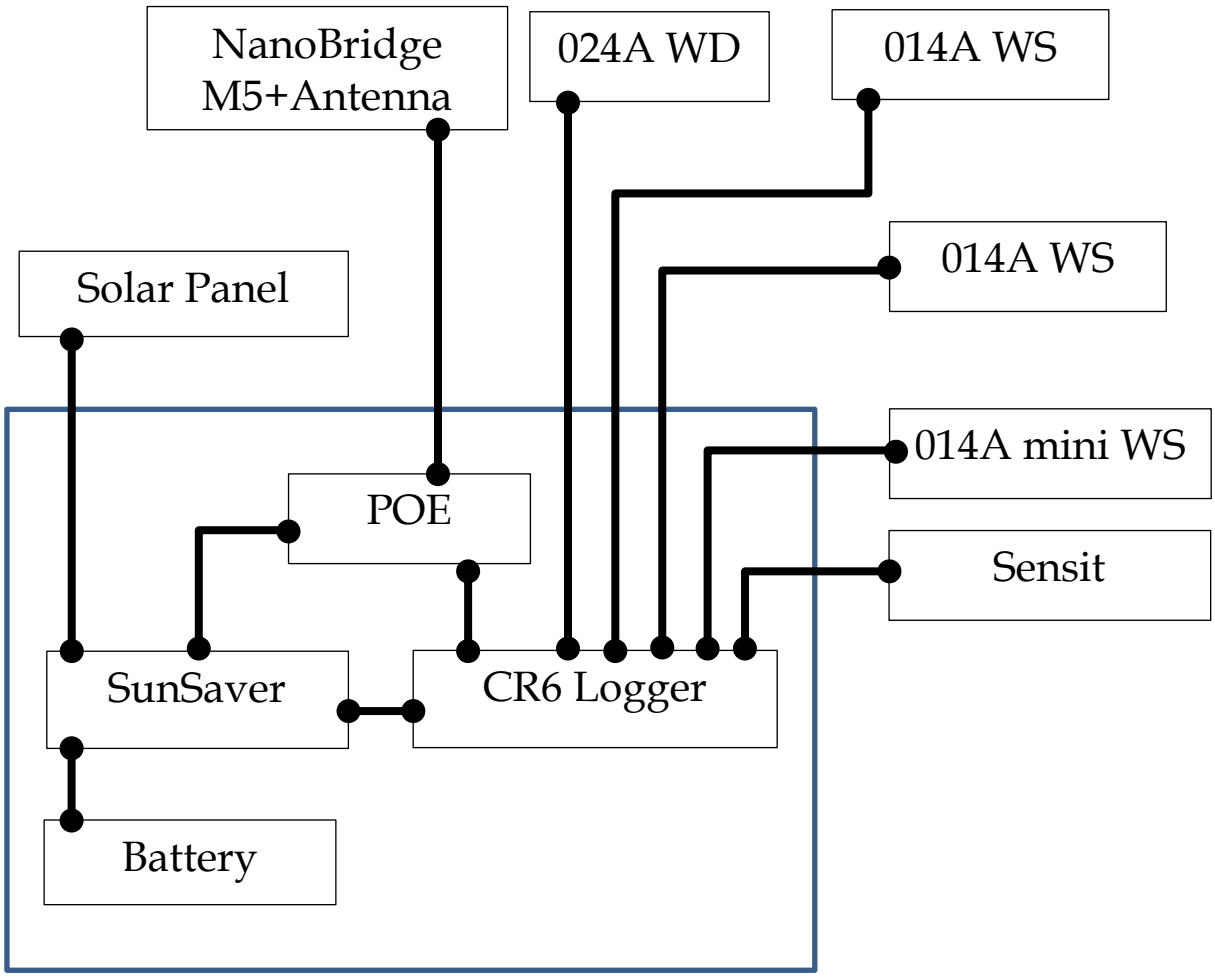
- Keypad for CR6
- Metric measuring tape
- Combination wrench set
- 20-mil PVC pipe wrap tape
- RS-232 cable

2.2 Wiring Diagram

The wiring diagram for the instruments, datalogger and power system is shown below.



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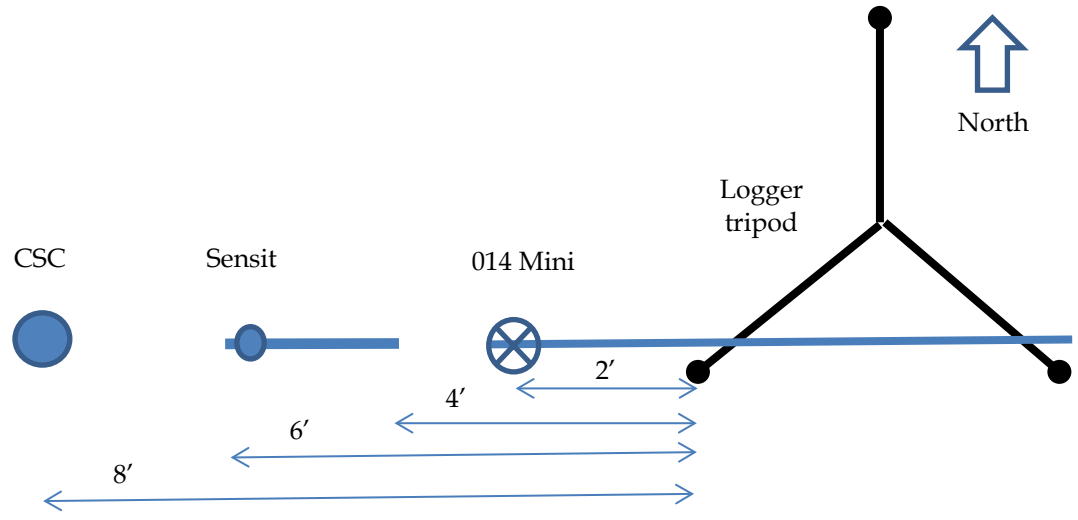
2.3 Monitoring Site Location and Installation

1. Before deploying, prepare the enclosure by installing the back plate on the left side of the back wall. Make sure there is an accessible wiring access port at the left back side of the enclosure. Mount the CR6 datalogger, SunSaver Regulator, and POE Adaptor to the back plate.
2. Prepare the CR6 datalogger by loading the appropriate program and entering the correct Sensit serial number and site ID. Make sure the logger is set to Pacific Standard Time.
3. Using standard navigation procedures and the portable GPS unit, locate the appropriate monitoring site. The site should be approximately 8′ by 10′ and be generally level with minimal obstruction in the predominant wind directions. Instruments are to be installed in a west-to-east alignment, with the CSC on the west, the Sensit in the center and the datalogger tripod on the east as shown below. All access to the monitoring site should be from the direction that has the lowest frequency of high winds to avoid disturbing the surface upwind of the sensors. **Ensure that all field personnel approach the location only from that preferred direction**. At Salton Sea, high winds from the east are extremely rare; therefore, access should be from the east to avoid disturbing the surface upwind of the sensors.
4. Begin by installing the datalogger tripod. Refer to the Tripod Installation Manual Models CM110, CM115, CM120 (Campbell Scientific, Inc. 2015) for detailed tripod installation instructions. Orient the legs so that one leg points north and the other two to the south as shown below. The legs should be placed so the mast tilts to the northeast direction.

Figure 1. Sensit/Met Station Instrumentation Orientation



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5. Place the ground level anemometer support:
    a. If the low-level anemometer is being held by a pole, attach an 8-foot pole to the base of the south facing legs so that the pole extends to the west. The pole should be level and placed at a height of about 4 inches above ground.
    b. If the low level anemometer is being held by a stand, place the center of the stand two feet west of the southwest foot of the tripod.
6. Next, mark a location approximately 4 feet due west of the southwest foot of the tripod and install the ~5′ pipe for the Sensit stand using the post pounder, leaving approximately 24″ above the ground.
7. Continue by marking a location approximately 8′ due west of the southwest foot of the tripod for the CSC. Measure the length of the CSC from the bottom of the gasket to the bottom of the CSC. Using the coring auger, bore a hole at this location for the CSC, with an initial depth equal to this length.
8. Install the CSC into the bored hole until the center of the inlet sits at 15 cm (6″) from the surface. Soil may need to be added or removed at the bottom of the hole to reach this dimension. If soil is added, make sure to pack the soil down firmly before setting the CSC to ensure it will not settle later. Once the height is correct, pack excess soil around the CSC until it is firmly set into the ground. **Carefully distribute remaining loose soil in an area that is away from predominant high wind directions.**
9. Assemble the remainder of the Sensit stand using the 1″ iron pipe and Nu-Rail clamps. The ~2′ horizontal arm should be oriented in a westerly direction, and the bottom of the ~1′ vertical arm should be positioned approximately 25 cm (10″) above the ground level.
10. Wrap the foam insulation around the short vertical arm of the Sensit stand. Trim the foam so it does not extend below the end of the pipe.
11. Position the Sensit on the foam insulation so that the center of the crystal sensor ring is 15 cm (6″) above the ground surface. With the help of an assistant, use the PVC tape to tightly bind the Sensit to the vertical arm of the Sensit stand. Carefully wrap and secure the Sensit cable to the Sensit stand, leaving enough slack for future Sensit height adjustments. Run the Sensit cable along the ground back toward the tripod.
12. Mount the enclosure to the north leg of the tripod, leaving at least a 2″ gap between the enclosure and the surface.
13. Ensure that the external power lead is connected to the correct lugs on the 110ah battery, and then install the battery into the enclosure.
14. Attach the solar panel to the south legs of the tripod so the panel faces south. An angle-iron bracket may be used to securely attach the panel. Make sure the ends of the solar panel cables are taped so the leads do not short out.

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15. Drive the grounding rod into the ground at a convenient location near the enclosure. Attach the grounding clamp and grounding wire to the rod.
16. Mark the 2-m height above ground on the mast. Lower the mast and mark the 5-m height. Attach the lightning rod to the very top of the mast, then attach the NanoBridge M5 radio antenna just below. Aim the dish in the direction of the receiving station. Attach the Ethernet cable to the NanoBridge and cable tie it to the mast.
17. Attach the two cross-arms to the mast for the 2-m and 6-m measurements using the 2-m and 5-m marks as reference. Orient the cross-arms in an east-west direction, using a declination value of 11.5° East for Salton City, with the upper cross arm attached at its midpoint and the lower attached so the pole extends west.
18. Using the 1"x 3/4" Nu-Rail fittings, attach a 024A vane to the east side of the upper cross arm. Ensure that the stainless steel shoulder screw is installed in the 024A instrument hub.
19. Aided by a compass, align the sensor so that the counter weight is oriented toward true south. When the sensor is properly aligned, remove the stainless steel shoulder screw from the instrument hub and ensure that the vane assembly rotates smoothly. Retain the stainless steel shoulder screw for future audit procedures.
20. Attach the cables to the sensors and label the lead end of the cables so identification on the logger side is easier. Ensure that the connector is properly keyed, and finger-tighten the knurled ring.
21. Using the 1"x3/4" Nu-Rail fittings, attach a 014A anemometers to the west side of the upper and mid-level cross arms.
22. Attach the sensor cable to the connector on the 014A. Ensure that the connector is properly keyed, and finger-tighten the knurled ring.
23. Secure all cables to the mast using cable ties, allowing slack for adjustment. Raise the mast and collect the cables, securing the cables to the tripod allowing slack at the mast hinge so the mast can be raised and lowered freely.
24. Attach the 014A mini anemometer to the ground level pole or stand, using either a Nu-Rail fitting or threaded rod. Adjust the height based on the application (for example, 15 cm if used with a Sensit). Wire the sensor with a shielded twisted pair cable and run the cable back to the logger, securing with cable ties.
25. Confirm that the SunSaver charge controller has been turned off, pass all loose leads through the access port, and then complete all remaining electrical connections:
    - Charge leads from the solar panel to the charge terminals on the SunSaver
    - External battery lead to the appropriate plug on the SunSaver
    - Connect the wind vane to the CR6 datalogger (U1 and U2).
    - Connect the three anemometers to the CR6 datalogger (6-m in U3, 2-m in U5, and ground level in U7).

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- Attach the Sensit lead to the datalogger, according to the attached example wiring diagram (Appendix A) for the appropriate Sensit model (using C1 and C2).
- Connect the Ethernet cable from the NanoBridge to the POE adaptor.
- Attach a short Ethernet cable from the CR6 logger to the POE adaptor.
- Ground the wire between the ground lug on the underside of the enclosure to the clamp on the ground rod.

26. Firmly pack putty around the wiring access port in the bottom of the enclosure in an effort to prevent moisture and insects from entering the enclosure.
27. Carefully loop and wrap all loose leads to a convenient location on the tripod using the 20-mil PVC tape or cable ties.
28. Turn on the SunSaver. Following the CR6 SOP, confirm that the correct site ID and Sensit serial number have been entered into the datalogger program. Verify that the datalogger clock is set to PST.
29. Check the height of the CSC inlet and the Sensit sensor ring and adjust as necessary.
30. Confirm that the Sensit is responding normally by evaluating its response in real-time. Select **Num Display** from the toolbar, and then select **Display 1** to view the real-time station data. Rub the sensor with a pen or similar object, and view the results in **Display 1**. A properly operating Sensit will display a measurable reading (a non-zero value) for the particle count (PC) and kinetic energy (KE) data fields. If these values are **0** during a manual agitation, the Sensit is not operating properly or is not wired correctly. Inspect the integrity of the Sensit cable, verify the datalogger connections, and check the instrument again. If the Sensit is still not responding normally, notify the project monitoring manager for further instruction.
31. Confirm that the wind speed and direction are responding correctly.
32. Determine the wind direction program multiplier by dividing the sensor's full scale input voltage (FSIV) by 360 degrees. The FSIV is the maximum voltage output from the wind vane. When an instrument's program multiplier is found, it must then be entered into the existing datalogger program, replacing any previously defined value.
33. When all instrumentation is installed and operating, begin a site log entry, either electronically on the field laptop or using hard copy forms provided.
34. Audit the wind speed following the procedures in Section 4.

2.4 Data Records and Management

After the site installation is complete and the station is under stable operating conditions, the field technician must complete the initial Site Check and Audit Form. A hard copy is found in Appendix B if an electronic copy is not available on the field laptop.

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3.0 SITE VISIT PROCEDURES

3.1 CSC Tube Preparation

1. Disassemble empty sample tubes, removing any caps, rubber rings, and rubber stoppers from the clear plastic tube.
2. Clean all parts of the sample tube using soap and water with a bottle brush and tube plunger as necessary. Ensure that all old sample material and residue have been removed from each piece.
3. Using rubbing alcohol, remove any existing notes that have been written on the tube.
4. Allow all pieces to fully dry before reassembly.
5. Reassemble tubes with only a rubber stopper fully inserted into the bottom of the tube. The stopper should be inserted with the larger diameter up and the smaller diameter flush with the bottom of the clear tube. Do not install the rubber ring or cap at this time.
6. Following the operational procedures for the Scientech electronic balance (Appendix C), weigh each sample tube assembly to a resolution of 0.1 grams.
7. Using a permanent marker, write the tare weight of each empty sample tube assembly directly on the sample tube.
8. Insert a cap/stopper on the tube inlet. The sample tube is now ready for installation at a sampling site.

3.2 Field Collection Procedures

Sand flux monitoring sites must only be approached from an easterly direction. It is best to walk to each site; if an ATV is used for access, the vehicle must be parked no closer than 10 m from the monitoring site.

1. Before leaving the field office, ensure that the field computer is configured to PST to prevent an erroneous update of the datalogger to PDT. If the Sensit and meteorological data are being telemetered, then the data set should be checked prior to the site visit to confirm that the instruments are operating and identify possible issues. Sensits with little activity or no activity should have their response checked
2. Once at site, begin by recording the "Start Time" on the electronic Site Check and Audit Form on the most recent "Field_Site_Logger"workbook. Continue by entering data in the appropriate fields on the Site Check and Audit Form.
3. Inspect the station for any obvious damage, alignment issues, excessive dirt build-up, loose wiring connections, frayed or chewed cables, or vandalism. With some soil types and pole materials, the pole may not lock into place and the Sensit assembly may rotate in the wind. This should be noted on the electronic Site Check and Audit Form, and corrective action must be taken to stop further rotations. Record all corrective actions on the Site Check and Audit Form.

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4. Look for evidence of rain splatter. If rain splatter is seen, check the appropriate box in the site log and take a picture of the Sensit and CSC documenting the splatter.
5. Unlock the enclosure and connect the field computer to the datalogger using an RS-232 cable. Following the data collection procedure in the appropriate datalogger SOP, confirm that the datalogger clock setting is correct and collect all data saved for that site.
6. While still connected to the station, select **Num Display** from the toolbar, and then select **Display 1** to view the real-time station data. Here you can check the station battery voltage.
    - Test the Sensit response in real-time, and view the results in **Display 1**. Rub the sensor with a pen or similar object. A properly operating Sensit will display a measurable reading (a non-zero value) for the particle count (PC) and kinetic energy (KE) data fields. If these values are **0** during a manual agitation, the Sensit is not operating properly. For instances of improper Sensit operation, inspect the integrity of the Sensit cable and verify that the datalogger connections are solid. If the problem is not resolved during the field visit, notify the project monitoring manager for further instruction. The Sensits should be tested during each CSC collection event and for Sensit troubleshooting diagnostic visits.
    - If a Sensit needs to be removed from field deployment and replaced with a new instrument, follow these steps:
        - Modify the datalogger program to include the serial number of the new Sensit, and upload the new program to the datalogger. It is imperative that the datalogger program modification be completed accurately. Reference instructions in the appropriate datalogger manual (Campbell Scientific Inc., 2015b) for guidance.
        - Following modification of the datalogger program and its successful upload to the datalogger, manually test the Sensit to verify its appropriate response.
        - Once operation of the Sensit has been verified, wait at least 10 minutes before downloading the data.
        - Open the downloaded **Min05** comma-separated variable DAT data file in Microsoft Excel and verify that the site ID and Sensit serial number are correct. If the values are correct, the Sensit has been successfully changed and the datalogger program appropriately updated.
        - Consult with the monitoring manager on the need to collect the CSC tube and to replace it with a new one, if requested.
        - Take the Sensit to the field office, where it should be bench-tested to verify operation status (working or not).
        - If the Sensit is still not working at the shop, dispose of it.
        - If the Sensit is working at the field shop, test the instrument and system to establish the reason for failure in the field.

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7. Confirm that the height from the playa surface to the center of the Sensit's sensor ring is 15 cm ±1 cm. Adjust this height as necessary and record the final dimension and any corrective actions taken on the electronic Site Check and Audit Form.
8. Carefully remove the CSC inlet head and set it aside. Brush any portion of the sand sample that has gathered on the top rim of the sample tube into the tube.
9. Remove the sample tube from the CSC. Remove the rubber top ring. Remove the cap from the tare-weighted "clean" sample tube and place it on the recently removed sample tube. Confirm that the site ID has been written on the sample tube, and, using a permanent marker, write the date of the collection.
10. Install the rubber top ring to the "clean" tube. Using a permanent marker, write the site ID on the "clean" sample tube. Insert the "clean" tube into the CSC and carefully reinstall the CSC inlet head.
11. Confirm that the height from the playa surface to the center of the CSC inlet is 15 cm ±1 cm. Adjust this height as necessary and record the final dimension and any corrective actions taken on the electronic Site Check and Audit Form.
12. Using a field camera, take one or more photos of the sample tube, showing a clear view of the collected sand sample, the site ID, and the collection date as written on the sample tube, as well as the surface conditions immediately adjacent to the sampling location.
13. Verify operation of the wind speed and direction sensors. If an audit is needed, conduct it at this time, following the procedures from Section 4.
14. The field computer may now be disconnected from the station.
15. Finish the field collection by recording the "End Time" on the electronic Site Check and Audit Form prior to leaving the sampling location.
16. Carefully return the samples back to the field office, keeping the tubes upright.

3.2.1 Maintenance and Adjustments

Review the performance of the all sensors and determine what adjustments are required, if any. Follow the maintenance and adjustment guidelines presented in the Instruction Manual (see the Campbell Scientific website for specific instrument manuals).

3.2.2 Post-Adjustment System Checks

If any maintenance or adjustments were performed, the steps listed in the Pre-Adjustment System Checks section of this procedure should be repeated and recorded on the Wind Speed Calibration Form. Results of the post-adjustment checks should be closely evaluated. If the output values do not closely match the expected values, perform troubleshooting, maintenance, and adjustments as needed to correct the sensor response. If the sensor is not deemed repairable, it should be replaced as soon as possible from the stock of back-up sensors for the monitoring project.

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3.3 Post-Collection Procedures

1. After all of the CSC sand mass samples are collected, the tubes are transported in an upright position and delivered to the field office for weighing.
2. Once at the field office, store the sample tubes upright in a secure location. If the samples are wet or damp, remove the caps from each sample tube to allow the samples to dry for several days. This drying process may be expedited by using a small fan to gently blow clean, dry air across the open ends of the sample tubes.
3. Generate a weigh sheet from the Excel based spreadsheet.
4. Prepare the Scientech electronic balance for measuring the mass of each sample.
5. Start the weighing session by verifying the scale accuracy with NIST[1] weights, following the appropriate operational procedures (Appendix C).
6. Record the site ID as written on the sample tube in the appropriate fields on the CSC Weigh Data spread Sheets (Appendix D). Continue to fill out the remaining fields as the data are available.
7. Begin by preparing an empty Ziploc storage bag for each sand sample. Write the site ID and collection date on the bag. Weigh the empty storage bag using the electronic balance. Write this "Empty Bag" weight directly on the empty bag for future reference and also on the Weigh Data Sheets.
8. Carefully pour each sand sample into its previously prepared Ziploc bag, being careful to not lose any remaining portion of the sample. Remove the stopper at the bottom of the sample tube and brush any sample that remains on the bottom stopper into the storage bag. With a clean tube plunger, push any remaining portion of the sand sample through the tube and out the bottom, into the storage bag. Using tweezers, carefully remove any insects or foreign material from the sample. Weigh the bag containing the sample, and record this value on the Weigh Data Sheets as the "Full Bag" weight.
9. Calculate the difference of the "Full Bag" weight and the "Empty Bag" weight, and record this value as the "Sample Weight" on the Weigh Data Sheets.
10. Repeat this process for all sample tubes.

    Note: Every tenth sample "Full Bag" should be re-weighed. The re-weigh data must be recorded in the Re-Weigh Section of the CSC Weigh Data Sheets (Appendix D).
11. Finish weighing by verifying the scale accuracy with NIST weights.
12. All samples should be stored in the laboratory for future reference.
13. Enter the CSC sample weigh data into the spreadsheet. Scan the completed hard-copy CSC Weigh Data Sheets, and archive a digital copy of the hard-copy notes and spreadsheet file to the Air Sciences Cataloger server. Distribute the sand-flux sample weigh data to all interested parties.

[1] National Institute of Standards and Technology

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3.4 Data Records and Management

Field personnel must maintain a thorough and complete set of site visit records. Every maintenance, CSC collection, or data download visit must be recorded on the Site Check and Audit Form. A hard copy of this form is provided in Appendix B if an electronic copy is not available on the field laptop. All hard copy forms must be stored at the project office.

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4.0 AUDIT PROCEDURES

This section provides procedures for properly auditing the performance of the Met One 014A Wind Speed Sensor and the Met One 024A Wind Direction Sensor.

4.1 Equipment and Supplies

- R.M. Young 18811 (or similar model) anemometer drive, motor, and attachment accessories
- R.M. Young 18802 (or similar model) anemometer drive, motor, and attachment accessories
- Met One 050 Torque wheel and black plastic screws (0.1 gm-cm)
- Tripod-mounted, survey-grade compass
- Site log book/audit sheets

4.2 Wind Speed Audit Procedures

Follow the steps below to audit the performance of the Met One 024A Wind Direction Sensor. Refer to the particular manufacture sensor instructions for a more detailed instrument protocol.

1. Remove the three-cup anemometer wheel from the sensor shaft.
2. Place the plastic adapter bushing on top of the wind sensor column assembly.
3. Attach the anemometer drive support bar assembly to the plastic bushing and gently tighten the clamp tension screw.
4. Slide the rubber tubing off the flexible coupling adapter onto the wind sensor shaft.
5. Attach the motor to the bar assembly and carefully align the anemometer and motor coupling, gently tighten the clamp on the motor assembly, and tighten the collar of the flexible coupling adapter to the shaft of the motor.
6. The sensor is then challenged at the speeds specified on the Wind Speed Calibration Form (30 through 1,800 revolutions per minute [RPM]). Note that both the 18802 and 18811 anemometer drives are needed to complete the entire range. The speeds measured by the datalogger for each specific RPM input value are compared to the calculated wind speed values. The equation for calculating wind speed as a function of anemometer drive RPM is provided on the Wind Speed Audit Form.
7. Carefully disassemble the anemometer drive materials upon completion of the testing.

Prior to installing the three-cup anemometer wheel, the sensor shall undergo a starting torque test. Follow these steps to perform the torque test for the 014A wind speed sensor with the torque wheel.

1. Remove the 014A from its mounting hardware and fix it to a horizontally leveled surface.
2. Attach the torque wheel to the anemometer shaft.

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3. Measure the starting torque and record it on the Wind Speed Audit Form. If the starting torque of the sensor is greater than 0.288 g-cm (0.004 in-oz.) clockwise or counterclockwise, the bearings may need to be refurbished.

4.3 Wind Direction Audit Procedures

Follow these steps to audit the performance of the Met One 024A Wind Direction Sensor.

1. Record the audit start time and the site information on the audit form.
2. Measure the orientation of the instrument crossarm using the tripod-mounted compass, taking into account the local magnetic declination (approximately 11.5° East for Salton Sea).
3. To ensure accuracy in this value, when possible, measure the crossarm orientation from a point located on the opposite end of the crossarm to confirm that both measurements are 180° apart.
4. Record the angle of the crossarm orientation as the initial source degree audit point on the audit form. Each consecutive audit point shall be calculated at 90° clockwise from its preceding audit point and recorded on the audit form.
5. Following safe working procedures, carefully lower the meteorological tower until the wind instruments are at a convenient working height.
6. While an assistant monitors the output at the logger display, hold the wind vane in a position that is parallel to the crossarm while recording the angular value as reported by the logger display.
7. Rotate the wind vane 90° clockwise, hold it in this position, and again record the logger display value on the audit form (a small square may be used to confirm that the wind vane is held at 90° to the crossarm). Repeat this step for the final two audit points.
8. The Met One 024A Wind Vane is supplied with a locking shoulder screw. Insert this locking shoulder screw, which will lock the wind vane at 180°. Record the source value and the logger display value on the audit form.
9. Carefully remove the wind vane from the rotational shaft and install the Met One 050 torque wheel on the sensor shaft. Measure the starting torque in both clockwise and counter-clockwise directions and record these values on the audit form. If the starting torque of the sensor is greater than 6.48 g-cm (0.09 in-oz.) clockwise or counterclockwise, the bearings may need to be refurbished.
10. Replace the wind vane on the instrument shaft, install the shoulder screw, and check the potentiometer orientation. If necessary, adjust the potentiometer until the value matches the reading recorded in Step 8.
11. Carefully return the meteorological tower to the upright, operational position.
12. Record the audit end time on the audit form.

4.4 Data Records and Management

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At the conclusion of the audit, follow these steps.

1. Complete all audit forms, noting any adjustments made, maintenance performed, and/or corrective actions, if taken.
2. Note the specific time that the audit for the wind speed sensor began and ended.
3. Invalidate the entire time period during which the sensors were compromised or removed.
4. Sign and date the audit form under any comments made.
5. When possible, collect a scanned image of the hard-copy document for electronic archival purposes.

Refer to Appendices B and E for site check and audit forms.

4.5 Troubleshooting

Refer to the instrument specific instruction manuals for troubleshooting guidelines.

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5.0 REFERENCES

Air Sciences Inc. 2015a. *Standard Operating Procedure: Calibration and Audit Procedures for the Met One 024A Wind Direction Sensor*

Air Sciences Inc. 2015b. *Standard Operating Procedure: Calibration and Audit Procedures for the Met One 014A Wind Speed Sensor.*

Air Sciences Inc. 2015c. *Standard Operating Procedure: Configuration and Operation of the Campbell Scientific CR6 Dataloggers.*

Bagnold R.A. 1941. *The Physics of Blown Sand and Desert Dunes.* New York: Methuen.

Campbell Scientific Inc. 2015a. *Tripod Installation Manual Models CM110, CM115, CM120.* https://s.campbellsci.com/documents/us/manuals/cm110-cm115-cm120.pdf. Accessed October 6, 2015.

Campbell Scientific Inc. 2015b. *CR6 Measurement and Control System*. https://s.campbellsci.com/documents/us/manuals/cr6.pdf. Accessed October 6, 2015.

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Shao Y.P. 2008, Physics and Modelling of Wind Erosion 2nd ed. (Heidelberg: Springer)

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Appendix A: Example Sensit Wiring Conventions

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EXAMPLE SENSIT WIRING CONVENTIONS

H11B Sensit

- White (positive) – 12v
- Black (negative) – Ground
- Red (particle count) – P1
- Brown (kinetic energy) – P2
- Green (kinetic energy power) – Unused
- Blue (particle count power) – Unused

H11-LIN and H14-LIN Sensits

- Red (positive) – 12v
- Black (negative) – Ground
- White (particle count) – P1
- Orange (or occasionally Brown, kinetic energy) – P2
- Blue (PHA output) – Unused
- Green (Gain) – If Sensit response is weak, gain should be connected to 12v

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Appendix B: Site Check and Audit Form

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AIR SCIENCES INC.

AIR MONITORING PROGRAM
SITE CHECK AND AUDIT FORM

Date:	Start Time (PST):
Operator(s):	End Time (PST):
Site ID:	Battery Voltage:
Visual Inspection: ☐ Pass ☐ Fail	Observations:

Datalogger Information

Serial #:	Type:
☐ Data Download	Final Data Record Date/Time:

Maintenance and Operations

☐ Solar Panel Cleaned	☐ Datalogger Clock Check	Reset Clock? ☐ Yes ☐ No
☐ Audit Conducted	☐ Ground/Wiring Connection Check	Fittings Secure? ☐ Yes ☐ No

Comments:

Sensit/CSC Equipment Check

Sensit Serial Number (e.g., 123):	
Radio Tested: ☐ Yes ☐ No	Radio Serial Number:
Note: Measurement is from the ground surface to the middle of the sensor ring.	
Sensor Height (cm):	System Response to Manual Test: ☐ Yes ☐ No
Evidence of Rain Splatter? ☐ Yes ☐ No	Photo Taken? ☐ Yes ☐ No
CSC Inlet Height (cm):	☐ Tube Removed for Weighting
Second CSC Inlet Height (cm):	☐ Second Tube Removed for Weighting
Comments:	

Note: Measurement is from the ground surface to the middle of the inlet opening.

Estimate and Document the Parameters Below

Parameter	Estimated	Logger	Audit
Speed 6 m (m/s)			
Direction* (deg)			
Speed 2 m (m/s)			
Speed 15 cm (m/s)			

*Direction wind is from

Comments/Unusual Occurrences or Weather

Signature: _____

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Appendix C: Scientech Electronic Balance Operation

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SCIENTECH ELECTRONIC BALANCE OPERATION

Note: This electronic balance is sensitive to air movement, changes in temperature, vibration, direct sunlight, etc., and should be set up on a solid surface that is free of these conditions.

1. Confirm that the electronic balance is level. If necessary, adjust the feet until the balance is level.
2. Turn on the balance by pressing the **ON/OFF** button. Allow the balance to reach equilibrium for one hour before proceeding.
3. Confirm that the balance is set to measure in grams. Ensure that the balance pan is clean and free of any foreign matter.
4. Allow the balance display to stabilize, and press the **ZERO** button to establish the zero set point.
5. Perform a multipoint verification. One at a time, place each of the six calibration weights (200 mg, 1 g, 10 g, 100 g, 1000 g, and 2000 g) on the balance pan. Allow each reading to stabilize and record the displayed weight on the Scale Weight Calibration Section of the CSC Weigh Data Sheet. Verification weights should be within ±0.1 g from the target, as this is the resolution of the scale.
6. Proceed by weighing each sample. Be careful to allow the display to stabilize before recording any mass data. Confirm that the display returns to zero before proceeding with the next measurement and placing anything on the balance pan.
7. Re-weigh every tenth sample bag to confirm repeatability and record this re-weigh in the Re-Weigh Section of the CSC Weigh Data Sheet.
8. After all samples have been weighed, perform a second multipoint verification. One at a time, place each of the six calibration weights on the balance pan. Allow each reading to stabilize and record the displayed weight on the Scale Weight Calibration Section of the CSC Weigh Data Sheet. Verification weights should be within ±0.1 g from the target, as this is the resolution of the scale.
9. The electronic balance may now be powered off and covered for storage.

Reference

Scientech. 2006. *Scientech Series 12000 Electronic Balance Setup and Operating Procedures PN11756C*. September 21, 2006. http://www.affordablescales.com/pdfs/users_manual_pdf/sm50.pdf. Accessed October 6, 2015.

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Appendix D: Sample CSC Weigh Data Sheets

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Salton Sea Air Monitoring Program **Collection #_____**

CSC SAMPLE LOCATION	COLLECTION DATE	COLLECTION TIME	EMPTY BAG WT. (g)	FULL BAG WT. (g)	SAMPLE WEIGHT (g)	SCALE OP. & DATE	CATCH FULL (YES/NO)	CATCH WET OR DAMP (WET/DRY)	SPILL OR LEAK (YES/NO)	HEIGHT OF CATCH (cm)	ANY MATERIAL OTHER THAN SAND (YES/NO) If yes, describe other material	COMMENTS

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RE-WEIGH SECTION:

(REWEIGH EVERY 10th Sample WEIGHED)

REWEIGHED CSC SAMPLE LOCATION	COLLECTION DATE	COLLECTION TIME	FULL BAG WT. (g)	SCALE OP. & DATE

SCALE WEIGHT CALIBRATION SECTION:

(check scale before and after every group of measurements)

WEIGHT	DISPLAY	TIME	DATE
200 mg			
1 g			
10 g			
100 g			
1 kg			
2 kg			
200 mg			
1 g			
10 g			
100 g			
1 kg			
2 kg			

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Appendix E: Wind Speed and Direction Audit Forms

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METEOROLOGICAL AUDIT/CALIBRATION DATA



Client:
Job No.:
Site:

Date:
Time In:
Time Out:

Auditors:

Data Logger Model :
Serial No.:

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WIND DIRECTION 024A CALIBRATION, Upper: Height = _____ (m)

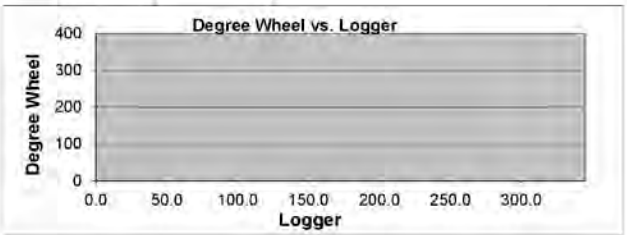
Model: _____ Serial No.: _____

System Linearity Check Declination = _____ East

Orientation	Compass (Degrees)	Target (Degrees)	Logger Reading (Degrees)	Difference (Degrees)	Acceptance Criteria
1. Crossarm (E)			-		±5
2. Crossarm (W)			-		±5
3. Vane (locked)	-				±5

	Initial Logger (Degrees)	Difference (Degrees)	Corrected Logger (Degrees)	Difference (Degrees)	Acceptance Criteria
45					±3
90					±3
135					±3
180					±3
225					±3
270					±3
315					±3

Avg _____



WIND DIRECTION 024A AUDIT, Upper Level Height = _____ (m)

Model: _____ Serial No.: _____

Performance Audit Declination = _____ East

Orientation	Compass (Degrees)	Target (Degrees)	Logger Reading (Degrees)	Difference (Degrees)	Acceptance Criteria
1. Crossarm (E)					±5
2. Crossarm (W)					±5
3. Vane (locked)	-				±5

	Logger (Degrees)	Difference (Degrees)	Acceptance Criteria
90			±5
180			±5
270			±5
360			±5

Avg _____

Bearing Torque Test (Passing 6.48 gm-cm)

Clockwise _____ gm-cm

Counterclockwise _____ gm-cm

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WIND SPEED 014A, Upper Height = _____ (m)

Drive Model Number: _____ Disk Model Number: _____

Drive Serial Number: _____ Disk Serial Number: _____

System Linearity Check

	Input rpm	Target* m/s	Logger Reading m/s	Difference m/s	Acceptance Criteria (±)
1.	0.0	0.4			0.0
2.	30.0	1.2			0.26
3.	60.0	2.0			0.30
4.	90.0	2.8			0.34
5.	180.0	5.2			0.46
6.	300.0	8.4			0.62
7.	600.0	16.4			1.02
8.	900.0	24.4			1.42
9.	1400.0	37.8			2.09
10.	1800.0	48.4			2.62

Bearing Torque Test (Passing 0.288 gm-cm)

Clockwise _____ gm-cm

Counterclockwise _____ gm-cm

Met One
*Target (mps) = (rpm/37.5067)+0.447

WIND SPEED 014A, Mid Level Height = _____ (m)

Drive Model Number: _____ Disk Model Number: _____

Drive Serial Number: _____ Disk Serial Number: _____

System Linearity Check

	Input rpm	Target* m/s	Logger Reading m/s	Difference m/s	Acceptance Criteria (±)
1.	0.0	0.4			0.0
2.	30.0	1.2			0.26
3.	60.0	2.0			0.30
4.	90.0	2.8			0.34
5.	180.0	5.2			0.46
6.	300.0	8.4			0.62
7.	600.0	16.4			1.02
8.	900.0	24.4			1.42
9.	1400.0	37.8			2.09
10.	1800.0	48.4			2.62

Bearing Torque Test (Passing 0.288 gm-cm)

Clockwise _____ gm-cm

Counterclockwise _____ gm-cm

Met One
*Target (mps) = (rpm/37.5067)+0.447

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WIND SPEED 014A, Lower Level Height = _____ (m)

Drive Model Number: _____ Disk Model Number: _____

Drive Serial Number: _____ Disk Serial Number: _____

System Linearity Check

	Input rpm	Target* m/s	Logger Reading m/s	Difference m/s	Acceptance Criteria (±)
1.	0.0	0.4			0.0
2.	30.0	1.2			0.26
3.	60.0	2.0			0.30
4.	90.0	2.8			0.34
5.	180.0	5.2			0.46
6.	300.0	8.4			0.62
7.	600.0	16.4			1.02
8.	900.0	24.4			1.42
9.	1400.0	37.8			2.09
10.	1800.0	48.4			2.62

Bearing Torque Test (Passing 0.288 gm-cm)

Clockwise _____ gm-cm

Counterclockwise _____ gm-cm

Met One
*Target (mps) = (rpm/37.5067)+0.447

COMMENTS

Invalidated meteorological data from: _____

NOTES:

Signature: _____ **Date:** _____

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APPENDIX D.3.
STANDARD OPERATING PROCEDURES: ROUNDSHOT LIVECAM D2

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Standard Operating Procedure
Roundshot Livecam D2 Installation and Operation at Salton Sea

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Document Information:

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Appendix A: Site Check Form
Appendix B: Solar Panel Wiring Diagram

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1.0 INTRODUCTION

This document describes the procedures for properly locating, installing, and operating a Roundshot Livecam D2 video monitoring station for use in the Salton Sea Air Basin. The station consists of a digital scan unit, lens, motor unit, weatherproof viewing enclosure, and mast holder for the video system; a solar power system; and data storage and telemetry equipment. This document has been written specifically for application to Salton Sea project and may not be applicable to other jobsite locations.

This document is in accordance with the Environmental Protection Agency's *Guidance for Preparing Standard Operating Procedures (SOPs)* (EPA 2007).

1.1 Principles of Operation

Video observations are a critical component of a windblown dust activity monitoring network, providing near-real-time "eyes" that are always on, tracking and recording dust plume activity continuously over large areas. To provide full coverage, video networks routinely consist of several strategically placed stationary cameras surrounding an area, with the collective fields of view (FOV) providing complete observational coverage. There exists a trade-off with a stationary camera site between FOV and resolution: a high FOV will observe a large area at low resolution, and at focal lengths less than 18mm will also introduce distortion. On the other hand, a large focal length (20mm and higher) will increase resolution but narrow the FOV substantially and necessitate more cameras to observe the same area.

The Roundshot Livecam digital camera observation platform alleviates this trade-off by using a motor-driven scanner to create a horizontal FOV of up to 360°. The camera consists of a 3-linear RGB vertical line sensor coupled with a Nikon Nikkor-style lens (up to 70mm focal length) mounted on a motorized turntable. Turning the base while capturing 1-pixel-wide line "images" creates a single panoramic frame. Thus, the horizontal FOV is not diminished when the focal length is increased, allowing a single station to observe a wide area at high resolution.

1.2 Safety Precautions

- All field staff should carry a working cell phone and wear the appropriate Personal Protective Equipment (PPE).
- Disconnect power before working with electrical components.
- Take normal precautions to avoid electrical shock.

1.3 Sampling Interferences/Precautions

- Check the forecast to ensure safe weather and environmental conditions before visiting a video station. Site visits and maintenance should not occur under high wind or stormy conditions to avoid damaging equipment and injury to the operator.
- Ensure proper grounding for good performance.

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- If vehicle access is necessary, the field vehicle must always be parked a minimum of 10 meters away from the monitoring site.
- All data should be collected using Pacific Standard Time (PST). Configure all field laptops, tablets, on-site computers, and other devices (e.g. a GPS) using PST to prevent accidental computer clock updates to Pacific Daylight Savings Time (PDT).
- The site operator needs to confirm that the video capture software is appropriately configured with the monitoring site ID included in the image filenames. Database and website problems are likely to occur if the site ID is incorrect or absent.

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2.0 SITE LOCATION AND INSTALLATION

2.1 Equipment and Supplies

- Roundshot Assembly
    - Waterproof cover ("hat")
    - Cover screws (3)
    - Insulation ring
    - Roundshot D2 digital scan unit
    - Lens (Nikkor AF-S 18-55mm zoom lens or AF-S 70mm telephoto lens)
    - Motor electronics unit (turntable base)
    - Silica gel pack
    - Waterproof power/communications connector
    - Mast holder
    - Power and Ethernet cables with waterproof plugs
- NEMA[1] Enclosure
    - Router
    - Compact PC (eee box PC, fitPC, or similar) with 2 GB RAM and ≥256GB HDD
    - Mimo monitor, flexible rugged keyboard, mini-mouse (for PC operation on-site)
- "Job box" battery enclosure (3 enclosures; only one enclosure will contain the power system)
    - Charge regulator (1)
    - Combiner Box (1)
    - Power-Over-Ethernet (POE) Adapter for the NanoBridge (1)
    - 110ah external storage batteries (8 total, max. 3 per enclosure)
    - Pre-fab 24"–36" cables for joining the batteries in parallel
- 90 W solar panel with mounting bracket
- NanoBridge M5 Ethernet radio with antenna
- 20' tripod with anchors and guy-wire kit
- Grounding package, including 6' copper grounding rod, clamp, cable, and lightning rod
- Various U-Bolts
- Portable GPS unit with monitoring site location file pre-loaded
- T-Post pounder

[1] National Electrical Manufacturers Association

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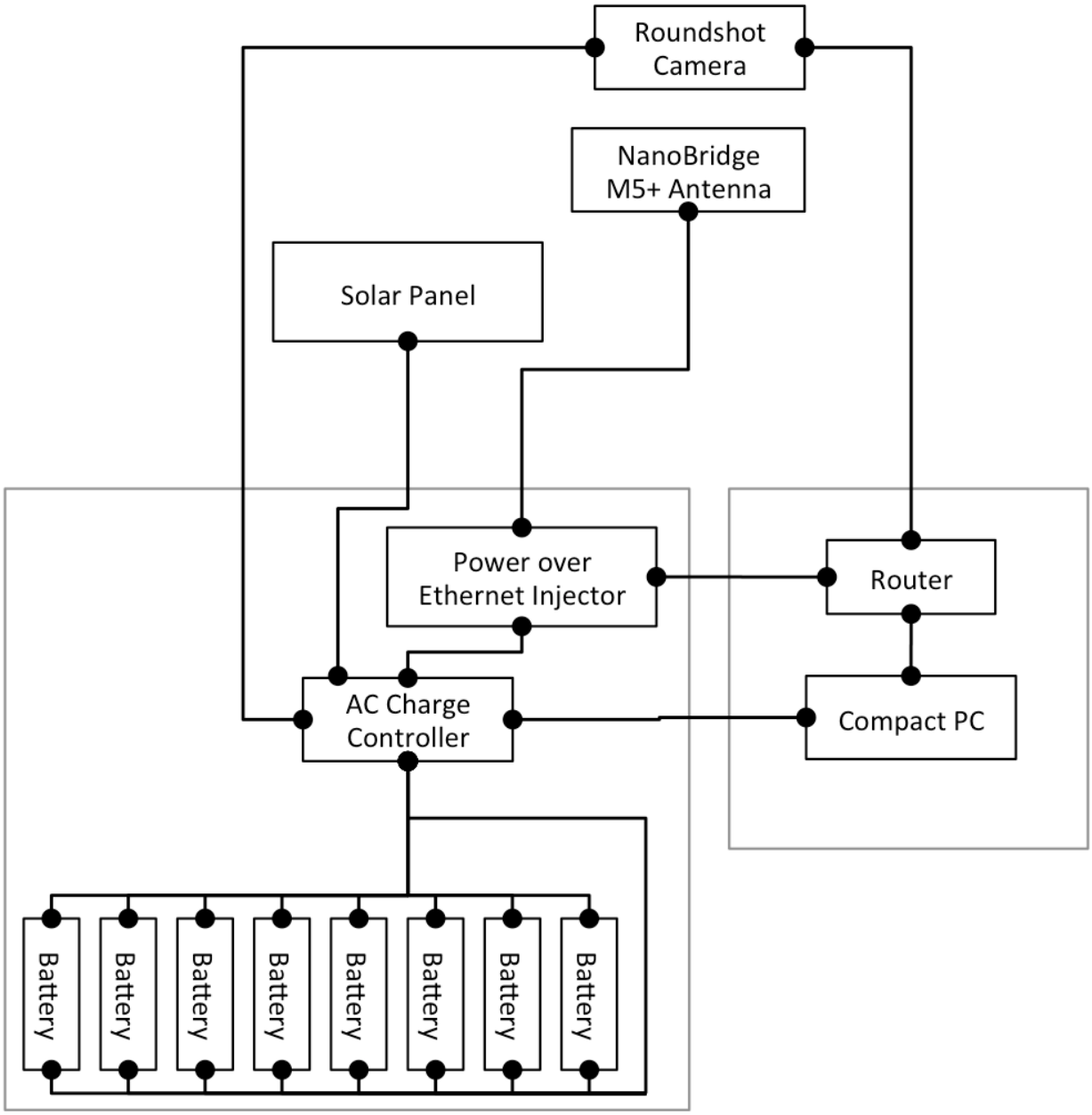
- Packing putty
- Small straight-bladed screwdriver
- Large Allen keys
- Metric measuring tape
- Combination wrench set
- 3″ waterproof tape

2.2 Wiring Diagram

The wiring diagram for the instruments, datalogger, and power system is shown below.



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2.3 Roundshot Monitoring Site Location and Installation

1. Before deploying, prepare the enclosure by installing the back plate on the back wall. Make sure there is an accessible wiring access port at the left back side of the enclosure. Mount the AC charge controller, POE Adaptor, combiner box, and inverter to the back plate.
2. Wire the charge controller, combiner box, and inverter. Refer to TriStar Solar System Controller Installation and Operation Manual pp. 9–18.
3. Prepare the compact PC by loading the Roundshot software and configuring system settings. Refer to the Roundshot Livecam D2 HD Instruction Manual (Seitz Phototechnik AG, 2013), pp. 9–11 for detailed instructions on preparing the PC. Make sure the PC is set to Pacific Standard Time (PST). Configuring the Roundshot camera with the software is done on-site.
4. Prepare the mast holder. Refer to the Roundshot Livecam D2 HD Instruction Manual (Seitz Phototechnik AG, 2013), pp. 7–8 for detailed instructions on mounting the mast holder to the tripod mast. *An adapter may be required match the inner diameter of the mast holder to the outer diameter of the mast.*
5. Using standard navigation procedures and the portable GPS unit, locate the appropriate monitoring site. The site should be approximately 10' by 10' and generally level with minimal obstructions. All access to the monitoring site should be from the direction that is out of the FOV of the camera as much as possible. **Ensure that all field personnel approach the location only from that preferred direction**. The FOV will be specific to each site and should be recorded during site installation.
6. Begin by installing the tripod. Refer to the Tripod Installation Manual Models CM110, CM115, CM120 (Campbell Scientific, Inc. 2012) for detailed tripod installation instructions.
7. Mount the NEMA enclosure to the north leg of the tripod, leaving at least a two-inch gap between the enclosure and the surface. Arrange the compact PC inside the enclosure.
8. Arrange the job boxes around the tripod. Place three batteries each into two of the boxes, and two into the third box that will contain the AC power system. Ensure the box with the power system is closest to the NEMA enclosure. Connect the batteries in parallel with the pre-fab power cables, making sure the end leads are taped.
9. Attach the solar panel to the south legs of the tripod so the panel faces south. An angle-iron bracket may be used to securely attach the panel. Make sure the ends of the solar panel cables are taped so the leads do not short out.
10. Drive the ground rod into the ground at a convenient location near the enclosures. Attach the grounding clamp and grounding wire to the rod.
11. Lower the mast. Attach a cross-arm to the mast 0.5m from the top of the mast. Attach the lightning rod to the crossarm, then attach the NanoBridge M5 radio antenna just below the

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crossarm. Aim the dish in the direction of the receiving station. Attach the Ethernet cable to the NanoBridge and cable-tie it to the mast.

12. Mount the Roundshot to the top of the mast with the pre-prepared mast holder. Refer to the Roundshot Livecam D2 HD Instruction Manual (Seitz Phototechnik AG, 2013), p. 69 for instructions on proper camera handling. Attach the power and Ethernet cables with waterproof plugs. Label the lead end of the cables so identification on the PC side is easier.
13. Secure the cables to the cross arm and mast using cable ties, allowing slack for adjustment. Raise the mast and collect the cables, securing the cables to the tripod allowing slack at the mast hinge so the mast can be raised and lowered freely.
14. Confirm that the AC charge controller has been turned off, pass all loose leads through the access port in the job box, and then complete all remaining electrical connections:
    - Charge leads from the solar panel to the charge terminals on the AC charge controller
    - Battery cable lead to the combiner box on the AC charge controller
    - Roundshot power plug and compact PC plug to the inverter included with the AC charge controller
    - Roundshot and compact PC Ethernet cables to the router
    - The Ethernet cable from the NanoBridge to the POE adaptor
    - An Ethernet cable from the router to the POE adaptor
    - Ground wire between the ground lug on the underside of the enclosure to the clamp on the ground rod
15. Firmly pack putty around the wiring access ports in the NEMA enclosure and job boxes in an effort to prevent moisture and insects from entering the enclosures.
16. Carefully loop and wrap all loose leads to a convenient location on the tripod using cable ties.
17. Turn on the AC charge controller and compact PC. Verify that the PC clock is set to PST.
18. Configure the Roundshot camera. Configuration includes adjusting the tilt angle, which will require lowering the mast (potentially several times), and programming the image collection characteristics. Refer to the Roundshot Livecam D2 HD Instruction Manual (Seitz Phototechnik AG, 2013), pp. 12–44 for detailed instructions on camera configuration. To determine the camera degree of rotation, starting point, and end point; the collection frequency; and the image resolution, refer to the monitoring study plan.
19. Once the camera is configured, lower the mast once more and secure the camera dome to the mast assembly. Place a silica gel pack inside the dome, making sure that will not obstruct the camera once the mast is raised, and secure dome with the rubber O-Ring and screws. Finish sealing the dome seam by wrapping it with waterproof tape.
20. When all instrumentation is installed and operating, begin a site log entry, either electronically on a field laptop or using the hard copy forms provided in Appendix A.

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2.4 Data Records and Management

After the site installation is complete and the station is under stable operating conditions, the field technician must complete the initial Site Check Form electronically on the most recent "Field_Site_Logger"workbook. This workbook can be found on the "Salton Sea Field Operations" Dropbox folder.

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3.0 SITE VISIT PROCEDURES

3.1 Field Collection Procedures

If the camera images are being telemetered, the images should be checked prior to the site visit to confirm that the cameras are operating and identify possible issues. Refer to the Roundshot Livecam D2 HD Instruction Manual (Seitz Phototechnik AG, 2013), pp. 69–72 for maintenance and troubleshooting.

It is best to walk to each site; if an ATV is used for access, the vehicle must be parked no closer than 10 m from the monitoring site.

1. Before leaving the field office, ensure that you have extra waterproof tape, silica gel packs, lens cleaner, and a can of compressed air in case the camera dome must be unsealed and cleaned.
2. Begin by recording the "Start Time" on the electronic Site Check Form in the most recent "Field_Site_Logger"workbook. Continue by entering data in the appropriate fields on the Site Check Form.
3. Inspect the station for any obvious damage, alignment issues, excessive dirt build-up, loose wiring connections, frayed or chewed cables, or vandalism. Record all corrective actions on the Site Check Form.
4. Lower the mast, wipe clean the camera dome window, and look for evidence of moisture or dust inside the dome. If moisture/dust is seen, check the appropriate box in the site log and proceed with inspecting and cleaning the camera assembly:
    a. Look for evidence of damage to the dome seal or any other possible entry point for water/dust, noting this in the site log.
    b. Unseal the dome by removing the waterproof tape. Clean the inside of the dome and rest it in a relatively clean spot (such as inside a job box) to prevent damage or dirtying.
    c. Clean the camera assembly by dusting with compressed gas. Clean the camera lens with a lens cleaner. Inspect the assembly for damage (e.g. rusting) and then promptly reseal the dome, applying fresh waterproof tape around the seam.
5. Unlock the job box that contains the charge controller. Check the status (including voltage) of the solar power system by viewing the indicator lights on the front of the charge controller. Anything other than a solid green light may mean a problem with the power system. Refer to TriStar Solar System Controller Installation and Operation Manual Appendix 3 for detailed information on status indicators and troubleshooting. Note any corrective actions in the Site Log.
6. Unlock the NEMA enclosure and connect to the PC with the Mimo monitor, keyboard, and mouse stored on-site. Check the computer clock and adjust if necessary, noting any changes in the Site Log.
7. Finish the field collection by recording the "End Time" on the electronic Site Check Form prior to leaving the sampling location.

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3.2 Data Records and Management

Field personnel must maintain a thorough and complete set of site visit records. Every maintenance or data download visit must be recorded on the Site Check Form electronically in the most recent "Field_Site_Logger." This workbook can be found on the "Salton Sea Field Operations" Dropbox folder.

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4.0 REFERENCES

Air Sciences Inc. 2015a. *Standard Operating Procedure: Calibration and Audit Procedures for the Met One 024A Wind Direction Sensor*

Air Sciences Inc. 2015b. *Standard Operating Procedure: Calibration and Audit Procedures for the Met One 014A Wind Speed Sensor.*

Air Sciences Inc. 2015c. *Standard Operating Procedure: Configuration and Operation of the Campbell Scientific CR6 Dataloggers.*

Campbell Scientific Inc. 2015. *Tripod Installation Manual Models CM110, CM115, CM120.* https://s.campbellsci.com/documents/us/manuals/cm110-cm115-cm120.pdf. Accessed October 6, 2015.

Environmental Protection Agency. 2007. *Guidance for Preparing Standard Operating Procedures (SOPs).* EPA/600/B-07/001. April 2007. http://www2.epa.gov/sites/production/files/2015-06/documents/g6-final.pdf. Accessed October 6, 2015.

Seitz Phototechnik AG. 2013. *Roundshot Livecam D2 HD Instruction Manual.* Seitz Phototechnik AG Hauptstr. 14 8512 Lustdorf / Switzerland. May 2013.

TriStar Solar. Nd. *Solar System Controller Installation and Operation Manual.* Morningstar Corporation 1098 Washington Crossing Road Washington Crossing, PA 18977 USA.

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Appendix A: Site Check Form

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VIDEO MONITORING PROGRAM
SITE CHECK FORM

Date:	Start Time (PST):
Operator(s):	End Time (PST):
Site ID:	Battery Voltage:
Visual Inspection: ☐ Pass ☐ Fail	Observations:

Computer Information

Serial #:	Type:
☐ Data Download	Final Data Record Date/Time:

Maintenance and Operations

☐ Solar Panel Cleaned	☐ Computer Clock Check	Reset Clock? ☐ Yes ☐ No
☐ Camera Dome Window Cleaned	☐ Ground/Wiring Connection Check	Fittings Secure? ☐ Yes ☐ No

Comments:

Video Equipment Check

Camera Serial Number:	
Ethernet Bridge Tested? ☐ Yes ☐ No	Ethernet Bridge Serial Number:
Evidence of water/dust intrusion into the dome? ☐ Yes ☐ No	Camera Response to Manual Test? ☐ Yes ☐ No
Evidence of computer reboot? ☐ Yes ☐ No	Silica gel pack inside camera dome replaced? ☐ Yes ☐ No
Evidence of tampering/vandalism? ☐ Yes ☐ No	Solar power system status normal? ☐ Yes ☐ No

Comments:

Unusual Occurrences or Weather:

Signature: _____

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Appendix B: Solar Panel Wiring Diagram

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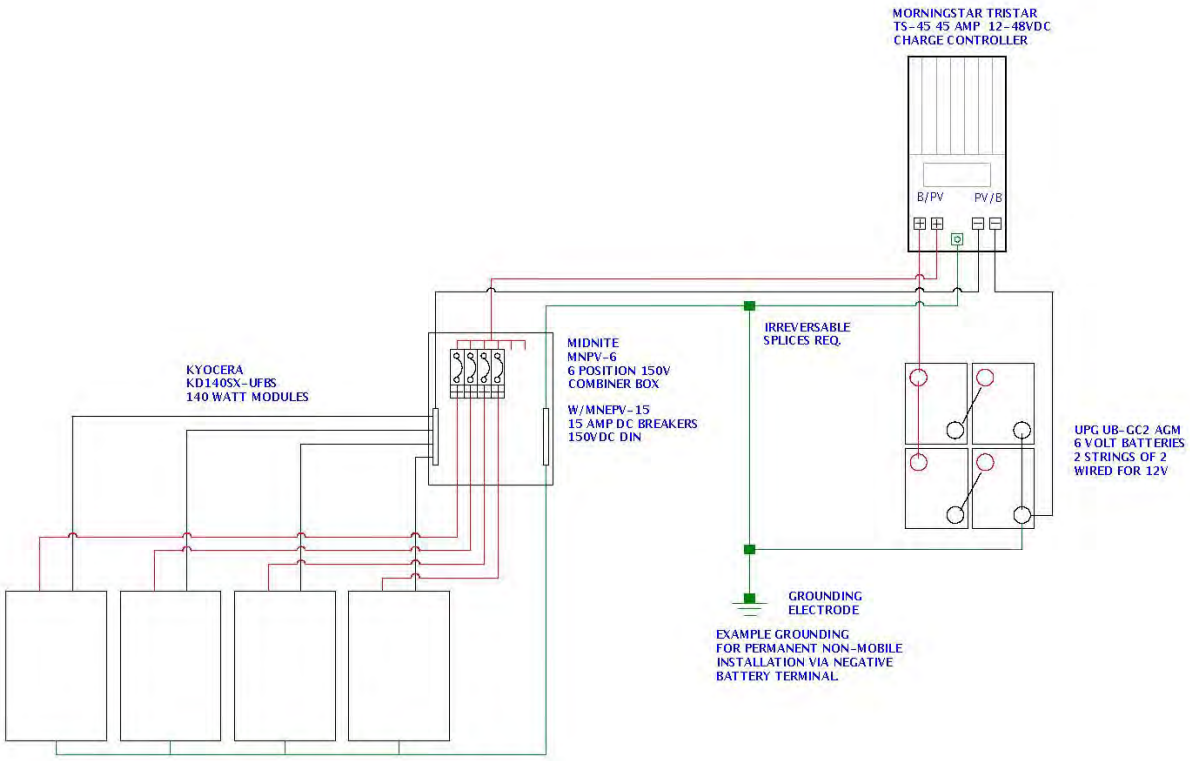
Wholesale Solar
DC Off-Grid Wire Diagram
for Air Sciences

12 VOLT SYSTEM



IMPORTANT:

READ ALL MANUALS COMPLETELY PRIOR TO INSTALLATION OF SYSTEM COMPONENTS & WIRING FOR ADDITIONAL & CRITICAL INSTALLATION SEQUENCES, SAFETY INFORMATION, & OPERATION PROCEDURES.

BATTERIES MUST BE CONNECTED TO CHARGE CONTROLLER PRIOR TO PV MODULE CONNECTIONS FOR PROPER SYSTEM FUNCTION.

ALL WIRING MUST COMPLY WITH NEC GUIDELINES AND LOCAL AUTHORITY HAVING JURISDICTION.

THIS DRAWING DEPICTS TYPICAL WIRING PATHS. IT MAY NOT REPRESENT THE ACTUAL LAYOUT OF THE EQUIPMENT OR LOCATION OF WIRING TERMINATION LOCATIONS.

PLEASE REFER TO THE SUPPLIED MANUALS AND LABELS FOR ACTUAL LOCATIONS.

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APPENDIX D.4.
STANDARD OPERATING PROCEDURES: STARDOT TECHNOLOGIES SC H.264

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Standard Operating Procedure
StarDot Technologies SC H.264 Installation and Operation at Salton Sea

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3.1 Sample Tube Preparation (for CSC Tubes not Obtained from District) **Error! Bookmark not defined.**
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Appendices

Appendix A: Example Sensit Wiring Conventions
Appendix B: Sand Flux Monitoring Site Check and Audit Form
Appendix C: Scientech Electronic Balance Operation
Appendix D: Sample CSC Weigh Data Sheets

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1.0 INTRODUCTION

This document describes the procedures for properly locating, installing, and operating a Roundshot Livecam D2 video monitoring station for use in the Salton Sea Air Basin. The station consists of a digital scan unit, lens, motor unit, weatherproof viewing enclosure, and mast holder for the video system; a solar power system; and data storage and telemetry equipment. This document has been written specifically for application to Salton Sea project and may not be applicable to other jobsite locations.

This document is in accordance with the Environmental Protection Agency's *Guidance for Preparing Standard Operating Procedures (SOPs)* (EPA 2007).

1.1 Principles of Operation

Video observations are a critical component of a windblown dust activity monitoring network, providing near-real-time "eyes" that are always on, tracking and recording dust plume activity continuously over large areas. To provide full coverage, video networks consist of several strategically placed stationary cameras surrounding an area, with the collective fields of view (FOV) providing complete observational coverage. There exists a trade-off with a stationary camera site between FOV and resolution: a high FOV will observe a large area at low resolution, and at focal lengths less than 18mm will also introduce distortion. On the other hand, a large focal length (20mm and higher) will increase resolution but narrow the FOV substantially and necessitate more cameras to observe the same area. In addition, high-resolution images require more available bandwidth to transfer data for remote observation.

The StarDot SC H.264 digital camera provides maximum flexibility to achieve optimum FOV and resolution by employing a scalable RGB sensor, up to 10 megapixel (MP) resolution, and allowing the use of vari-focal lenses. The camera IP-ready and is equipped with Power over Ethernet (PoE), with a single Ethernet cable powering the device and transferring data. Image capture is configurable by setting the resolution, saturation, contrast, exposure (shutter speed), and color balance.

1.2 Safety Precautions

- All field staff should carry a working cell phone and wear the appropriate Personal Protective Equipment (PPE).
- Disconnect power before working with electrical components.
- Take normal precautions to avoid electrical shock.

1.3 Sampling Interferences/Precautions

- Check the forecast to ensure safe weather and environmental conditions before visiting a video station. Site visits and maintenance should not occur under high wind or stormy conditions to avoid damaging equipment and injury to the operator.
- Ensure proper grounding for good performance.

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- If vehicle access is necessary, the field vehicle must always be parked a minimum of 10 meters away from the monitoring site.
- All data should be collected using Pacific Standard Time (PST). Configure all field laptops, tablets, on-site computers, and other devices (e.g. a GPS) using PST to prevent accidental camera clock updates to Pacific Daylight Savings Time (PDT).
- The site operator needs to confirm that the video capture software is appropriately configured with the monitoring site ID included in the image filenames. Database and website problems are likely to occur if the site ID is incorrect or absent.

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2.0 SITE LOCATION AND INSTALLATION

2.1 Equipment and Supplies

- StarDot camera Assembly
    - Dotworkz ST-BASE outdoor enclosure
    - StarDot SC H.264 camera
    - StarDot 8–48mm vari-focal lens (LEN-M848MN)
- Tripp Lite outdoor rated 100-ft. patch cable
- Battery Enclosure (3-battery)
    - Veracity Power-over-Ethernet (PoE) injector
    - Sunsaver 10A 12V voltage regulator
    - Campbell Scientific backplate (18826)
    - 100ah external storage batteries (2 total)
    - Battery cables
- 90 W solar panel with mounting bracket
- NanoBridge M5 Ethernet radio with antenna
- 20‘ tripod with anchors and guy-wire kit
- One 4-foot cross-arm with support brackets
- 6’ Copper grounding rod, clamp, and cable
- Various U-Bolts
- Portable GPS unit with monitoring site location file pre-loaded
- Field laptop with an Ethernet jack, Ethernet cable, and a standard web browser for configuring camera settings
- T-Post pounder
- Packing putty
- Small straight-bladed screwdriver
- Metric measuring tape
- Combination wrench set

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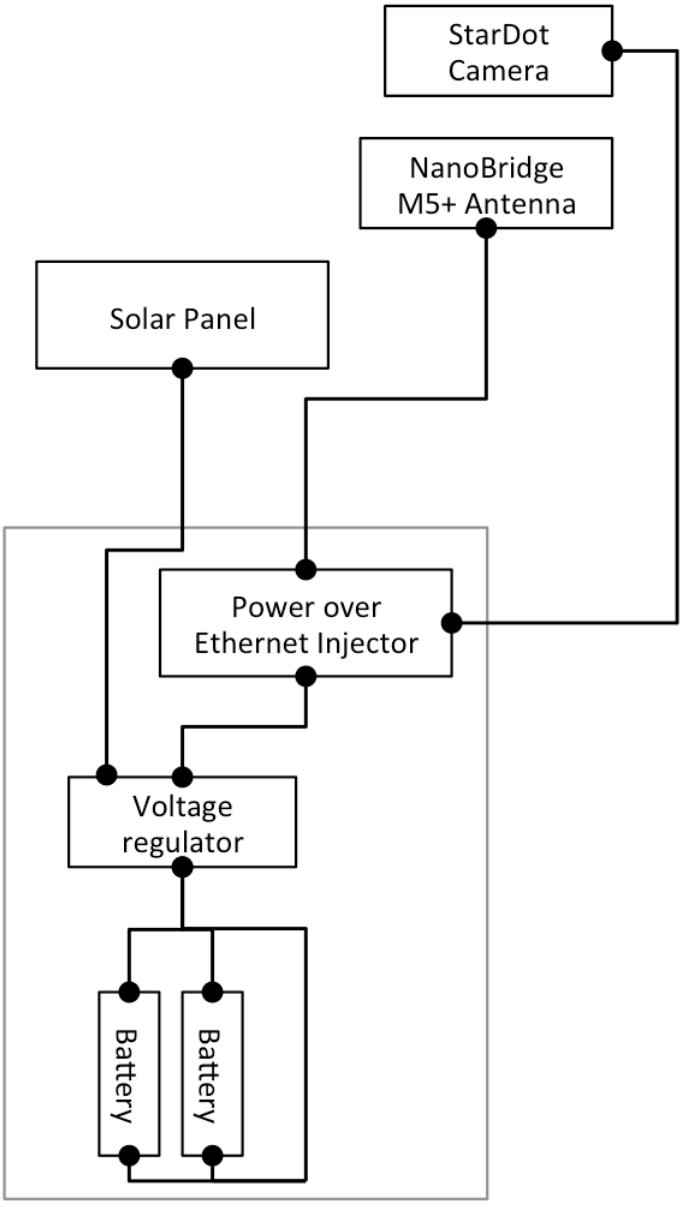
2.2 Wiring Diagram

The wiring diagram for the instruments, communications, and power system is shown below.



2.3 StarDot Monitoring Site Location and Installation

1. Before deploying, prepare the enclosure by installing the back plate on the back wall. Make sure there is an accessible wiring access port at the left back side of the enclosure. Mount the voltage regulator and PoE Adaptor to the back plate.

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2. Make sure the field laptop is set to Pacific Standard Time (PST). Configure the StarDot camera network and assign it an IP address. Refer to the NetCam SC H.264 Mexapixel Hybrid IP Camera User's Manual (StarDot Technologies, 2010), pp. 7–8 for detailed instructions. Bookmark the IP address (e.g. http://192.168.1.5) in the field laptop web browser; the remainder of the camera configuration is done on-site via a web browser.
3. Using standard navigation procedures and the portable GPS unit, locate the appropriate monitoring site. The site should be approximately 10′ by 10′ and generally level with minimal obstructions. All access to the monitoring site should be from the direction that is out of the FOV of the camera as much as possible. **Ensure that all field personnel approach the location only from that preferred direction**. The FOV will be specific to each site and should be recorded during site installation.
4. Begin by installing the tripod. Refer to the Tripod Installation Manual Models CM110, CM115, CM120 (Campbell Scientific, Inc. 2015) for detailed tripod installation instructions.
5. Mount the enclosure to the north leg of the tripod, leaving at least a two-inch gap between the enclosure and the surface. Arrange the batteries inside the enclosure. Connect the batteries in parallel with the power cables, making sure the end leads are taped.
6. Attach the solar panel to the south legs of the tripod so the panel faces south. An angle-iron bracket may be used to securely attach the panel. Make sure the ends of the solar panel cables are taped so the leads do not short out.
7. Drive the ground rod into the ground at a convenient location near the enclosures. Attach the grounding clamp and grounding wire to the rod.
8. Lower the mast and mark the 4-m height. Attach the lightning rod to the very top of the mast, then attach the NanoBridge M5 radio antenna just below. Aim the dish in the direction of the receiving station. Attach an Ethernet cable to the NanoBridge and cable tie it to the mast.
9. Mount the camera enclosure to the mast with a U-Bolt using the 4-m mark as a reference. Place the camera inside the enclosure and connect an Ethernet cable to the NET port on the back of the camera. Seal the enclosure, placing a silica gel pack inside to reduce moisture.
10. Secure the cables to the cross arm and mast using cable ties, allowing slack for adjustment. Raise the mast and collect the cables, securing the cables to the tripod allowing slack at the mast hinge so the mast can be raised and lowered freely.
11. Confirm that the voltage regulator has been turned off, pass all loose leads through the access port in the enclosure, and then complete all remaining electrical connections:
    - Charge leads from the solar panel to the charge terminals on the voltage regulator
    - Battery cable lead to the voltage regulator
    - NanoBridge Ethernet cable and camera Ethernet cable to the PoE adapter
    - Ground wire between the ground lug on the underside of the enclosure to the clamp on the ground rod

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12. Firmly pack putty around the wiring access ports in the enclosure in an effort to prevent moisture and insects from entering the enclosures.
13. Carefully loop and wrap all loose leads to a convenient location on the tripod using cable ties.
14. Turn on the voltage regulator. Unplug the NanoBridge from the PoE adapter and plug in the field laptop.
15. Configure the StarDot camera using the field laptop. Configuration includes adjusting the tilt angle, which will require lowering the mast (potentially several times), and programming the image collection characteristics. Refer to the NetCam SC H.264 Mexapixel Hybrid IP Camera User's Manual (StarDot Technologies, 2010), pp. 12–40 for detailed instructions on camera configuration. Ensure the timezone is set to PST. Leave settings for contrast, exposure, and image quality in the "auto" or default mode. To determine the camera collection frequency; data transfer delay; and the camera resolution, refer to the monitoring study plan.
16. Once configuration is complete, plug the NanoBridge back in to the PoE adapter.
17. When all instrumentation is installed and operating, begin a site log entry, either electronically on a field laptop or using the hard copy forms provided in Appendix A.

2.4 Data Records and Management

After the site installation is complete and the station is under stable operating conditions, the field technician must complete the initial Site Check Form electronically on the most recent "Field_Site_Logger"workbook. This workbook can be found on the "Salton Sea Field Operations" Dropbox folder.

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3.0 SITE VISIT PROCEDURES

3.1 Field Collection Procedures

If the camera images are being telemetered, the images should be checked prior to the site visit to confirm that the cameras are operating and identify possible issues.

It is best to walk to each site; if an ATV is used for access, the vehicle must be parked no closer than 10 m from the monitoring site.

1. Before leaving the field office, ensure that you have extra silica gel packs, waterproof tape, lens cleaner, and a can of compressed air in case the camera enclosure must be unsealed and cleaned.
2. Begin by recording the "Start Time" on the electronic Site Check Form in the most recent "Field_Site_Logger"workbook. Continue by entering data in the appropriate fields on the Site Check Form.
3. Inspect the station for any obvious damage, alignment issues, excessive dirt build-up, loose wiring connections, frayed or chewed cables, or vandalism. Record all corrective actions on the Site Check Form.
4. Lower the mast, wipe clean the camera enclosure window, and look for evidence of moisture or dust inside the dome. If moisture/dust is seen, check the appropriate box in the site log and proceed with inspecting and cleaning the camera assembly:
    a. Look for evidence of damage to the enclosure seal or any other possible entry point for water/dust, noting this in the site log.
    b. Unseal the enclosure. Remove the camera, resting it in a relatively clean spot (such as inside the battery enclosure) to prevent damage or dirtying, and clean the inside of the enclosure.
    c. Clean the camera assembly by dusting with compressed gas. Clean the camera lens with a lens cleaner. Inspect the assembly for damage (e.g. rusting) and then promptly return to enclosure and reseal, applying waterproof tape around the seam if necessary.
5. Unlock the battery enclosure and connect a field laptop to the PoE adapter. Check the camera clock and adjust if necessary, noting any changes in the Site Log.
6. Finish the field collection by recording the "End Time" on the electronic Site Check Form prior to leaving the sampling location.

3.2 Data Records and Management

Field personnel must maintain a thorough and complete set of site visit records. Every maintenance or data download visit must be recorded on the Site Check Form electronically in the most recent "Field_Site_Logger." This workbook can be found on the "Salton Sea Field Operations" Dropbox folder.

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4.0 REFERENCES

Campbell Scientific Inc. 2015. *Tripod Installation Manual Models CM110, CM115, CM120.* https://s.campbellsci.com/documents/us/manuals/cm110-cm115-cm120.pdf. Accessed October 6, 2015.

StarDot Technologies. 2010. NetCam SC H.264 Mexapixel Hybrid IP Camera User's Manual. 6820-H StarDot Technologies. Orangethorpe AveBuena Park, CA 90620 U.S.A.

Environmental Protection Agency. 2007. *Guidance for Preparing Standard Operating Procedures (SOPs).* EPA/600/B-07/001. April 2007. http://www2.epa.gov/sites/production/files/2015-06/documents/g6-final.pdf. Accessed October 6, 2015.

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Appendix A: Site Check Form

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VIDEO MONITORING PROGRAM
SITE CHECK FORM

Date:	Start Time (PST):
Operator(s):	End Time (PST):
Site ID:	Battery Voltage:
Visual Inspection: ☐ Pass ☐ Fail	Observations:

Computer Information

Serial #:	Type:
☐ Data Download	Final Data Record Date/Time:

Maintenance and Operations

☐ Solar Panel Cleaned	☐ Camera Clock Check	Reset Clock? ☐ Yes ☐ No
☐ Camera Enclosure Window Cleaned	☐ Ground/Wiring Connection Check	Fittings Secure? ☐ Yes ☐ No

Comments:

Video Equipment Check

Camera Serial Number:

Ethernet Bridge Tested? ☐ Yes ☐ No	Ethernet Bridge Serial Number:
Evidence of water/dust intrusion into the dome? ☐ Yes ☐ No	Camera Response to Manual Test? ☐ Yes ☐ No
Evidence of camera malfunction? ☐ Yes ☐ No	Silica gel pack inside camera enclosure replaced? ☐ Yes ☐ No
Evidence of tampering/vandalism? ☐ Yes ☐ No	Solar power system status normal? ☐ Yes ☐ No

Comments:

Unusual Occurrences or Weather:

Signature: _____

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APPENDIX D.5.
STANDARD OPERATING PROCEDURES:
SOP 4, GROUNDWATER SAMPLING AND WATER LEVEL MEASUREMENTS

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FORMATION ENVIRONMENTAL

STANDARD OPERATING PROCEDURE No. 4

GROUNDWATER SAMPLING AND WATER LEVEL MEASUREMENTS

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed during measurement of water levels and depths of monitoring wells and piezometers, and for water quality sampling from monitoring wells. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate modifications to the procedures may be made to accommodate project-specific protocols when approved in writing or via email by the Project Manager.

The objectives of the groundwater sampling procedures are to minimize changes in groundwater chemistry during sample collection and to maximize the probability of obtaining a representative, reproducible groundwater sample.

2.0 BASIS FOR METHODOLOGY

The methods and procedures described in this SOP were developed from these sources:

- USEPA Standard Operating Procedure for the Standard/Well-Volume Method for Collecting a Ground-Water Sample from Monitoring Wells for Site Characterization.
- USEPA Region 1 (2010) Low Stress (low flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells. EQASOP-GW-001. Region 1 Low-Stress (Low-Flow) SOP, Revision Number 3, July 30, 1996, Revised January 19, 2010.
- USEPA (2002) Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Ground Water Forum Issue Paper. U.S Environmental Protection Agency, Technology Innovative Office, Office of Solid Waste and Emergency Response, Washington D.C., EPA 542-S-02-001.
- U.S. Geological Survey (USGS) (variously dated) National Field Manual for the Collection of Water-Quality Data: U.S. Geological Survey

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Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, Chapters A1-A9.

3.0 WATER LEVEL AND WELL DEPTH MEASURMENT PROCEDURES

Prior to performing water level and well depth measurements, the construction details and previous measurements for each well or piezometer shall be reviewed by the field geologist or other field personnel so any anomalous measurements may be identified. Well construction details and previous measurements shall be available in the field for review.

In general, water-level measurements shall be performed before groundwater is removed from the well by purging or sampling.

3.1 Equipment

Equipment that may be necessary to perform measurements (depending on measurements to be performed):

- Well/piezometer construction details;
- An electronic water-level meter with accuracy of 0.01 foot;
- Water Level Monitoring Record Sheet, Groundwater Sampling Record or field notebook; and
- Weighted surveyor's rope (measured to the nearest 0.1 foot).

3.2 Measuring Point

A measuring point (MP) shall be selected and marked for each monitoring well and piezometer in which water level measurements will be made. Generally, the MP will be on the north side of the top of the well casing. The MP will be permanently marked using an indelible marker or a notch cut into the PVC casing. When the top-of-casing elevation of a monitoring well or piezometer is surveyed, the licensed surveyor shall measure the MP elevation and reference this measurement to an appropriate datum (such as feet above mean sea level).

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3.3 Water Level Measurements

When water levels are measured to describe the groundwater potentiometric surface, the water level will be measured prior to purging. All wells to be gauged during a monitoring event and used to construct the potentiometric surface should have water levels measured within the same 24-hour period, as practical. All water level measurements will be recorded to the nearest 0.01 foot. Instruments used for each measurement will be noted on the Groundwater Sampling Record (attached form or similar). Water levels are measured using the electronic probe method, as discussed below.

An electronic probe consists of a contact electrode attached to the end of an insulated electrical cable, and a reel which houses an ammeter, a buzzer, or other closed circuit indicator. The indicator shows a closed circuit and flow of current when the electrode touches the water surface.

The procedure for measuring water levels with an electric probe is as follows:

1. Switch on and test that the battery is charged and set the sensitivity dial to the middle position.

2. Lower the probe into the well until the ammeter or buzzer indicates a closed circuit. Raise and lower the probe slightly until the shortest length of cable that gives the maximum response on the indicator is found.

3. With the cable in this fixed position, note the depth to water from the Measuring Point (MP).

4. Repeat as necessary until at least two identical duplicate measurements are obtained.

Calibration of the electronic probe will be checked at regular intervals as part of regular maintenance measuring the position of the electrode to check that the calibration marks on the electronic probe correspond to those on a weighted surveyor's rope or other suitable measuring device.

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3.4 Well Depth Measurements

The total depth of a well shall be measured by sounding with a weighted surveyor's rope or other suitable measuring device. For shallow wells, the electronic water-level probe may also be used as a measuring device. Procedures to be followed are specified below.

A. For calibration, measure the distance between the zero mark on the end of the measuring tape and the bottom of the weight to the nearest 0.1 foot at the beginning of each well depth measurement activity day, and whenever the apparatus is altered.

B. To measure well depth, lower a weighted tape into the well until the tape becomes slack or there is a noticeable decrease in weight, which indicates the bottom of the well. Care should be taken to lower the tape slowly to avoid damage to the bottom of the well by the weight. Raise the tape slowly until it just becomes taut, and with the tape in this fixed position, note the tape reading opposite the MP to the nearest 0.1 foot. Add the values from the distance from the end of the tape to the end of the weight together, round this number to nearest 0.1 foot, and record the resulting value as "Total Depth (feet [ft], below measuring point [BMP])" on the Groundwater Sampling Record or field notebook.

3.5 Documentation and Records Management

Water levels observed in wells selected for the groundwater level monitoring program will be tabulated on the Groundwater Sampling Record form during each monitoring period (in print or electronic format – see attached form) or in the field notebook. The date and time of each measurement will also be recorded in the field. All water level measurements shall be recorded to the nearest 0.01 foot, and all depth measurements shall be noted to the nearest 0.1 foot.

Water level data will be recorded as feet BMP so that water level elevations may be calculated from the depth-to-water measurement (from the MP) and the surveyed elevation of the MP at each well or piezometer. The MP will also be described and documented in the Groundwater Sampling Record and/or field notebook (i.e., top of PVC casing, top of protective casing, or below ground surface).

Well depth measurements may also be recorded on the Groundwater Sampling Record.

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4.0 GROUNDWATER SAMPLE COLLECTION PROCEDURES

4.1 Low Flow Sample Collection

For wells that are sampled for regulatory compliance, a low flow sample collection technique shall be employed whenever possible to ensure that representative groundwater samples are collected from each well. Additionally, low flow sampling is to be the preferred method for groundwater sampling unless site specific conditions warrant a volume-based approach or a non-purge approach such as a HydraSleeve™ (as discussed in Sections 4.2 and 4.3, respectively).

A. Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference MP on the well casing with an electronic water level indicator or steel tape and recorded.

B. For wells with non-dedicated equipment (i.e., no dedicated tubing, pump, or docking station), place the pump at the wellhead and slowly lower the pump and tubing down into the well until the location of the pump intake is set to the midpoint of the screened interval, unless otherwise specified in the monitoring plan. Care should be taken to minimize disturbance to the water column during insertion of the pump. A variable rate submersible centrifugal or positive displacement type pump (i.e., bladder or piston pump) will be used for purging and sampling; however, if the water table is less than 20 ft below ground surface (bgs) a peristaltic pump may be employed as long as the constituents measured are not influenced by negative pressures. The pump and associated tubing used shall be constructed of inert materials and compatible with the parameter(s) to be collected. The placement of the pump intake should be positioned with a calibrated sampling pump hose, sounded with a weighted-tape or using a pre-measured hose. Refer to the available well information to determine the depth and length of the screened interval. The pump should be adequately supported once it has been lowered to ensure that it will not shift during purging. Record the depth of the pump intake after lowering the pump into location. For wells with dedicated pumping equipment, pump depth should be confirmed and equipment condition recorded.

C. Measure the water level (nearest 0.01 feet) and record the information on the Groundwater Sampling Record and/or in the field notebook. The water level indicator should remain in the well to allow for periodic measurement of the water level during purging.

D. Connect the discharge line from the pump to a flow-through cell to measure field water quality parameters. If turbidity measurements are to be collected using a separate instrument from that employed to monitor water quality in the flow through cell, a “T” connection is needed prior to the flow-through cell to allow for the collection of water for turbidity measurements. The discharge line from the flow-through cell must be directed to a container to hold the

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purge water during the purging and sampling of the well.

E. Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Adjust pump speed until little or no drawdown is evident (less than 0.33 ft). If the minimal drawdown that can be achieved exceeds 0.33 feet but remains stable, continue purging until field parameters stabilize. Typically flow rates should be within 0.1 L/min to 0.5 L/min; however highly productive aquifers may allow for higher flow rates to be used. Adjustments to the flow rate to achieve stabilization should be made as quickly as possible to minimize agitation of the water column. It should be noted that this goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on well-specific conditions and site experience.

F. Measure the discharge rate of the pump using a calibrated discharge volume measurement and stopwatch. Also, measure the water level and record both flow rate and water level on the Groundwater Sampling Record and/or in the field notebook. Continue purging, monitor and record water level and pump rate every three to five minutes during purging.

G. During purging, a minimum of one tubing volume (including the volume of water in the pump and flow-cell) must be purged prior to recording the water-quality indicator parameters. Then monitor and record the water-quality indicator parameters every three to five minutes. The water-quality indicator field parameters are turbidity, dissolved oxygen, specific conductance, pH, ORP, and temperature. The parameters are considered to have stabilized if on three successive readings of the water quality field parameters meet the following criteria:

- pH +/- 0.1 S.U.
- Specific Conductance 3% difference
- Temperature +/- 1ºC
- ORP +/- 10 mV
- Turbidity 10% difference for values greater than 10 NTU
- Dissolved Oxygen 10% difference

H. If a stabilized drawdown in the well can't be maintained at 0.33 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is shut off. Begin pumping at a lower flow rate, if the water draws down to the top of the screened interval again, turn pump off and allow for recovery. If two tubing volumes (including the volumes of water in the field pump and flow-cell) have been removed during purging, then sampling can proceed next time the pump is turned on. This information should be noted in the field notebook or Groundwater Sampling Record.

I. If specified in the monitoring plan, a clean plastic disposable apron may be placed adjacent to or around the well to prevent equipment and sample containers from coming into contact with surface materials, prior to collecting samples from a well. Alternatively, a clean field table may be set up near the

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well. If used, the table will be cleaned (Section 5.1) before and after use at each well.

J. During sampling, maintain the same pumping rate or reduce slightly for sampling in order to minimize any additional disturbance of the water column. Samples should be collected directly from the discharge port of the pump tubing prior to passing through the flow-cell. The sequence of the sampling is immaterial unless filtered (dissolved) samples are collected which must be done last. All sample containers should be filled with minimal turbulence by allowing the groundwater to flow from the tubing gently down the inside of the container. In the event that the groundwater is turbid (greater than 10 NTUs) a filtered metals sample may be collected. If a filtered metals sample is to be collected, then an in-line filter is fitted at the end of the discharge tubing and the sample is collected after the filter.

Sample bottles that do not contain preservative should be rinsed with the sample water prior to filling.

K. Remove the pump from the well. Decontaminate the pump and tubing if non-dedicated equipment is used.

L. Where more than one well within a specific field or site is to be sampled, the sampling sequence should begin with the well having the lowest suspected level of contamination, if known. Successive samples should be obtained from wells with increasing suspected contamination. If the relative degree of suspected contamination at each well cannot be reasonably assumed, sampling should proceed from the perimeter of the site towards the center of the site. The sampling sequence should be arranged such that wells are sampled in order of increasing proximity to the suspected source of contamination, starting from the wells upgradient of the suspected source.

M. Sampling activity for each monitoring well will be recorded on a Groundwater Sampling Record and the stabilized field parameters may also be recorded in the field notebook.

4.2 Volume-Based Sample Collection

In instances where low-flow sampling is not possible based on site-specific conditions (a minimum and stable drawdown cannot be maintained) samples from wells will be collected using a volume-based approach, if the yield of the well is sufficient, as follows:

A. The depth to water in a well and the total depth will be measured using the procedures discussed in Section 3, above.

B. A positive displacement pump, submersible pump, and/or bailer will be used for removing the groundwater from the monitoring wells (purging). Equipment used for purging and sampling may be permanently installed (dedicated) in

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the monitoring wells. Care must be taken that bailers and/or tubing are constructed from materials that will not affect the sample analyses. The well pump intake is to be set at the midpoint of the screened interval, unless otherwise specified in the monitoring plan in a manner consistent with that specified for the low-flow sampling above. Pumping is to be performed in such manner as to remove stagnant water while trying to minimize exposing the screened interval to atmospheric conditions and obtain the most representative sample.

C. Wells will be pumped or bailed until at least the volume of water removed is equal to three well casing volumes (volume of standing water in the well based upon total depth of well, the depth to water, and the well casing diameter). The purge rate must not reach a point where the recharge water is entering the well in an agitated manner (cascading water over the screen interval) and the water level in the well during purging should not be allowed to drop below the pump intake. During pumping, water level measurements will be collected (as described for low-flow sampling) and the purging rate adjusted to ensure that these conditions do not occur.

D. To ensure that the water samples are representative of the water-yielding zone, periodic measurements of the temperature, pH, dissolved oxygen, ORP, specific conductance and turbidity will be made. A flow-through cell may be used if purging with a pump. Measurements will be recorded for the initial water removed at a minimum following each well volume purged. Note that indicator parameters dissolved oxygen and ORP cannot be accurately measured using discrete samples obtained during bailing (due to exposure to the atmosphere and entrained air becoming trapped in the sampling probe). These parameters will only be collected using a flow-through cell. The sample will be collected only when the indicator parameters have stabilized (as discussed above in Section 4.1). No more than six well volumes should be removed to prevent the effects of over pumping. If the indicator parameters have not stabilized following six well volumes the field instruments will be recalibrated and checked for possible malfunction. If no problems are found, sampling can be conducted; however, the Project Manager will be notified and all information will be recorded in the field notebook and/or Groundwater Sampling Record. If the yield of the well is low such that it can be bailed or pumped dry, then the recharged groundwater in the well will be considered representative regardless of the number of casing volumes of groundwater removed, since all standing water in the well has been replaced by recharge from the water-yielding zone. If a well is purged dry, the well can be sampled upon 90% recovery or after two hours, whichever occurs first.

E. If specified in the monitoring plan, a clean plastic disposable apron may be placed adjacent to or around the well to prevent equipment and sample containers from coming into contact with surface materials, prior to collecting samples from a well. Alternatively, a clean field table may be set up near the well. If used, the table will be cleaned (Section 5.1) before and after use at each well.

F. Sample containers prepared specifically for the required analyses by the analytical laboratory or their supplier will be used for sample collection. Glass

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sample bottles should be filled to near the top. To account for slight expansion due to temperature changes, leave headspace approximately equivalent to the volume of liquid which would fill the bottle's cap. Plastic sample bottles should be filled completely. Splashing of the water in the sample container and exposure to the atmosphere shall be minimized during sampling. The container cap will be screwed on tightly immediately after filling the sample container. Under this protocol, samples should be collected in order of decreasing volatility (i.e., most volatile samples will be collected first). Sample filtration, if necessary, is discussed in Section 4.5 of this SOP.

Sample bottles that do not contain preservative should be rinsed with the sample water prior to filling.

G. Where more than one well within a specific field or site is to be sampled, the sampling sequence should begin with the well having the lowest suspected level of contamination, if known. Successive samples should be obtained from wells with increasing suspected contamination. If the relative degree of suspected contamination at each well cannot be reasonably assumed, sampling should proceed from the perimeter of the site towards the center of the site. The sampling sequence should be arranged such that wells are sampled in order of increasing proximity to the suspected source of contamination, starting from the wells upgradient of the suspected source.

H. Sampling activity for each monitoring well will be recorded on a Groundwater Sampling Record and the stabilized field parameters may also be recorded in the field notebook.

4.3 Non-Purge Sample Collection Using a HydraSleeve™

In monitoring wells with very low yield and/or where low-flow sampling or volume-based purging is not practical, a non-purge method, sampling using a HydraSleeve™, may be used to collect groundwater samples by the following procedure:

A. The depth to water in a well and the total well depth will be measured using the procedures discussed in Section 3, above. This measurement can be used to determine the preferred position of the HydraSleeve within the well screen.

B. Determine the necessary length of HydraSleeves needed for the specific well screen length and/or water column height to recover the necessary sample volume. HydraSleeves are manufactured in standard lengths of 30, 36, and 60 inches. However, up to three 30-inch HydraSleeves may be installed in series on a single tether (using plastic cable ties) to achieve more volume. Alternatively, a TurboSleeve may be used, which is a larger HydraSleeve that allows recovery of more sample volume. Per manufacturer's recommendations, the TurboSleeve should be allowed to equilibrate in the

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well for 24 hours before retrieval to allow for full compression of the sleeve for full sample recovery (see step G below).

C. Measure the correct amount of tether cord needed to suspend the HydraSleeve in the well so the weight will not rest on the bottom of the well and the desired depth is achieved.

D. Remove the HydraSleeve from its packaging, unfold and hold it by its top. Crimp the top of the HydraSleeve by folding the hard polyethylene reinforcing strips at the holes.

E. Attach the spring clip to the holes to ensure the top of the HydraSleeve will remain open until the sampler is retrieved. Attach the tether to the spring clip with a strong knot (or tether can be attached to one of the holes at the top of the HydraSleeve).

F. Fold the flaps with the two holes at the bottom of the HydraSleeve together and slide the weight clip through the holes. Attach the weight to the bottom of the weight clip to ensure the HydraSleeve will descend to the desired depth.

G. To deploy the HydraSleeve, carefully lower the HydraSleeve on its tether to the desired depth in the water column. Hydrostatic pressure will keep the self-sealing check valve at the top of the HydraSleeve closed and ensure that it remains flat and empty and will only fill with groundwater from the desired interval when it is retrieved.

H. To retrieve the HydraSleeve to collect groundwater samples, pull up the tether 30 to 45 inches (36 to 54 inches for longer HydraSleeves) in one smooth motion at a rate of about one inch per second or faster. This motion will open the top check valve and allow the HydraSleeve to fill. When the HydraSleeve is full, the top check valve will close and the full weight of the HydraSleeve can be felt by the sampler. Continue to pull the HydraSleeve upward to the top of the well to retrieve. Two persons are needed to retrieve a TurboSleeve, if used, due to its length and flexibility.

I. Once recovered, decant and discard the small volume of water trapped in the HydraSleeve above the top check valve.

J. To fill sample bottles, remove the discharge tube from its sleeve. While holding the HydraSleeve at the check valve, puncture the HydraSleeve just below the check valve with the pointed end of the discharge tube. Discharge the water into the sample bottles as needed.

K. Any leftover water from the HydraSleeve can be poured into a separate vessel for the measurement of groundwater field parameters as needed.

L. Dispose each used HydraSleeve after use at an individual well.

4.4 Non-Purge Sample Collection by Bailer

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In monitoring wells with very low yield where low-flow sampling or volume-based purging is not practical and sampling with HydraSleeves™ is not feasible, sampling by bailer without purging the well may be used to collect groundwater samples.

Sampling by bailer may be used by the following procedure:

A. The depth to water in a well and the total depth will be measured using the procedures discussed in Section 3, above. This measurement can be used to determine the height of water and the volume of groundwater within the well screen.

B. A clean, sufficiently weighted PVC or polyethylene bailer will be used attached to a pre-measured length of either coated stainless steel cable or nylon rope tether for each well to be sampled by bailing.

C. The bailer will be slowly lowered through the water column to the well screen interval on the pre-measured tether. Slow and consistent movement of the bailer downward through the well allows the water within the well to pass through the bailer.

D. When the desired depth within the well screen interval is reached, the downward movement of the bailer will immediately be reversed and the bailer slowly retrieved to the surface. This action allows the bailer to collect water representative of conditions within the well screen interval while minimizing generation of turbid conditions within the well.

E. Steel cable or rope will not be allowed to touch the ground surface during retrieval. A reel, tub, tarp, or plastic sheeting can be used to prevent contact with the ground.

F. Upon retrieval of the bailer, sample bottles for total and dissolved metals analysis will be filled first, followed by the remaining sample bottles for other parameters. If more sample volume is needed, the bailer will again be slowly lowered to the screen interval and retrieved as necessary until required sample bottles have been filled.

G. If a filtered metals sample is to be collected, the necessary volume can be filtered from one clean, non-preserved sample bottle as needed.

H. Field parameters will be measured in the instrument cup or other rinsed container following collection of sample bottles. A small aliquot of sample volume will be poured from the bailer for the collection of field parameters.

I. If the well bails dry but additional sample volume is required, the volume will be removed from the well via bailer if such recharge occurs in the well within 24 hours.

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4.5 Sample Filtration

When required, a field-filtered water sample will be collected using a disposable, in-line 0.45 micron (μm) filter. The water sample will be pumped through the filter attached directly to the discharge tubing. A peristaltic pump and a clean section of Tygon (polyvinylchloride) tubing, silicone tubing, or other appropriate method may be used if the sample is collected via bailer. The filter cartridge will be rinsed according to the manufacturer's recommendations. If there are no recommendations available, for rinsing pass through a minimum aliquot of 100 ml of sample water prior to collection of sample in to the containers. Both the filter and tubing will be disposed between samples.

4.6 Sample Containers and Volumes

The sample containers will be appropriate to the analytical method and will be obtained from the water analysis laboratory or other approved source. Different containers will be required for specific groups of analytes in accordance with USEPA Methods, project-specific requirements, and/or other local jurisdictional guidance. The sampler will confirm with the laboratory performing the analyses that appropriate bottleware and preservatives are used and ensure that a sufficient volume of sample is collected.

4.7 Sample Labeling

Sample containers will be labeled with self-adhesive tags. Each sample will be labeled with the following information using waterproof ink:

- Project identification;
- Lab Name;
- Sample identification;
- Date and time samples were obtained;
- Matrix;
- Requested analyses and method;
- Bottle type;
- Treatment (preservative added, filtered, etc.);
- Lab QC (if applicable); and
- Initials of sample collector(s).

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4.8 Sample Preservation and Storage

If required by the project or analytical method, water samples submitted for chemical analysis will be stored at 4 ºC in ice-cooled, insulated containers immediately after collection. Preservation and storage methods depend on the chemical constituents to be analyzed and should be discussed with the laboratory prior to sample collection. USEPA and/or other local jurisdictional requirements and/or the requirements of a project-specific plan (e.g., sampling and analysis plan, work plan, quality assurance project plan, etc.) shall be adhered to in preservation and storage of water samples.

4.9 Sample Custody

Samples shall be handled and transported according to the sample custody procedures discussed in JRS SOP No. 2 (SAMPLE CUSTODY, PACKAGING, AND SHIPMENT). Sampling personnel shall document each sample on the Chain-of-Custody Record

4.10 Field Measurements

Specific conductance, pH, dissolved oxygen, ORP, temperature, and turbidity measurements will be performed on water samples at the time of sample collection. The only exceptions will be for DO and ORP when the samples are collected via bailer or in those instances where a flow-through cell cannot be used. Data obtained from these (or other) field water quality measurements will be recorded on the appropriate sampling records or in the field notebook. Separate aliquots of water shall be used to make field measurements (i.e., sample containers for laboratory analysis shall not be reopened).

For groundwater samples, field measurement intervals will be as presented above. If the parameters have not stabilized, check to insure that the field instruments are operating correctly and remain calibrated. Recalibrate the instruments if needed, if an instrument cannot be calibrated it will be labeled needing repair and removed from service. Field measurements and purging will continue until three consecutive readings have stabilized to within the following limits or until a maximum of six casing volumes have been removed:

- pH +/- 0.1 S.U.;

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- Specific Conductance 3% difference;
- Temperature +/- 1ºC;
- ORP +/- 10 mV;
- Turbidity 10% difference for values greater than 10 NTU; and
- Dissolved Oxygen 10% difference.

4.10.1 Temperature Measurement

Temperature will be measured directly from the water source or from a separate sample aliquot. Temperature measurements will be made with a mercury-filled thermometer, bimetallic-element thermometer, or electronic thermistor. All measurements will be recorded in degrees Celsius (°C). When a flow-through cell is used the temperature can be measured directly via a multi-parameter instrument as per the manufacturer's instructions.

4.10.2 pH Measurement

A pH measurement will be made by dipping the probe directly into the water source or into a separate sample aliquot. Prior to measurement, the container in which the field parameter sample will be collected will be acclimated to the approximate temperature of the sample. This can be accomplished by immersing the container in water removed from a well during the purging process. The pH measurement will be made as soon as possible after collection of the field parameter sample, preferably within a few minutes, using a pH electrode. The value displayed on the calibrated instrument will be recorded after the reading has stabilized. If the value falls outside of the calibrated range, then the pH meter will be recalibrated using the appropriate buffer solutions. When a flow-through cell is used, the pH can be measured directly via a multi-parameter instrument as per the manufacturer's instructions.

4.10.3 Dissolved Oxygen

Dissolved oxygen (DO) will be measured by using a suitable multi-parameter meter that can be placed into a flow-through cell and sealed such that exposure to the atmosphere is prevented. DO measurements will be reported in milligrams per liter (mg/L). The instrument will be calibrated in accordance with JRS SOP No. 31 (WATER QUALITY METER CALIBRATION).

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4.10.4 Oxidation Reduction Potential

Oxidation Reduction Potential (ORP) will be measured by using a suitable multi-parameter meter that can be placed into a flow-through cell and sealed such that exposure to the atmosphere is prevented. ORP measurements will be reported in mV. The instrument will be calibrated in accordance with JRS SOP No. 31 (WATER QUALITY METER CALIBRATION).

4.10.5 Specific Conductance Measurement

Specific conductance will be measured by dipping the probe directly into the water source or into a separate sample aliquot. The probe must be immersed to the manufacturer's recommended depth. Specific conductance will be reported in micromhos/cm or microsiemens/cm at 25 ºC. If the meter is not equipped with an automatic temperature compensation function, then the field value will be adjusted at a later time using the temperature data and the following formula:

$$SC_{25} = SC_T / [1 + \{(T - 25) \times 0.025\}]$$

where: SC_{25} = specific conductance at 25 ºC
SC_T = specific conductance measured at temperature T (ºC)
T = sample temperature (ºC)

The value displayed on the calibrated instrument will be recorded after the reading has stabilized. If the value falls outside of the calibrated "range" set by the range dial on the instrument, then the range setting will be changed to a position that gives maximum definition. If the specific conductance value falls outside of the calibrated range of the conductivity standard solution, then the instrument will be recalibrated using the appropriate standard prior to measurement. When a flow-through cell is used the specific conductance can be measured directly via a multi-parameter instrument as per the manufacturer’s instructions.

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4.10.6 Turbidity

Turbidity will be measured by using a field portable nephlometer separate from the multi-parameter meter used for DO and ORP and capable of reading down to 0.1 NTU. Turbidity will be measured directly from the water source or from a separate sample aliquot. The instrument will be calibrated at least daily prior to initiating field activities and periodically throughout the day or as recommended by the instrument manufacturer. Turbidity measurements will be reported in nephlometric turbidity units (NTU). When a flow-through cell is used, the turbidity can be measured directly via a multi-parameter (e.g., YSI Sonde 6920) instrument, if so equipped, as per the manufacturer's instructions.

4.10.7 Equipment Calibration

Equipment used to measure field parameters will be calibrated daily in the field in accordance with JRS SOP No. 31 (WATER QUALITY METER CALIBRATION) prior to any measurements being taken.

5.0 DOCUMENTATION

5.1 Groundwater Sampling Record

Each sampling event for each monitoring well will be recorded on a Groundwater Sampling Record form (which may be in paper or electronic format) or in the field notebook.

The documentation should include the following:

- Project identification;
- Location identification;
- Sample identification(s) (including quality control samples);
- Date and time of sampling;
- Purging and sampling methods;
- Sampling depth;
- Name(s) of sample collector(s);
- Inventory of sample bottles collected including sample preservation (if any), number, and types of sample bottles;
- Total volume of water purged;

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- Results of field measurements and observations (time, cumulative purge volume, temperature, pH, specific conductance, turbidity, sediment, color, purge rate);
- Equipment cleaning record;
- Description and identification of field instruments and equipment; and
- Equipment calibration record; and
- Number of photos (if any were taken).

When the sampling activity is completed, the Groundwater Sampling Record (whether in print or electronic format) will be checked by the Project Manager or his/her designee, and the original record will be placed in the project file.

6.0 QUALITY ASSURANCE/QUALITY CONTROL

6.1 Equipment Decontamination/Cleaning

Steel surveyor's tapes, electric well probes, and other measuring tapes shall be cleaned prior to use and after measurements in each well are completed. Cleaning shall be accomplished by either: (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, final rinsing with distilled or deionized water, or (2) steam cleaning followed by rinsing with distilled or deionized water.

Sample bottles and bottle caps will be pre-cleaned and prepared by the analytical laboratory or their supplier using standard USEPA-approved protocols. Sample bottles and bottle caps will be protected from dust or other contamination between time of receipt by the sampler(s) and time of actual usage at the sampling site.

Groundwater sampling equipment may be dedicated to a particular well at a project site. Prior to installation of this equipment, all equipment surfaces that will be placed in the well or may come in contact with groundwater will be cleaned to prevent the introduction of contaminants.

Sampling equipment that will be used at multiple wells or sampling locations will be cleaned after sampling at each location is completed in accordance with the SOP entitled EQUIPMENT DECONTAMINATION (JRS SOP No. 7).

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Equipment such as submersible electric pumps, which cannot be disassembled for cleaning, will be cleaned by circulating a laboratory-grade detergent (e.g., Alconox) and potable water solution through the assembly, followed by clean potable water from a municipal supply, and then by distilled or deionized water. Equipment cleaning methods will be recorded on the Groundwater Sampling Record.

6.2 Technical and Records Reviews

The Project Manager or designated reviewer will check and verify that documentation has been completed and filed per this procedure.

In addition, all calculations of water-level elevations must be reviewed before they are submitted to the project file and used to describe site conditions. The calculation review should be performed by technical personnel familiar with this procedure. Evidence of the completed review and any necessary corrections to calculations should also be submitted to the project file.

7.0 REFERENCES

U.S. Environmental Protection Agency (USEPA), Region 9. Standard Operating Procedure for the Standard/Well-Volume Method for Collecting a Ground-Water Sample from Monitoring Wells for Site Characterization. Available online at: www.epa.gov/region9/qa/pdfs/finalgwsamp_sop.pdf.

USEPA, 2010. Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells._EQASOP-GW-001 Region 1 Low-Stress (Low-Flow) SOP, Revision Number 3, July 30, 1996, Revised January 19, 2010. http://www.epa.gov/region1/lab/qa/pdfs/EQASOP-GW001.pdf

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Ground Water Forum Issue Paper. U.S Environmental Protection Agency, Technology Innovative Office, Office of Solid Waste and Emergency Response, Washington D.C., Douglas Yeskis, EPA Region 5, Chicago IL, and Bernard Zavala, EPA Region 10, Seattle, WA, EPA 542-S-02-001. May 2002. http://www.epa.gov/superfund/remedytech/tsp/download/gw_sampling_guide.pdf

U.S. Geological Survey (USGS), variously dated. National Field Manual for the Collection of Water-Quality Data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapters A1-A9. Available online at http://pubs.water.usgs.gov/twri9A.

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APPENDIX D.6.
STANDARD OPERATING PROCEDURES:
SOP 7, EQUIPMENT DECONTAMINATION

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STANDARD OPERATING PROCEDURE No. 7

EQUIPMENT DECONTAMINATION

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the methods to be used for decontamination of all reusable field equipment that could become contaminated during use and/or sampling. Field equipment may include split spoons, reusable bailers, trowels, scissors, shovels, hand augers, or any other type of equipment used during field activities. Decontamination is performed as a quality assurance measure and a safety precaution; it prevents cross contamination between samples and also helps to maintain a clean working environment. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate revisions may be made to accommodate site-specific conditions or project-specific protocols when approved in writing or via email by the Project Manager.

Decontamination is achieved primarily by rinsing with liquids which may include: steam, soap and/or detergent solutions, potable water, distilled weak acid solution, and/or methanol or other solvent. Equipment may be allowed to air dry after being cleaned or may be wiped dry with chemical-free towels or paper towels if immediate re-use is necessary.

At most project sites, decontamination of equipment that is re-used between sampling locations will be accomplished between each sample collection point. Waste produced by decontamination procedures, including waste liquids, solids, etc., will be discharged to the land surface and will not be allowed to runoff into any water body.

2.0 BASIS FOR METHODOLOGY

The methods and procedures described in this SOP were developed from these sources:

- ASTM D5088. Standard Practice for Decontamination of Field Equipment

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Used at Waste Sites. American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2008.

- Parker and Ranney, 1997a. Decontaminating Ground Water Sampling Devices, CRREL Special Report 97-25, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

- Parker and Ranney, 1997b. Decontaminating Materials Used in Ground Water Sampling Devices, CRREL Special Report 97-24, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

3.0 PROCEDURES

3.1 Responsibilities

It is the responsibility of the field sampling supervisor to ensure that proper decontamination procedures are followed and that all waste materials produced by decontamination are properly managed. It is the responsibility of the project safety officer to draft and enforce safety measures that provide the best protection for all persons involved directly with sampling and/or decontamination.

It is the responsibility of any subcontractors (e.g., drilling contractors) to follow the proper, designated decontamination procedures that are stated in their contracts and outlined in the Site-Specific Health and Safety Plan. It is the responsibility of all personnel involved with sample collection or decontamination to maintain a clean working environment and ensure that any contaminants are not negligently introduced to the environment.

3.2 Supporting Materials

Materials needed for equipment decontamination include:

- Cleaning liquids: laboratory grade soap and/or detergent solutions (Alconox, etc.), potable water, distilled water, methanol, weak nitric acid solution, etc.
- Personal protective safety gear as defined in the Site-Specific Health and Safety Plan
- Chemical-free towels or paper towels

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- Disposable nitrile gloves
- Cleaning containers: plastic and/or stainless steel pans and buckets
- Cleaning brushes
- Steam cleaner

3.3 Methods

The extent of known contamination will determine the degree of decontamination required. If the extent of contamination cannot be readily determined, cleaning should be done according to the assumption that the equipment is highly contaminated. Decontamination procedures should account for the types of contaminants known or suspected to be present. In general, high levels of organic contaminants should include an organic solvent wash step, and high levels of metals contamination should include a weak acid rinse step.

The procedures listed below constitute the full field decontamination procedure. If different or more elaborate procedures are required for a specific project, they may be specified in the project planning documents. Such variations in decontamination protocols may include all, part, or an expanded scope of the decontamination procedure stated herein.

1. Remove gross contamination from the equipment by dry brushing, and rinse with potable water.
2. Wash with laboratory-grade detergent solution or steam cleaner.
3. Rinse with potable water or steam cleaner.
4. Rinse with methanol (optional, for equipment potentially contaminated by organic compounds).
5. Rinse with acid solution (optional, for equipment potentially contaminated by metals).
6. Rinse with distilled or deionized water or steam cleaner.
7. Repeat entire procedure or any parts of the procedure as necessary.
8. Air dry.

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4.0 DOCUMENTATION

Field notes will be kept describing the decontamination procedures followed. The field notes will be recorded according to procedures described in SOP No. 1 (FIELD DOCUMENTATION).

5.0 QUALITY CONTROL

To assess the adequacy of decontamination procedures, field rinsate blanks may be required. The specific number of field rinsate blanks will be defined in the project-specific Sampling and Analysis Plan (SAP) or Quality Assurance Project Plan (QAPP).

Rinsate blanks with elevated or detected contaminants will be evaluated by the Project Manager, who will relay the results to the field personnel. Such results may be indicative of inadequate decontamination procedures that require corrective actions (e.g., retraining).

6.0 REFERENCES

ASTM D5088-02 (2008). Standard Practice for Decontamination of Field Equipment Used at Waste Sites. American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2008. Available online at http://www.astm.org/

Parker and Ranney, 1997a. Decontaminating Ground Water Sampling Devices, CRREL Special Report 97-25, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

Parker and Ranney, 1997b. Decontaminating Materials Used in Ground Water Sampling Devices, CRREL Special Report 97-24, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

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APPENDIX D.7.
STANDARD OPERATING PROCEDURES: SOP 2, SAMPLE CUSTODY, PACKAGING, AND SHIPMENT

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STANDARD OPERATING PROCEDURE No. 2

SAMPLE CUSTODY, PACKAGING, AND SHIPMENT

1.0 SCOPE AND APPLICABILITY

The following Standard Operating Procedure (SOP) describes the protocol for sample custody and packaging and shipment of samples. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate modifications to the procedures may be made when approved in writing or via email by the Project Manager.

This SOP applies to any liquid or solid sample that is being transported by the sampler, a courier, or an overnight delivery service.

2.0 BASIS FOR METHODOLOGY

The methods and procedures described in this SOP were developed from these sources:

- 49 CFR 173. Shippers – Shippers – General Requirements for Shipping. United States Code of Federal Regulations available online at http://www.gpoaccess.gov/cfr/index.html
- 49 CFR 178. Specifications for Packaging. United States Code of Federal Regulations available online at http://www.gpoaccess.gov/cfr/index.html
- ASTM D 4220-95 (2000). Standard Practices for Preserving and Transporting Soil Samples, American Society for Testing and Materials available online at http://www.astm.org/
- ASTM D 4840-99 (2010). Standard Guide for Sampling Chain-of-Custody Procedures. American Society for Testing and Materials available online at http://www.astm.org/

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3.0 PROCEDURES

The objectives of this packaging and shipping SOP are to minimize the potential for sample breakage, leakage, or cross contamination; to provide for preservation at the proper temperature; and to provide a clear record of sample custody from collection to analysis.

3.1 Packaging Materials

The following is a list of materials that will be needed to facilitate proper sample packaging:

- Chain-of-Custody (COC)/Request for Analysis (RA) forms;
- Analyte List;
- Coolers (insulated ice chests) or other shipping containers as appropriate to sample type;
- Transparent packaging tape;
- Duct tape or similar (for sealing cooler drain);
- Zip-lock type bags (note: this is used as a generic bag type, not a specific brand name);
- Large garbage bags;
- Protective wrapping and packaging material;
- Contained ice (packaged and sealed to prevent leakage when melted) or “Blue Ice”; and
- Chain-of-Custody seals.

3.2 Sample Custody from Field Collection to Laboratory

After samples have been collected, they will be maintained under chain-of-custody procedures. These procedures are used to document the transfer of custody of the samples from the field to the designated analytical laboratory. The same chain-of-custody procedures will be used for the transfer of samples from one laboratory to another, if required.

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The field sampling personnel will complete a COC/RA form and provide an Analyte List for each separate container of samples to be shipped or delivered to the laboratory for chemical or physical (geotechnical) analysis. Information contained on the form will include:

1. Project identification;
2. Date and time of sampling;
3. Sample identification;
4. Sample matrix type;
5. Sample preservation method(s);
6. Number and types of sample containers;
7. Sample hazards (if any);
8. Requested analysis(es);
9. Method of shipment;
10. Carrier/waybill number (if any);
11. Signature of sampling personnel;
12. Name of Project Manager;
13. Signature, name and company of the person relinquishing and the person receiving the samples when custody is being transferred;
14. Date and time of sample custody transfer;
15. Condition of samples upon receipt by laboratory; and
16. Chain of Custody identification number.

The samples will be carefully packaged into shipping containers/ice chests.

The sampling personnel whose signature appears on the COC/RA form is responsible for the custody of a sample from the time of sample collection until the custody of the sample is transferred to a designated laboratory, a courier, or to another employee for the purpose of transporting a sample to the designated laboratory. A sample is

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considered to be in their custody when the custodian: (1) has direct possession of it; (2) has plain view of it; or (3) has securely locked it in a restricted access area.

Custody is transferred when both parties to the transfer complete the portion of the COC/RA form under "Relinquished by" and "Received by." Signatures, printed names, company or organization names, and date and time of custody transfer are required. Upon transfer of custody, the sampling personnel who relinquished the samples will retain a copy of the COC/RA form.

3.3 Sample Custody within Laboratory

The designated laboratory will assume sample custody upon receipt of the samples and COC/RA form. Sample custody within the analytical laboratory will be the responsibility of designated laboratory personnel. The laboratory will document the transfer of sample custody and receipt by the laboratory by signing the correct portion of the COC/RA form. Upon receipt, the laboratory sample custodian will note the condition of the samples, by checking the following items:

1. Agreement of the number, identification and description of samples received by comparison with the information on the COC/RA form; and

2. Condition of samples (any bottle breakage; leakage, cooler temperature, etc.).

If any problems are discovered, the laboratory sample custodian will note this information on the "Laboratory Comments/Condition of Samples" section of the COC/RA form, and will notify the sampling personnel or Project Manager immediately. The Project Manager will decide on the final disposition of the problem samples.

The laboratory will retain a copy of the COC/RA form and return an electronic copy to the originator with the final laboratory report of analytical results. The original of the COC/RA form will be retained as part of the permanent documentation in the project file. A record of the history of the sample within the laboratory containing sample status and storage location information will be maintained in a logbook, or a computer sample tracking system, at the laboratory. The following information will be recorded for every sample access event:

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1. Sample identification;
2. Place of storage;
3. Date(s) and time(s) of sample removal and return to storage;
4. Accessor's name and title;
5. Reason for access; and
6. Comments/observations (if any).

The laboratory will provide a copy of the logbook or computer file information pertaining to a sample upon request.

3.4 Sample Custody during Inter-Laboratory Transfer

If samples must be transferred from one laboratory to another, the same sample custody procedures described above will be followed. The designated laboratory person (sample custodian) will complete a COC/RA form and sign as the originator. The laboratory relinquishing the sample custody will retain a copy of the completed form. The laboratory receiving sample custody will sign the form, indicating transfer of custody, retain a copy, and return the original record to the originator with the final laboratory report of analytical results. The COC/RA form will be retained as part of the permanent documentation in the project file.

3.5 Packaging and Shipping Procedure

All sample containers will be properly labeled and all samples will be logged on the COC/RA form in accordance with the procedures explained.

All samples will be packed in the cooler so as to minimize the possibility of breakage, cross-contamination, and leakage. Before placing the sample containers into the cooler, all sample bottle caps will be checked and tightened if necessary. A large garbage bag will be placed as a liner inside the cooler and duct tape (or similar) will be used to seal off any drain openings on the inside and/or outside of the cooler. Bottles made of breakable material (e.g., glass) will also be wrapped in protective material (e.g., bubble wrap, plastic gridding, or foam) prior to placement in the cooler. Each sample set or soil

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tube liner (for a California, Shelby Tube or Split-spoon Sampler) will be placed into a zip-lock bag to protect from cross-contamination and to keep the sample labels dry. Sample containers will be placed upright in the cooler. Stacking glass sample bottles directly on top of each other will be avoided.

If required by the method, samples will be preserved to 4°C prior to the analysis. Water ice or "blue ice" will be used to keep the sample temperatures at 4°C. The ice will be placed in two zip-lock bags if the samples are to be transported by someone other than the sampler (e.g., a courier or overnight delivery service). The zip-lock bags of ice will be placed in between, on the bottom, and/or on top of the sample containers so as to maximize the contact between the containers and the bagged ice. If the sampler is transporting the samples to the laboratory shortly after sample collection, the water ice may be poured over and between the sample bottles in the cooler.

If there is any remaining space at the top of the cooler, packing material (e.g., Styrofoam pellets or bubble wrap) will be placed to fill the open space of the cooler. After filling the cooler, the garbage bag will be sealed, a copy of the COC/RA form and Analyte List will be placed in a zip-lock bag and taped to the inside of the cooler lid, the top of the cooler will be closed, and the cooler will be shaken to verify that the contents are secure. Additional packaging material will be added if necessary.

When transport to the laboratory by the sampler is not feasible, sample shipment will occur via courier or overnight express shipping service that guarantees shipment tracking and next morning delivery (e.g., Federal Express Priority Overnight or UPS Next Day Air). The same procedures will be followed to pack and fill the cooler and provide the COC/RA form and Analyte List, as if the sampler were transporting the samples to the laboratory. The cooler will be taped shut with packaging tape. Packaging tape will completely encircle the cooler, and chain-of-custody seals will be signed and placed across the front and side of the container opening.

Copies of all shipment records provided by the courier or overnight delivery service will be retained and maintained in the project file.

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4.0 DOCUMENTATION AND RECORDS MANAGEMENT

Daily Field Records or a field notebook with field notes will be kept describing the packaging procedures and the method of shipment. Copies of all shipping records and chain-of-custody records will be retained in the project file.

5.0 QUALITY ASSURANCE

The Project Manager or designated reviewer will check and verify that documentation has been completed and filed per this procedure.

6.0 REFERENCES

49 CFR 173. Shippers – General Requirements for Shipments and Packagings. United States Code of Federal Regulations. Available online at http://www.gpoaccess.gov/cfr/index.html

49 CFR 178. Specifications for Packaging. United States Code of Federal Regulations. Available online at http://www.gpoaccess.gov/cfr/index.html

ASTM D 4220-95 (2000). Standard Practices for Preserving and Transporting Soil Samples, ASTM International, West Conshohocken, PA, 2000. Available online at http://www.astm.org/

ASTM D 4840-99 (2010). Standard Guide for Sampling Chain-of-Custody Procedures, ASTM International, West Conshohocken, PA, 2010. Available online at http://www.astm.org/

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ACZ Laboratories, Inc.

2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

CHAIN of CUSTODY

Report to:

Name:	Address:
Company:	
E-mail:	Telephone:

Copy of Report to:

Name:	E-mail:
Company:	Telephone:

Invoice to:

Name:	Address:
Company:	
E-mail:	Telephone:

If sample(s) received past holding time (HT), or if insufficient HT remains to complete analysis before expiration, shall ACZ proceed with requested short HT analyses? YES ☐ NO ☐

If "NO" then ACZ will contact client for further instruction. If neither "YES" nor "NO" is indicated, ACZ will proceed with the requested analyses, even if HT is expired, and data will be qualified

Are samples for SDWA Compliance Monitoring? Yes ☐ No ☐

If yes, please include state forms. Results will be reported to PQL for Colorado.

Sampler's Name: _____ **Sampler's Site Information** **State**_____ **Zip code**_____ **Time Zone**_____

***Sampler's Signature:** _____

*I attest to the authenticity and validity of this sample. I understand that intentionally mislabeling the time/date/location or tampering with the sample in anyway, is considered fraud and punishable by State Law.

PROJECT INFORMATION

Quote #:

PO#:

Reporting state for compliance testing:

Check box if samples include NRC licensed material? ☐

ANALYSES REQUESTED ***(attach list or use quote number)***

SAMPLE IDENTIFICATION	DATE:TIME	Matrix	# of Containers								
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐

Matrix: SW (Surface Water) · GW (Ground Water) · WW (Waste Water) · DW (Drinking Water) · SL (Sludge) · SO (Soil) · OL (Oil) · Other (Specify)

REMARKS

Level 4B reporting
requested

Please refer to ACZ's terms & conditions located on the reverse side of this COC.

RELINQUISHED BY:	DATE:TIME	RECEIVED BY:	DATE:TIME

FRMAD050.06.14.14 White - Return with sample. Yellow - Retain for your records.

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APPENDIX D.8.
STANDARD OPERATING PROCEDURES:
SOP 31, WATER QUALITY METER CALIBRATION

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STANDARD OPERATING PROCEDURE No. 31

WATER QUALITY METER CALIBRATION

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed for calibration of the field water quality sampling multi-parameter instrument used during environmental monitoring and sampling activities. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate modifications to the procedures may be made to accommodate project-specific protocols when approved in writing or via email by the Project Manager or detailed in a project work plan, sampling plan, or quality assurance project plan.

The objective of calibrating field instruments is to establish the accuracy and reliability of the instrument and to ensure that field readings are consistent with other measurements.

2.0 BASIS FOR METHODOLOGY

The methods and procedures described in this SOP were developed from this source:

- U.S. Geological Survey (USGS) (variously dated) National Field Manual for the Collection of Water-Quality Data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, Chapters A1-A9.

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3.0 EQUIPMENT AND SUPPLIES

3.1 Multi-Parameter Sensors

Multi-parameter sensors can vary between manufacturers of instruments and as technology advances. The following are the sensors generally used on multi-parameter instruments for collecting water quality parameters: water temperature, pH, specific electrical conductance (SC), oxidation-reduction potential (ORP), and dissolved oxygen (DO). Turbidity is generally measured using a separate meter, but there are some instruments for which the turbidity sensor is included with the multi-meter sensor cluster.

- pH – sensor has a range between 2 to 12, or 0 to 14 pH units
- Water Temperature – sensor has a range of at least -5 to +45 degrees Celsius
- SC – sensor is temperature compensating, and measures in microsiemens per centimeter (uS/cm) or mS/cm
- DO – 2 types of sensors (polarographic and optical) both sensors range from 0.05 to 20 milligrams per liter (mg/L)
- ORP – sensor uses a platinum electrode, and measures in millivolts (mV)

3.2 Calibration Supplies

The following supplies are needed to calibrate a multi-parameter instrument: specific sensor buffers, standards, and calibration solutions, field notebooks, deionized water, bucket(s), disposable gloves, scrub brushes, and paper tissues.

4.0 CALIBRATION PROCEDURE

The multi-parameter instrument will be calibrated in the field once daily by personnel according to manufacturer's instructions prior to the collection of any samples. All calibration details will be recorded in a field notebook including, but not limited to: instrument type, instrument serial number, readings prior to calibration, buffers used, readings after calibration, names of personnel calibrating, and date and time of calibration. The following are general guidelines to follow when calibrating a multi-parameter instrument:

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A. Follow the manufacturer instructions;
B. Set the meter to the correct measurement units;
C. Allow the meter to warm up (at least 10 minutes or according to manufacturer recommendation);
D. Calibrate the instrument in a temperature-stable environment;
E. Use the calibration cup for calibration;
F. Use the recommended volume of calibration solution during calibration;
G. Do not over tighten the calibration cup;
H. Rinse the sensor with deionized water prior to the use of calibration solution, then rinse with a small amount of the calibration solution to be used before calibrating; and
I. Calibrate the meter sensors in the following order: water temperature, SC, DO, pH, and ORP.

4.1 Multi-Point Calibration

4.1.1 Water Temperature

Check to ensure the accuracy of the temperature sensor at least every 3 months if the multi-parameter instrument is in frequent use or according to the manufacturer's recommendations. The accuracy of the temperature sensor will be verified against a certified NIST-traceable digital or liquid-in-glass thermometer. Completely submerge the multi-parameter meter temperature sensor and allow at least 1 minute for the temperature to equilibrate and stabilize. Record the temperature value in degrees Celsius (°C). If the difference between the readings does not fall within the manufacturer-specified accuracy, contact the supplier or manufacturer for the next steps.

4.1.2 Specific Conductance (SC)

Calibration for SC is performed using a one-point calibration. Use the standard recommended by the manufacturer or a standard that is similar in conductivity to the sample water. The calibration cup and sensor will first be rinsed using a small amount of calibration solution prior to the start of calibration. Next the calibration cup will be filled with the recommended volume of calibration solution and the sensor completely

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submerged. When the readings stabilize save the calibration point and record in the field notebook the readings before and after calibration in uS/cm.

4.1.3 Dissolved Oxygen (DO)

Follow the manufacturer's guidelines for care, proper setup, and calibration of the DO sensor for the instrument in use. Whenever possible, ensure that the DO sensor has been appropriately calibrated by the instrument supplier or party responsible for maintenance prior to using the instrument in the field.

4.1.4 pH

Calibration of the pH sensor is performed using a two-point calibration. Select the pH 7 buffer as well as a second pH buffer (pH 4 or pH 10) that brackets the expected range of sample water pH. A calibration check using a third buffer can be performed at the end of calibration. To start, the calibration cup and sensor will be rinsed with deionized water and then with a small amount of the first buffer. Next the calibration cup will be filled with enough of the first buffer to completely cover the pH and temperature sensors (the pH value is temperature dependent). Wait for the pH and temperature sensors to equilibrate to the temperature of the buffer and record the temperature reading after stabilization. Adjust the calibration reading (to the true pH value at that temperature) using the chart provided by the buffer manufacturer. Record the temperature and pH readings before and after calibration of the first buffer in the field notebook. Follow the same steps starting with the rinsing of the calibration cup and sensor for the second buffer. If a third buffer is used to check the calibration, follow the same steps, but do not lock in a calibration point.

4.1.5 Oxidation-Reduction Potential (ORP)

Calibration of the ORP sensor is generally performed using a one-point calibration at a known temperature. The manufacturer's recommendation will be followed for calibration. The calibration cup and sensor will first be rinsed with a small amount of the solution. Next fill the calibration cup with enough of the solution to completely submerge the ORP sensor. Wait for the readings to stabilize and then enter the correct value of

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the solution at the current temperature. Record the ORP readings before and after calibration in mV, as well as the solution values used in the field notebook.

4.2 One-Point Calibration

Calibration may be performed using the In-Situ Quick Cal Solution when an In-Situ smarTROLL™ MP handheld water quality meter is used. The Quick Cal Solution performs a one-point calibration of all smarTroll™ MP sensors (pH, ORP, SC, and DO) at the same time. The manufacturer's recommendations will be followed for calibration as well as the following use and storage guidelines:

- Shake well before use;
- Allow to warm to room temperature before using;
- Store in refrigerator (needs to be stored in dark and cool environment);
- Use within three weeks after opening (document on bottle and calibration records when opened);
- Unopened shelf life is six months (check and document expiration date of bottle); and
- One-time use only (i.e. solution should not be re-used following single calibration).

5.0 DOCUMENTATION

The Project Manager or designated reviewer will check and verify that documentation of instrument calibration has been completed and the calibration records are filed in the project records.

6.0 REFERENCES

U.S. Geological Survey (USGS), variously dated. National Field Manual for the Collection of Water-Quality Data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, Chapters A1-A9. Available online at http://pubs.water.usgs.gov/twri9A.

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APPENDIX E – DUST CONROL MEASURE DESCRIPTIONS

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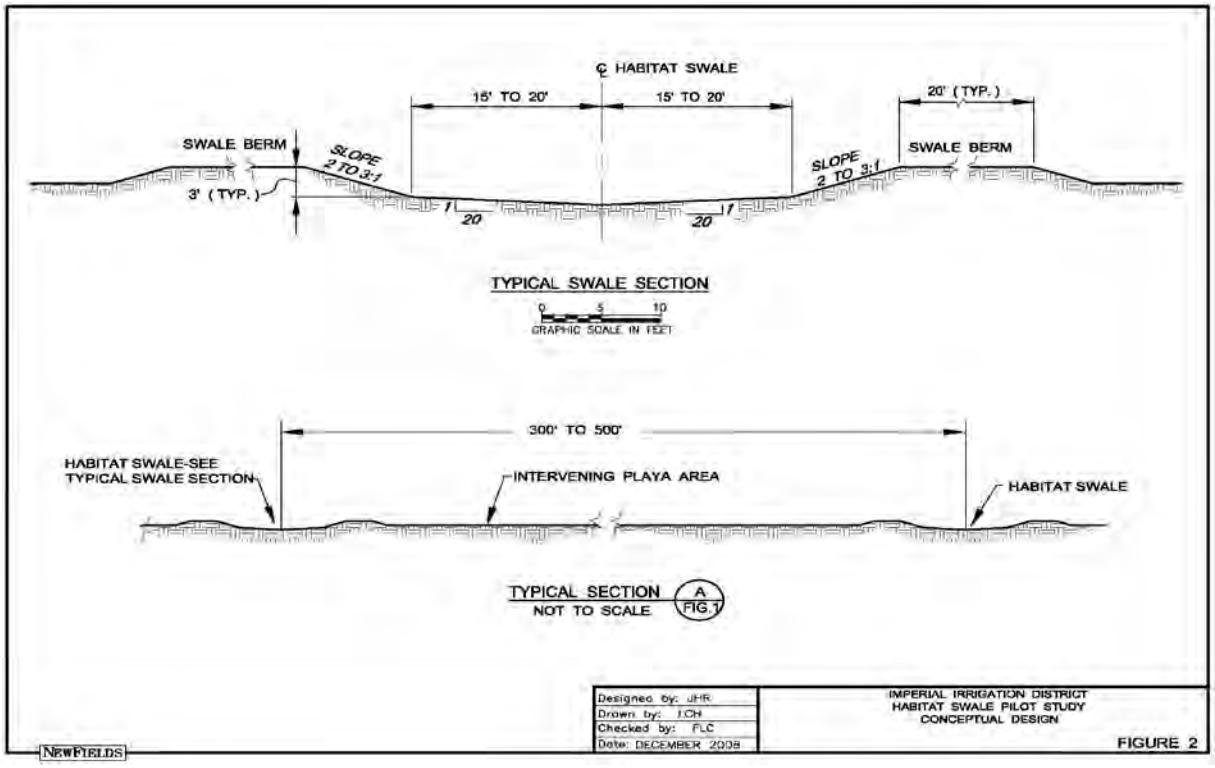
E.1 Vegetated Swales

Habitat swales are vegetated, earthen channels constructed by raising pairs of parallel berms approximately 60 feet apart, with adjacent pairs of berms spaced 200 to 500 feet from one another (Figure E-1). Habitat swales operate on the principle of interrupting wind fetch (the distance that wind has traveled over an unobstructed area) on a playa, leading to reduced wind velocity at the soil surface and suppression of sand flux and dust emissions in downwind areas. After vegetation is established, swales capture sand and immobilize it beneath the plant community's canopy. A combination of periodic surface wetting, natural crusting, regional reduction in sand motion, and reduced surface wind velocities due to sheltering of areas downwind of the swales results in dust control over the entire swale and inter-swale area.

Figure E-1. Habitat Swale Cross-Section Conceptual Design



E.1.1 Configuration

As described above, swales will consist of parallel berms approximately 60 feet apart. The swales will be designed with a 30- to 40-foot bottom width and four feet total depth. The top width of each earthen side berm will be approximately 20 feet, with the top of the berm approximately two feet above existing grade. The configuration of the swales will be refined during design based on site-specific investigations (i.e., topography, surface erosion potential, primary wind direction) and desired dust control efficiency.

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The swales and berms will be constructed from local, on-site materials. The import or borrow of soil, and the disposal of excess fill will be minimized.

Channel lengths and profile gradients will depend on site topography, but in general will be designed so that pulsed irrigation flows can be sustained along the full length of the swale without requiring excessively large and erosive flows at the head end. Given the relatively level topography of the sea floor (and therefore exposed playa in the future), longitudinal profile gradients are expected to be low. The swale cross-section will be sloped toward the center, where there will be a low-flow channel to provide drainage. Swale tailwater will be recycled for other uses or will flow to the Sea. Analysis of soil, wind, and water erosion potential will be conducted during the design phase and will help to determine adequate design criteria.

To achieve regional reductions in sand motion, and thus dust emissions, a network of swales (as described above) will be constructed at intervals of 200 to 500 feet, with traffic avoided to the maximum extent feasible on the intervening playa. A combination of natural crusting, regional reduction in sand motion, and reduced surface wind velocities due to sheltering of areas downwind of the swales will result in dust control over the entire swale and inter-swale area. Final swale spacing will be determined during the design phase as a function of topography, surface erosion potential, primary wind direction, and desired dust control efficiency targets.

E.1.2 Vegetation

Swale cross-sections would mimic natural channels, in which pulsed flow would spread laterally from the cross-section's low point. This favors development of a broad swath of vegetation, ranging from hydrophytic near the centerline to xeric and halophytic along the margins. Plant species will be selected based on suitability for range of the hydrologic regime and saline soil conditions of the site and location along the length of the swale (i.e., wetter conditions on the swale bottom and upstream; drier, more saline conditions on the swale margins and downstream).

In general, species will include sedges, rushes, and similar wetland vegetation located in the bottom and head end of the swale; grasses and other herbaceous species on both sides and downstream reaches of the swale; and shrub species up to the boundaries of anticipated swale seepage. Rhizomatous species should predominate in the swale because they increase the likelihood of re-establishment during long-term maintenance/management without the need for extensive re-planting. Vegetative cover within the swale will be established quickly, with gradual succession to more diverse native species. Stands of vegetation will provide ecological benefits (i.e., microhabitats) similar in character to desert wetlands and xeric native desert vegetation. This vegetation approach tends to discourage (but does not eliminate) establishment of invasive species, such as Tamarisk.

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E.1.3 Operation

The swales will be irrigated by pulse irrigation to shorten water's residence/travel time and therefore minimize stagnant water in the swales. During establishment, drain water (inflows to the Sea) would be pulsed through each swale bi-weekly. As vegetation is established, inflows will likely be reduced to a frequency of every few weeks, or longer, as needed to maintain vegetative growth. After establishment, water would be pulsed through each swale 5 to 12 times annually. The timing and duration of the pulses will be a function of inflow availability, soil conditions, and plant irrigation needs. Irrigation frequency and duration will be evaluated during design and the pilot study.

Water flow into each swale will be controlled with slide gates. Open-channel flow will be measured near each gate structure to measure flows entering each swale. The number of swales that can be irrigated simultaneously will be determined by balancing the required flow rate with the available inflow supply. Details regarding flows into the swales, such as amount of flow, cycle times, cutoff time, and other parameters, will be developed during the final design phase.

Tractor and backhoe/excavation (mainly tracked) equipment will be used during construction and operation of the swales and irrigation systems; lighter, wheeled equipment may be employed for planting/maintenance of vegetation. Intermittent tractor and/or backhoe access will be required during the maintenance activities, including, but not limited to, cultivation and weed control. Intermediate access between periods of maintenance will likely be by small utility four-track vehicles.

E.2 Plant Community Enhancement

The central concept of this Dust Control Measure (DCM) is managed enhancement of existing vegetation onto new playa areas. As the Sea recedes, plant communities along the shoreline may naturally expand, especially where freshwater inflows create fresher, shallow groundwater and/or leach salts from newly exposed playa and create more favorable growing conditions (Figure E-2). Species would likely include a mix of sedges, rushes, and similar wetland vegetation located near the wet shoreline; grasses and other herbaceous species near the middle of the landscape; and shrub species in drier areas near and above the historic shoreline. These plant communities can achieve plant cover densities that postpone or eliminate the need for more resource-intensive DCMs.

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Figure E-2. Existing Playa Vegetation Would be Expanded and Enhanced Under the Plant Community Enhancement Dust Control Measure



E.2.1 Configuration

The central concept of the vegetation enhancement DCM is enhancement of existing vegetation that can spread onto new playa as the Sea recedes. Configuration of the DCM, selection of vegetative species, and irrigation design will be determined by the existing vegetation and site-specific (landscape position, hydrologic, and salinity) conditions. Species would likely be a mix of sedges, rushes, and similar wetland vegetation located near the wet shoreline; grasses and other herbaceous species near the middle of the landscape; and shrub species in drier areas near and above the historic shoreline. Hydrophytic vegetation would likely line watercourses as they cross the playa.

As the Sea continues to recede, it is anticipated that the species mix (with the right management) will migrate down the playa with the shoreline. Over time, needed vegetation densities may no longer be sustainable in some areas without additional inputs, such as irrigation and/or artificial drainage. At this point, based on monitoring data, sensitive areas would likely be transitioned to another DCM as needed to sustain dust mitigation performance.

E.2.2 Operation

Any combination of flood, pulse, or drip irrigation may be used to meet plant water demand. When needed, fertilizer will be added to irrigation water to stimulate and support vegetative cover levels needed to meet the dust control efficiency requirements. The applied nutrients may include, but are not limited to: nitrogen, phosphorus, and potassium fertilizers, as well as small amounts of micronutrients. Soil and plant tissue will be monitored to determine fertilizer application rates based on plant nutrient needs, and to avoid excess application that might induce off-site migration of applied nutrients.

Tractor and tillage (tracked and/or wheeled) equipment may be used during construction and operation of the DCM, and for planting/maintenance of vegetation. Intermittent tractor and/or backhoe access will be required during the maintenance activities, including, but not limited to, cultivation and weed control. Intermediate access between periods of maintenance will likely be with personal and small utility four-track vehicles.

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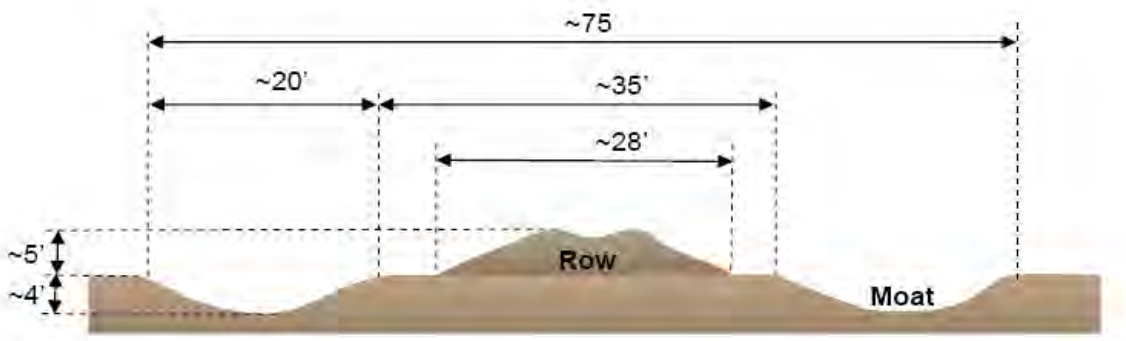
E.3 Moat and Row

Moat and row consists of an array of earthen berms (rows) flanked on either side by ditches (moats). Figure E-3 is a conceptual cross-section of this type of DCM. Spacing can vary depending on the surface type, the control effectiveness required, and the intensity of adjacent sand sources. Moats control dust by capturing moving soil particles and rows physically shelter the downwind playa by lifting wind velocity profiles, thereby reducing velocity at the soil surface. Moats and rows are constructed to run perpendicular to primary wind vectors. Dust control effectiveness can be enhanced by reducing the distance between rows, increasing the height of the rows, vegetating rows, or using gravel, sand fences, or similar methods to enhance sand capture between rows.

Figure E-3. Conceptual Cross-Section of a Moat and Row Dust Control Measure



E.3.1 Configuration

Moats and rows are generally parallel to one another and spaced at variable intervals so that fetch between rows is conducive to dust control. Spacing can vary depending on the surface type, the control effectiveness required, or exposure to and capture of sand coming from offsite. Previous experience indicates that Moat and Row spacing will generally vary from 250 to 1,000 feet. Spacing of Moat and Row elements is interdependent with cross-section design criteria (e.g., taller elements that shelter longer downwind fetches can be more widely spaced).

E.3.2 Operation

During operation, the Moat and Row array may need to be altered, improved, or maintained to achieve the required level of dust control. The extent, nature, and timing of these operational activities will be determined by monitoring results. Operational activities may include the following:

1. Construction of additional, intermediate moats and rows

2. Repair of existing moats and rows, mainly through excavation of adjacent playa to form new moats, and burial of sand-filled Moat and Row margins with spoil, effectively fattening the original row in the repaired section

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3. Addition of sand fences to increase row height or to enclose the site along an unprotected margin

4. Watering of moats or area between Moat and Row elements

5. Irrigation and planting of vegetation on rows or area between Moat and Row elements

6. Gravel armoring along the tops of rows to prevent erosion of the row

E.4 Water-Efficient Vegetation

In this DCM, control is achieved by vegetating playa surfaces with salt- and drought-tolerant species that stabilize and suppress soil and sand movement beneath their canopies. Water-efficient vegetation pilot projects will be conducted to assess the effect of different levels of infrastructure, vegetation density, and vegetation uniformity on dust control efficiency, as well as water use and cost efficiency.

E.4.1 Configuration

Vegetation will be seeded or planted on raised beds 1 to 3 feet high and spaced 5 to 15 feet apart (center-to-center). Previous work on dry, saline playas suggests that the most desirable species for dust control are salt- and drought-tolerant, may be rhizomatous (growth by the spread of underground roots and shoots), and must provide adequate cover even during dormant periods. Saltgrass (*Distichlis spicata*) is a common species, but native shrubs, such as salt bushes (*Atriplex* spp.), greasewood (*Sarcobatus vermiculatus*), and seepweed (*Suaeda moquinii*) may also be used alone or in combination with saltgrass. A mix of native species will provide the needed diversity to maintain adequate cover levels, reduce water demand, and suppress invasive species. Species diversity will also allow better cover within the vegetated areas because different species can occupy different microhabitats. This vegetation approach tends to exclude (but does not eliminate) invasive species, such as Tamarisk.

E.4.2 Operation

Flood, pulse, or drip irrigation will be used to meet plant water demand needs. When needed, fertilizer will be added to irrigation water to stimulate and support adequate vegetative growth and cover levels needed for dust control. The applied nutrients may include, but are not limited to: nitrogen, phosphorus, and potassium fertilizers, as well as small amounts of micronutrients. Soil and plant tissue will be monitored to determine fertilizer application rates based on plant nutrient needs, and to avoid excess application that might induce off-site migration of applied nutrients.

Where soil or groundwater conditions so dictate, drainage improvements will be made to reduce the influence of saline shallow groundwater on the plant root zone. Drainage improvements may include: augmentation of natural drainage by increasing the size (height and width) of the raised beds; excavation of drainage interceptor canals; and/or installation of a subsurface drainage network to maintain an adequate depth of leached and unsaturated soil for plant rooting. Drains will consist of perforated plastic pipes installed in covered trenches and placed between 4 and 10 feet below ground

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surface. The drains will be enveloped by coarse material (fine gravel or sand) and wrapped in a fabric liner to prevent sediment movement into the perforated pipe, while still allowing for water collection. Final site conditions, design needs, operational inputs, vegetative cover levels, and control efficiency requirements will determine the ultimate mix of infrastructure to achieve dust control.

Tractor and backhoe/excavation (tracked and/or wheeled) equipment will be used during construction and operation of the DCM and irrigation systems, and for planting/maintenance of vegetation. Intermittent tractor and/or backhoe access will be required during the maintenance activities, including, but not limited to, cultivation and weed control. Intermediate access between periods of maintenance will likely be with personal and small utility four-track vehicles.

E.5 Surface Roughening

This DCM consists of roughening the land surface, typically with conventional tillage implements, depending on soil conditions and the target roughness. The roughened surface is less susceptible to erosion due to the lifting of the boundary layer of moving air further above the land surface, and due to the capture of mobile sand within the furrows created by the roughened surface. To maintain control over time, Surface Roughening may need to be repeated periodically as the land surface may be smoothed by erosion, sedimentation, and settling.

E.5.1 Configuration

Where less than 100 percent of the land surface can be tilled to achieve target levels of control, Surface Roughening can be done in blocks or strips that facilitate tillage by minimizing turning, and that avoid traffic on untilled areas to the maximum extent practicable. The long axis of tilled blocks should be oriented perpendicular to the principal wind vectors. Long, uninterrupted fetches across untilled areas should be avoided.

For heavier (more clayey) soils, relatively deep cuts will require substantial draft power and have a relatively narrow working width (per pass), whether soil is turned with a dozer blade or plow. However, resulting roughness is substantial and should not require re-tillage as frequently as lighter soils.

On lighter (sandier) soils (which are rare on the Salton Sea playa), Surface Roughening may be more superficial and may be done with lighter, wider equipment (e.g., a sandfighter). It should therefore proceed more rapidly, but will likely have to be maintained at more frequent intervals.

E.5.2 Operation

Surface Roughening has significant cost and operational advantages over other dust control approaches. Relative to other DCMs, it can be designed and installed at fairly low cost with unspecialized equipment. However, maintenance costs may be significant, depending on the average return time for maintenance and the types of implements used. One of the great strengths of Surface Roughening, where applicable, is its potential for flexible, rapid, and relatively low-cost deployment.

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The main challenges of Surface Roughening are the need to adapt the approach to soil conditions and required level of control, and the potentially frequent maintenance activity. It could also be that, as soils dry on the playa, the effectiveness of Surface Roughening may decline, and the cost of adequate control may increase. Over time, Surface Roughening could also potentially become a significant dust source, both due to dust emissions during the tillage operation, and if the roughened surfaces are no longer sufficiently moist and stable to provide control. On the other end of the spectrum, when soils are too moist, it is difficult to achieve the draft power needed to pull or push equipment, and workability of the soil, functioning of equipment, and resulting roughened surface conditions can all be compromised.

E.6 Shallow Flooding

The goal of the Shallow Flood DCM is to provide dust control by maintaining a sufficiently wet surface, thereby reducing saltation and dust emissions. The areal extent of wettingdepends mainly upon the amount of water present on the surface, evaporation rate and lake bed topography, and required control efficiency.

E.6.1 Configuration

Shallow flooding can vary from sheet flow, with , consists of releasing water from arrays of low-flow water outlets spaced at intervals of between 60 and 100 feet along pipelines laid along lake bed contours. The pipelines are spaced between 500 and 800 feet apart. This arrayed configuration of water delivery creates large, very shallow sheets of braided water channels. Water depths in sheet flooded areas are typically at most just a few inches deep. The lower edge of sheet flooded areas has containment berms to capture and pond excess flows. The water slowly flows across the typically very flat lake bed surfaces downhill to tail-water ponds where pumps recirculate the water back to the outlets.

To maximize project water use efficiency, flows to sheet flow areas are regulated at the outlets so that only sufficient water is released to keep the soil wet. Although the quantity of excess water is minimized through system operation, any water that does reach the lower end of the control area is collected and recirculated back through the water delivery system. At the lower end of the sheet flooded areas, or at intermediate locations along lower elevation contours, excess water are collected along collection berms and pumped back up to the outlets to be reused.

Pondflooded areas have water containment berms that allow ponds to be formed that submerge the emissive lake bed areas. These ponds are much deeper than sheet-flooded areas—pond waters are up to four feet deep. The containment berms are typically rock-faced to protect them from wave erosion. Water is usually delivered through one large water inlet per pond. Water is delivered to the pond area until the pond reaches a size and depth sufficient to submerge the required amount of emissive area. Water delivery then ceases until evaporation reduces the pond size to a set minimum.

Non-wetted infrastructure associated with the Shallow Flood DCM includes raised berms, roadways, equipment pads and their associated sloped shoulders. In some cases the shoulders are rock-faced to

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protect them from wave erosion. Well-traveled roads are typically paved with gravel; less-traveled roads and berms are unpaved. Shallow Flooding requires water transmission, distribution and outlet infrastructure, excess water retention, collection and redistribution infrastructure and the construction of electrical power lines, access roads and water control berms

E.6.2 Operation and Maintenance

Water flows during the dust season will be maintained to provide the required water coverages in substantially evenly distributed standing water or surface-saturated soil. Maintenance activities associated with Shallow Flooding consist of grading, addition of supplemental water outlets, and berming on the control areas to ensure uniform water coverage and prevention of water channeling. Other activities include regular and preventative maintenance of pipeline, valves, pumping equipment, berms, roads and other infrastructure.

E.6.3 Monitoring

The actual wetness coverage for Shallow Flooding areas can be determined using Landsat Satellite Imagery. Satellite imagery is assessed using the Shortwave Infrared band (SWIR) and thresholding to derive a spatial map of standing water and saturated soil surfaces. The following portions of the areas designated for control with Shallow Flooding are exempted from the wetness coverage requirements:

1) Raised berms, roadways and their shoulders necessary to access, operate and maintain the control measure which are otherwise controlled and maintained to render them substantially non-emissive.

2) Raised pads containing vaults, pumping equipment or control equipment necessary for the operation of Shallow Flooding infrastructure which are otherwise controlled and maintained to render them substantially non-emissive.

E.7 Gravel Cover

Gravel Cover forms a non-erodible surface when the size of the gravel is large enough that the wind cannot move the surface. If the gravel surface does not move, it protects finer particles from being emitted from the surface. Gravel and rock coverings have been used successfully to prevent wind erosion from mine tailings in Arizona (Chow and Ono, 1992).

E.7.1 Configuration

A two to four-inch layer of coarse gravel (½ to 1½-inch and larger rocks) laid on the surface of the playa will prevent PM10 emissions by: (a) preventing the formation of efflorescent evaporite salt crusts, because the large pore spaces between the gravel particles disrupt the capillary movement of saline water to the surface where it can evaporate and deposit salts; and (b) creating a surface that has a high threshold wind velocity so that direct movement of the large gravel particles is prevented and the finer

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particles of the underlying lake bed soils are protected. Gravel Cover is effective on essentially any type of soil surface.

E.7.2 Operation and Maintenance

Once the Gravel Cover has been applied to the playa, limited maintenance would be required to preserve the Gravel Cover. The gravel will be visually monitored to ensure that the Gravel Cover was not filled with sand or dust, or had not been inundated or washed out from flooding. If any of these conditions were observed over large areas, additional gravel will be transported to the playa and applied to the playa surface

E.8 Alternative Land Use

Alternative land use practices can be implemented to cover exposed playa and thus eliminate or significantly mitigate the potential for emissions. Example land use practices include the following:

- **Reclamation of agricultural land.** Portions of exposed playa may be reclaimed for more conventional agricultural activities, such as graminoid forage crops typically grown in the Imperial Valley, or aquaculture crops, such as algae. These crops may be harvested for protein (food) or used as biomass for conversion to energy.

  The development of exposed playa for agriculture will be constrained by irrigation infrastructure, irrigation water availability, and agricultural markets. Certain areas around the southwest quadrant of the Sea have soil types that are suitable for conventional agricultural production of crops. The areas west of the New River delta include soil associations/complexes that are silty clays and various loams. The soils are also considered non-hydric and moderately-to well-drained. Aquaculture farming (i.e., algae and other aquatic vegetation) may be located on exposed playa areas with less suitable soils types. IID will continue evaluating areas around the Sea to evaluate reclamation potential for agricultural activity.

  IID is also evaluating several halophytic plants that might be suitable for crop use in playa areas or other high salt content soils. Vegetating playa with high salt tolerant plants may allow the reclamation of playa areas with less well drained soils and/or soils with higher salt content. IID may also elect to reclaim areas of playa for agricultural purposes or to develop specific crop types that could be used on playa areas without partnering with local entities.

- **Energy Generation Projects.** Energy generation projects that use geothermal and solar resources may also be located on exposed playa. The surface facilities needed to generate energy from these resources could be located on exposed playa and could also, with prior planning and design modification, be co-located with habitat projects.

  Geothermal: The Refined Conceptual Modeling and a New Resource Estimate for the Salton Sea Geothermal Field, Imperial Valley, California (Hulen, et. al. Sept 2002) defined the

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geothermal resources at the Salton Sea as more extensive than previously thought. The so-called Salton Sea Shallow Thermal Anomaly is mapped from east of the New River delta, through the Alamo River delta area and the Morton Bay/Mullet Island area and along the east side of the Salton Sea to the Imperial Wildlife Area-Wister Unit. The potential geothermal area extends out into the Sea up to three miles in some areas.

Solar: There are two types of solar energy recovery being considered for installation on exposed playa: photovoltaic panel technology and solar gradient ponds. Photovoltaic panel technology is a relatively well proven technology, although it has not been tested on the extreme environment of the Sea playa.

Solar gradient ponds, which extract energy by using solar rays to heat the lower water layer in a stratified impoundment, are being considered as a longer-term (greater than five years) use for the playa. While this technology has been moderately successful in other areas, it has not been tested in the Imperial Valley.

E.9 Species Conservation Habitat and other Habitat-Based Uses

Biological habitat is another type of land use that can cover exposed playa and thus eliminate or significantly mitigate the potential for emissions (analogous to Shallow Flood). Numerous habitat restoration projects are proposed in the Salton Sea area in an effort to sustain the fish and wildlife currently dependent on the Sea. Some of these projects will extend onto areas of the playa that would otherwise be exposed. These projects include, but are not limited to, the following:

- The Species Conservation Habitat Project will be located at the southern end of the Sea and will create up to 3,770 acres of relatively shallow water habitat. Ponds to support fish and wildlife species will be constructed and operated by the CA Department of Fish and Game and supplied with a combination of brackish and saline water, blended to maintain an appropriate salinity range.

- The US Fish and Wildlife Service has proposed development of approximately 700 acres of wading and shore bird habitat in Red Hill Bay in an effort to maintain wetland habitat values on this part of the National Wildlife Refuge.

- There is also potential for the Wister Unit of the Imperial Wildlife Area or the Sonny Bono Salton Sea National Wildlife Refuge Complex to expand habitat onto exposed playa.

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Staff Report

2018 State Implementation Plan for the Imperial County 12 µg/m^3 PM2.5 Annual Standard

Release Date: April 27, 2018
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I. INTRODUCTION

California law specifies that the California Air Resources Board (CARB) is the agency responsible for preparing and submitting state implementation plans (SIPs) to the U.S. Environmental Protection Agency (U.S. EPA). In California, local air districts develop and adopt the SIPs while working cooperatively with CARB. Since the State is ultimately responsible for submitting the SIP to U.S. EPA, CARB reviews and approves all SIPs developed by local air districts. If CARB determines the SIP does not meet the requirements set forth in the federal Clean Air Act (Act), CARB may return the SIP to the local air district to address the deficiencies.

In 2015, a portion of Imperial County was designated nonattainment for the 12.0 $\mu g/m^3$ annual PM2.5 ambient air quality standard (NAAQS or standard) necessitating the need to develop a SIP. This report summarizes CARB's assessment of the Imperial County Air Pollution Control District (District) 2018 PM2.5 SIP for the 12.0 $\mu g/m^3$ annual PM2.5 NAAQS (2018 PM2.5 Plan). The 2018 PM2.5 Plan relies on a special provision in the Act that enables states to prepare a SIP when transport of international pollution inhibits the ability to demonstrate attainment of the PM2.5 standard. The CARB staff reviewed the 2018 PM2.5 Plan developed by the District and determined that it met all applicable Act requirements. CARB staff will continue to work with the District and local community groups to develop additional emission reductions beyond the SIP to protect public health.

On April 24, 2018, the District adopted the 2018 PM2.5 Plan to address the annual 12.0 $\mu g/m^3$ annual PM2.5 standard for the Imperial County PM2.5 nonattainment area. The nonattainment area represents a portion of Imperial County that includes the most populated area of the county, including the cities of Brawley, El Centro, and Calexico. The Act requires the U.S. EPA to designate as nonattainment an area that violates the NAAQS and nearby areas that may contribute to the violation. In establishing the PM2.5 nonattainment area for Imperial County, U.S. EPA recognized the unique features and characteristics of the area and determined the boundaries based on multiple factors including air quality, emissions data, population, local meteorology, and geography/topography. Figure 1 shows the PM2.5 nonattainment area in Imperial County.

As a result of ongoing State and local control programs, PM2.5 air quality has improved throughout Imperial County in recent years. Monitors located in the cities of El Centro and Brawley record PM2.5 design values that are well below the standard. However, the Calexico monitor, located within one mile of the international border with Mexicali, Mexico, remains above the annual standard. Due to its proximity to the international border, Calexico is impacted daily by pollution from Mexicali. The highest PM2.5 concentrations in the Imperial County PM2.5 nonattainment area occur at Calexico in the winter months, typically during stagnant weather conditions when the predominant airflow is from the south. These days often coincide with wintertime holiday celebrations in Mexico where the use of bonfires and refuse burning, along with firework displays, are commonplace.

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The Act includes a specific provision for areas located next to an international border that allows states to take into consideration the impacts of cross border transport of pollutants on their attainment status. The 2018 PM2.5 Plan demonstrates that emissions in the Imperial County PM2.5 nonattainment area would be at a level sufficient to attain the annual PM2.5 standard in 2021 absent the impact of emissions from Mexicali, Mexico. Areas impacted by cross border pollution must still comply with requirements in the Act to demonstrate that appropriate actions have been taken to reduce local emissions and their air quality impact. For Imperial County, the SIP must include certain requirements and SIP elements for a moderate nonattainment area.

CARB staff continues to work with the District, U.S. EPA, representatives from Mexico's environmental agencies, and local community groups in efforts to improve air quality along the border region. For example, the Border 2020 Program is a multi-agency cooperative effort to improve environmental conditions, including air quality, along the Calexico-Mexico border. CARB's Heavy Duty Vehicle Inspection Program is another focused effort to improve border air quality. Heavy duty vehicles are periodically inspected at border crossings in Calexico to ensure that these vehicles entering the State meet California's strict vehicle emission standards.

Efforts by the District to enhance the dissemination of information about air quality in Imperial County are ongoing. An air quality and health information website notifies residents by email or cell phone when the levels of air pollutants are forecasted to be unhealthy in Imperial County. Residents may also download the free mobile app (Imperial Valley Air Quality) which sends alerts and notifications of the forecasted and current air quality in the region directly to user's mobile phones. The District also leads a "no burn" campaign that provides radio and television broadcasts to help educate residents in both Imperial County and Mexicali about the air quality impact from open burning. The District will continue these efforts as well as evaluate the potential for additional measures to improve air quality in the region.

Among the efforts in Imperial County to evaluate emission sources or activities that may potentially contribute to elevated levels of PM2.5 at the community level, the Imperial County Community Air Monitoring Project was launched in 2016. This purpose of this 4-year project is to establish a community air monitoring network for researchers while providing air quality information useful to local residents. The project is coordinated through a collaborative effort by the California Environmental Health Tracking Program with Comite Civico del Valle, a local environmental health advocacy group, and the University of Washington. The monitoring network consists of 40 low-cost air quality sensors that measure PM2.5 and PM10 throughout Imperial County. Although the technology of these air sensors is still evolving and work is on-going to establish the accuracy of their measurements, these sensors enable local residents the ability to collect information on PM levels in their community and provides valuable information on the spatial and temporal variability in air quality in their neighborhoods.

II. BACKGROUND

The Imperial County PM2.5 nonattainment area is an agricultural region located in the southeast corner of California that shares its southern border with Mexicali, Mexico.

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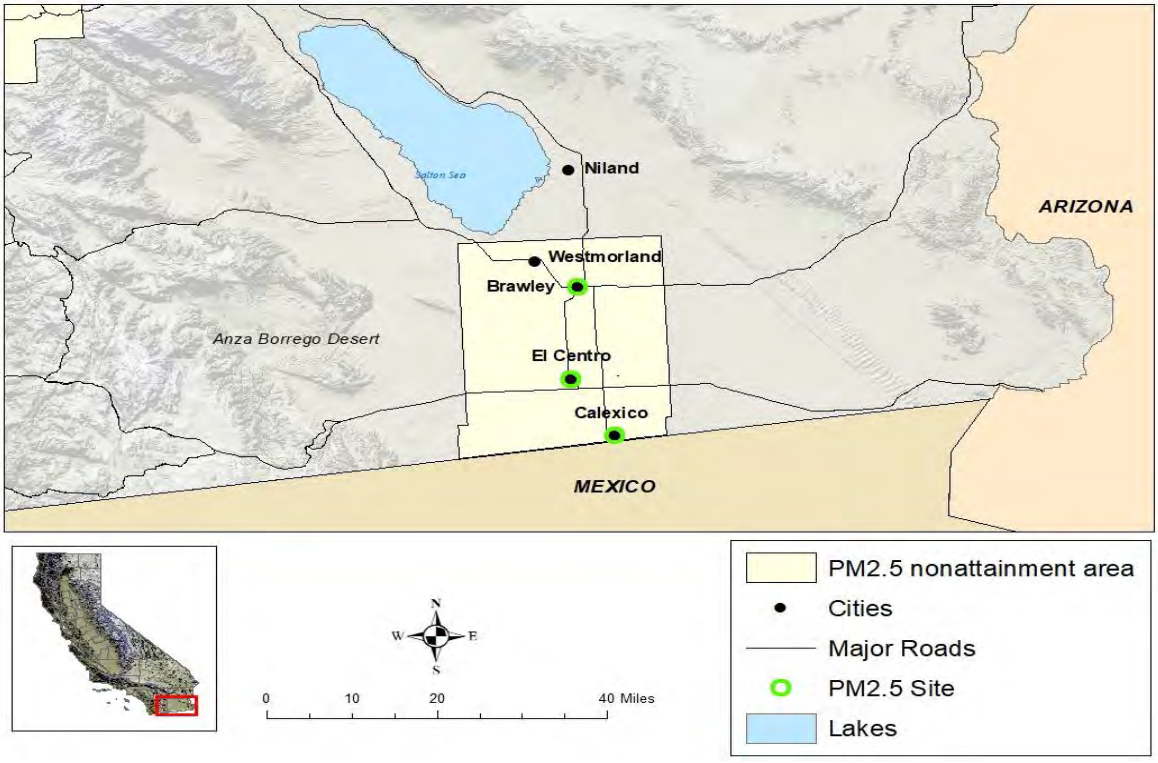
Most of the population, commercial activity, and farming operations occur in the PM2.5 nonattainment area, comprising approximately one-fourth the width of the county. The nonattainment area includes the three largest cities in Imperial County - Brawley, El Centro, and Calexico. Each of these cities are similar in size with populations of 25,000 to 43,000 people. A map of Imperial County, the boundaries of the PM2.5 nonattainment area, and the Mexico border area is shown in Figure 1.

Figure 1. Imperial County and the PM2.5 Nonattainment Area



The nonattainment area contains relatively few major industrial sources, with unpaved road dust and fugitive windblown dust emissions representing the largest emission sources. Other significant emission sources in the nonattainment area consist of off-road vehicles, farming operations, and managed burning and disposal.

In contrast, the city of Mexicali, with a population of nearly 700,000, has a large number of industrial, mobile, and area sources. These sources are generally subject to less stringent emission regulations than those in California. As a consequence, emissions from comparable source categories in Mexicali are significantly higher than in the Imperial County PM2.5 nonattainment area for nitrogen oxides (NOx), sulfur oxides (SOx), reactive organic gases (ROG) and ammonia (NH3).

A. Current Air Quality and Trends

The Imperial County nonattainment area is bordered by mountain ranges to the west, east, and southwest. These ranges act as barriers and channel airflow within the Imperial and Mexicali Valleys. Mountain valleys often enhance the formation of temperature inversions and result in little or no mixing of trapped pollutants. This is

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common in the Imperial Valley, particularly near the international border on nights with light winds. Inversions often occur over multiple days during the winter months resulting in high PM2.5 concentrations. The geography, topography, climate, and similar meteorology throughout the area does not restrict airflow between the Imperial and Mexicali Valleys which results in a shared airshed for the region.

Despite the challenges that Imperial County's geography, topography, meteorology, climate, and proximity to Mexico pose for air quality, the combined efforts of State and local control programs have resulted in improved air quality in the region. The State or Local Air Monitoring Stations (SLAMS) make up the ambient air quality monitoring sites that are operated by State or local agencies for the primary purpose of comparison to the NAAQS. Within the Imperial County PM2.5 nonattainment area, the District operates PM2.5 monitors at stations in Brawley and El Centro, and CARB operates a station in Calexico near the Mexico international border. A map of these monitoring stations is shown in Figure 1. Except for the monitor in Calexico, concentrations recorded at PM2.5 monitors in Imperial County currently comply with the 12.0 $\mu g/m^3$ annual PM2.5 standard.

The metric used for determining if an area attains the PM2.5 standard is called the design value. To reduce year-to-year variability, design values are based on a three-year annual average. In 2016, the Calexico annual PM2.5 design value was 12.6 $\mu g/m^3$, almost twice the design values from monitors located in Brawley and El Centro (7.4 $\mu g/m^3$ and 8.4 $\mu g/m^3$, respectively) (Figure 2). Since the emission sources and magnitudes are similar between Calexico, El Centro, and Brawley, we would assume that the Calexico design value should be in line with the annual design values at El Centro and Brawley, if not for the impact from Mexicali emissions.

Since 2001, air quality in Imperial County has improved. The trend in the PM2.5 annual design value at Calexico has improved significantly over the past few years. In 2001, the annual average at the Calexico monitor was 15.7 $\mu g/m^3$. In 2016, the annual average at Calexico decreased 20 percent to 12.5 $\mu g/m^3$. These reductions are generally due to CARB's mobile source control program and the District's increasingly stringent rules on stationary and area sources, especially on sources of windblown dust.

It is worth noting that the annual design value increased at Calexico from 2011-2014 due to three samples collected in 2011 and 2012 (October 15, 2011, March 31, 2012, and May 25, 2012) being included in the design value calculation. CARB deemed these samples to be invalid and not representative since collocated monitors showed substantially lower concentrations. U.S. EPA requested that these three samples be included as part of the design value calculation. In addition, the El Centro and Brawley design values increased in 2016 due to a few high PM2.5 values caused by wind events that caused the PM2.5 annual average values at these two sites to increase.

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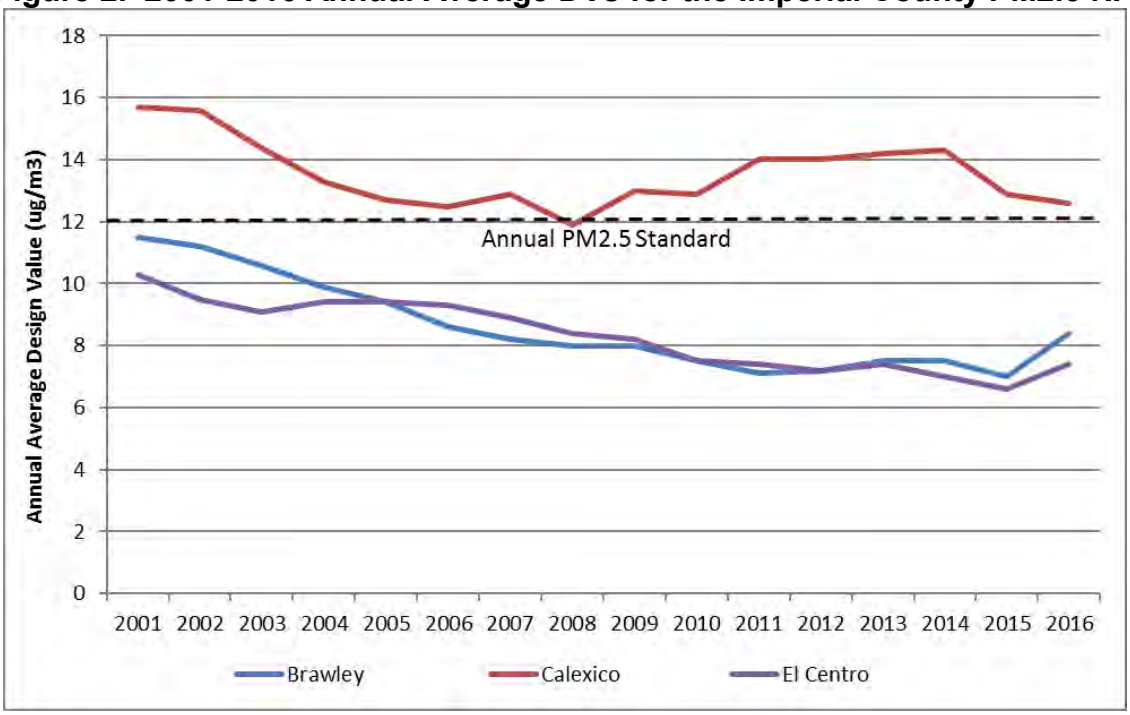
Figure 2. 2001-2016 Annual Average DVs for the Imperial County PM2.5 NA



* PM2.5 monitoring began in Imperial County in 1999; 2001 reflects the 1999-2001 design value year.

** The 2015 design value shown above is 12.9 µg/m3 and does not include data from the SPM that was included in 2015 at Calexico. AQS includes data from the SPM in quarters 1 and 4 of 2015, which results in a design value of 13.1 µg/m3.

B. SIP Requirements

The Imperial County PM2.5 nonattainment area was designated as nonattainment by U.S. EPA in 2014, and subsequently classified as moderate in 2015, requiring a SIP submittal by October of 2016. The 2018 PM2.5 Plan was developed under the provisions of section 179B of the Act that allows consideration of the impact of international cross border transport of pollutants. Under this provision, the Act does not require states to develop an attainment strategy addressing pollutants that originate from beyond the United States borders. The 2018 PM2.5 Plan includes a comprehensive technical analysis of these cross border impacts, and a demonstration that the Calexico monitor would have attained the 12.0 µg/m^3 annual PM2.5 standard in 2021, absent these international emissions from Mexicali. The 2018 PM2.5 Plan also addresses Act requirements to demonstrate that appropriate local actions have been taken to reduce emissions and provide ongoing public health protection.

III. CLEAN AIR ACT REQUIREMENTS

The required SIP elements in the 2018 PM2.5 Plan include an emissions inventory of sources in the nonattainment area; Reasonable Available Control Measures/Reasonable Available Control Technology (RACM/RACT) demonstration; Additional Reasonable Measures (ARM); Reasonable Further Progress (RFP); Quantitative Milestones in 2019 and 2022, contingency measures in case the area fails

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to meet RFP; transportation conformity budgets; and a technical demonstration of cross border impacts.

A. Emission Inventory

An emission inventory consists of a systematic listing of the sources of air pollutants with an estimate of the amount of pollutants from each source and source category over a given period of time. A SIP must contain base year and future year forecasts for all pollutants identified as contributing to PM2.5 concentrations. The base year inventory is an essential element of the plan that forms the basis for all future year projections and establishes the emission levels against which progress in emission reductions will be measured.

U.S. EPA regulations establish general guidelines for selecting an inventory base year. Based on those guidelines, CARB and the District selected 2012 as the base year for the 2018 PM2.5 Plan. In addition to a base year inventory, U.S. EPA regulations require future year inventory projections for specific milestone years. 2019 and 2022 were the inventory years used to address quantitative milestone requirements, and 2021 was the inventory year used to demonstrate attainment of the annual PM2.5 standard. Emission inventories for each of these years were developed for PM2.5, NOx, SOx, ROG and ammonia.

Figures 3 and 4 below show the percent that major source categories contribute to the PM2.5 and NOx emissions in the Imperial County PM2.5 nonattainment area in 2012. Area sources make up over 85 percent of the PM2.5 emissions in the Imperial County PM2.5 nonattainment area, mainly from unpaved road dust, fugitive windblown dust, and managed burning and disposal. More than 85 percent of the NOx emissions in the Imperial County PM2.5 nonattainment area are from mobile sources.

Figure 3. PM2.5 Major Source Categories Percent Contribution (2012)

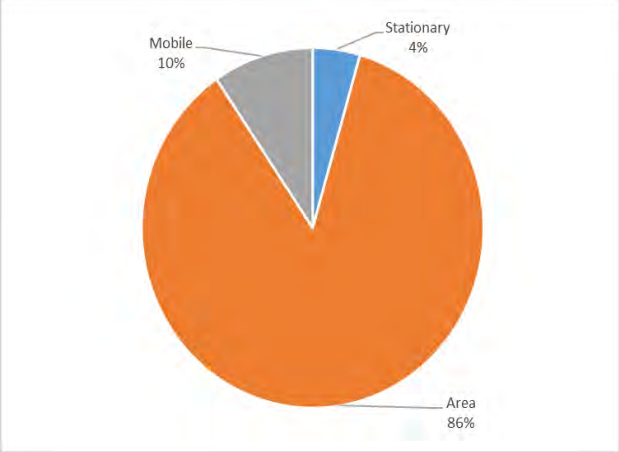
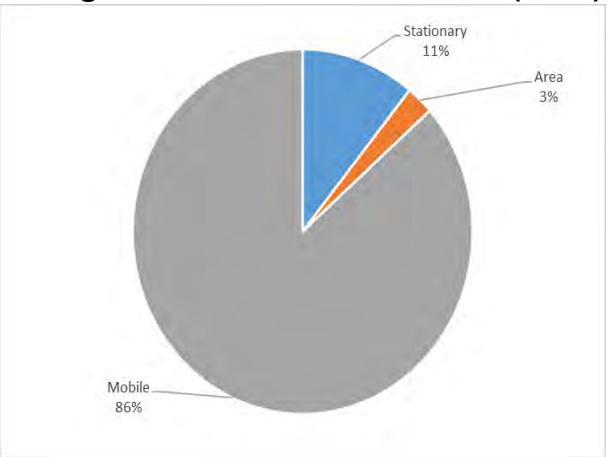


Figure 4. NOx Major Source Categories Percent Contribution (2012)



CARB and the District have developed a comprehensive emissions inventory for the 2018 PM2.5 Plan. The inventory includes a category-by-category review and update using the most recent information available on emissions-generating activities and anticipated population and economic growth in the region. A summary of the emissions

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inventory along with additional information on the inventory methodologies can be found in Chapter 3 of the District's 2018 PM2.5 Plan.

B. New District Rules

The Act requires that moderate nonattainment areas implement RACM)/RACT for significant emission sources within the nonattainment area. There are currently no major stationary sources of PM2.5 in the Imperial County PM2.5 nonattainment area. However, at the suggestion of the U.S. EPA, the District evaluated the emissions from the top PM2.5 stationary sources in the region and assessed RACT for them. The District determined the stationary sources located within the nonattainment area had a RACT level of control.

For RACM, the District evaluated the adequacy of its control measures on area sources of direct PM2.5 by reviewing the U.S. EPA Office of Air Quality Planning and Standards' Menu of Control Measures (MCM). The MCM is a list that provides a broad set of emission reduction measures for different pollutants and source types. Each control measure was then evaluated against existing District rules that address the same sources. From this analysis, it was determined that the District needed to implement a control measure for New Source Performance Standards (NSPS) for residential wood combustion. Thus, new measures addressing this source are part of the 2018 PM2.5 Plan.

In addition, U.S. EPA guidance requires the District to evaluate additional reasonable measures that could be implemented any time after the four-year period following designation through the end of the sixth calendar year after designation. Based on this guidance, the District identified a control measure to curtail residential wood combustion when 24-hour averaged PM2.5 concentrations are forecasted to exceed 35 $\mu g/m^3$ at Calexico as an ARM. The District also identified ARM related to sources of NOx and NH3 although the 2018 PM2.5 Plan deemed these PM2.5 precursors as not significant. While the comprehensive precursor demonstration has indicated that these PM2.5 precursors do not have a significant impact on PM2.5 levels causing nonattainment in Imperial County, the District is committed to the continued improvement of air quality in the region and thus is presenting rules related to these additional sources and pollutants as part of this 2018 PM2.5 Plan.

Table 1, on the next page, lists the control measures the District plans to pursue followed by a detailed explanation of each ARM measure.

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Table 1. District Proposed Control Measures for the 2018 PM2.5 Plan

Measure Type	Measure Title	Adoption Year / Implementation Year	Pollutant	Implementing Agency
RACM	Wood Burning Fireplaces and Wood Burning Heaters – NSPS Certification	2018 / 2019[b]	$PM_{2.5}$	ICAPCD
ARM	Wood Burning Fireplaces and Wood Burning Heaters– Curtailment	2018 / 2020	$PM_{2.5}$	ICAPCD
ARM	Boilers, Steam Generators, and Process Heaters	2019 / 2020	NO_X	ICAPCD
ARM	Biosolids, Animal Manure, and Poultry Litter Composting Operations	2019 / 2020	NH_3	ICAPCD
ARM	Residential Water Heaters	2019 / 2020	NO_X	ICAPCD

Proposed Wood Burning Fireplaces and Wood Burning Heaters Rule-Curtailment

The District is proposing a new rule to implement a control measure that would prohibit/curtail the combustion of wood or solid-fuel products in any wood-burning device in the city of Calexico during a curtailment period. The curtailment period would be defined as any period so declared to the public by the Air Pollution Control Officer when 24-hour averaged PM2.5 levels are forecast to exceed 35 $\mu g/m^3$ at the Calexico monitor. This rule would be adopted in or before December 2018 and implementation would begin in 2020. Prior to implementation, the District plans to develop and identify a source of funding for an incentive program for Calexico residents to purchase devices that may operate during mandated curtailment, such as gaseous-fueled devices.

Proposed Boilers, Steam Generators, and Process Heaters Rule

The District is proposing a new rule that will limit NOx emissions from boilers, steam generators, and process heaters rated 0.075 million British thermal units per hour (MMBtu/hr) to less than 5.0 MMBtu/hr. The new rule would affect emissions under the Manufacturing and Industrial and Service and Commercial subcategories, part of the Fuel Combustion Category, in the emission inventory. The new proposed Boiler, Steam Generators, and Process Heaters Rule will limit NOx emissions to less than or equal to 20 parts per million (ppm) of NOx emissions (at 3 percent oxygen [O2] dry). The limit will apply to new and replacement units rated 0.075 MMBtu/hr to less than 5.0 MMBtu/hr. It is estimated the rule would be adopted in the year 2019 and implemented in 2020.

Proposed Biosolids, Animal Manure, and Poultry Litter Composting Operations Rule

The District is proposing a new rule that would regulate biosolids, animal manure, and poultry litter composting operations. Specifically, facilities would be required to follow

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water management procedures to control ammonia emissions. The new rule would affect emissions under the Composting Solid Waste category in the emissions inventory. Imperial County composting operations largely involve the composting of animal manure, which comes from the county's large confined feedlot operations. It is estimated the rule would be adopted in the year 2019 and implemented in 2020.

Proposed Residential Water Heater Rule

The District is proposing a new rule that would limit NOx emission rates from new residential water heaters rated less than 75,000 Btu/hr. Specifically, the proposed rule would limit NOx emissions to 15 ppm (at 3 percent O2 dry). The new rule would affect emissions classified under the category known as Residential Fuel Combustion – Natural Gas – Water Heater. It is estimated the rule would be adopted in the year 2019 and implemented by January 1, 2020.

C. Quantitative Milestones

SIPs must provide for steady progress in reducing emissions during the years leading to attainment. These interim reductions are known as quantitative milestones. With a base year of 2012, the quantitative milestone years are 2019 and 2022. Emissions are provided in these years for directly-emitted PM2.5 emissions. With already adopted and proposed control measures, PM2.5 emissions are projected to decrease from 2012 to 2021 within the Imperial County PM2.5 nonattainment area. The quantitative milestones for the 2018 PM2.5 Plan involve two new Imperial County rules designed to implement additional control measures and further reduce emissions of PM2.5.

The District plans to adopt a NSPS certification rule that would apply to wood burning fireplaces and wood burning heaters. This rule would require new wood burning fireplaces and wood burning heaters to comply with NSPS certification requirements in effect at the time of installation. The District also plans to adopt a curtailment program for wood burning fireplaces and wood burning heaters which would prohibit residential wood burning in the city of Calexico on days forecasted to exceed 35 $\mu g/m^3$ at the Calexico air monitor. Once these rules are implemented, PM2.5 reductions will occur, leading to decreased PM2.5 concentrations in Calexico. The adoption and implementation of these rules serves as a quantifiable way for measuring progress towards the 2019 and 2022 quantitative milestone requirements.

D. Contingency Measures

Contingency measures are a required element of a nonattainment area SIP and provide additional emission reductions in the event the area fails to meet RFP. If the District fails to meet RFP, within 60 days of U.S. EPA making a determination in the Federal Register the District will lower the curtailment threshold from 35 $\mu g/m^3$ to 30 $\mu g/m^3$ and the curtailment will apply to the entire county when air quality is forecasted to be unhealthy.

The District also commits to lower the applicability threshold for open rural areas subject to District Rule 804 (Open Areas). Currently, District Rule 804 requires dust control on

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rural areas over three acres. If Imperial fails to meet RFP, the rural area threshold will be lowered to include rural areas down to 1000 square feet. This lowering of the applicability threshold would impose dust controls on an additional 529 rural acres in the Imperial County PM2.5 nonattainment area. The benefits of these two contingency measures collectively exceed the required one year of emission reductions (0.063 tons per day) and follow U.S. EPA's current guidance on contingency measures.

E. Transportation Conformity

Under Section 176(c) of the Act, transportation activities that receive federal funding must ensure that transportation emissions do not interfere with an area's air quality progress. Section 176 of the Act requires that transportation plans, programs, and projects conform to an area's plan before being approved by a metropolitan planning organization. In order for transportation emissions to conform to a plan, the activities must not:

1. Cause or contribute to any new violation of any standard;
2. Increase the frequency or severity of any existing violation of any standard in any area; or
3. Delay timely attainment of any standard or any required interim emission reductions or other milestones in any area.

The portion of the total emissions inventory allocated to highway and transit vehicles in the emission inventory is the motor vehicle emissions budget. The 2018 PM2.5 Plan establishes nonattainment area-level on-road mobile exhaust and municipal unpaved road dust emissions. Motor vehicle emission budgets were established for PM2.5 in the baseline year of 2012 and the milestone years of 2019 and 2022 using Southern California Association of Governments (SCAG) motor vehicle activity data and EMFAC2014 (CARB's most current mobile source emission inventory model).

IV. TECHNICAL DEMONSTRATION OF CROSS-BORDER IMPACTS

Section 179B of the Act for international border areas indicates that a SIP "…shall be approved by the Administrator if—(1) [the implementation plan meets all applicable requirements other than the attainment demonstration requirement], and (2) the submitting state establishes…that the implementation plan…would be adequate to attain and maintain the…NAAQS by the attainment date, but for emissions emanating from outside of the United States."[1] U.S. EPA guidance issued in 1994 therefore indicated that those border areas that provide a technical justification of attainment, but for emissions from foreign sources, are relieved of certain planning requirements including development of an attainment demonstration.[2] U.S. EPA guidelines identify the types of information that may be used in evaluating the impact of emissions from outside the U.S. on nonattainment areas. States may use one or more of the identified approaches based on specific circumstances and available data.

[1] Clean Air Act Amendments of 1990: Public Law 101-549.
[2] See 59 FR 42000-42002 (August 16, 1994).

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CARB staff examined the available monitoring, emissions, and meteorology data from Calexico, other Imperial County monitoring sites, and Mexicali. Guideline techniques were applied to evaluate the impacts of emissions emanating from Mexicali and Imperial County on attainment of the 12.0 $\mu g/m^3$ annual PM2.5 standard.

Staff first compared the area, population, and emissions data for Mexicali and the Imperial County nonattainment area. Mexicali has more than four times the population of the entire nonattainment area and more than 18 times the population of Calexico. Emissions from Mexicali are significantly higher than those in the Imperial County PM2.5 nonattainment area. For example, direct PM2.5 emissions in Mexicali are more than 50 percent higher than the level of direct PM2.5 emissions in the Imperial County PM2.5 nonattainment area, and NOx emissions are more than three times higher than comparable emissions in the Imperial County PM2.5 nonattainment area.

The most recent, verifiable emissions inventory for Mexicali is from 2005 and does not include all of the emissions sources to fairly compare to the emissions in the Imperial County PM2.5 nonattainment area. Windblown dust emissions, for example, are a major source of PM2.5 in the Imperial County PM2.5 nonattainment area but windblown dust and state point source emissions of PM2.5 are missing from the 2005 Mexicali emissions inventory. If windblown dust emissions and state point source emissions in Mexicali were included in the 2005 Mexicali emissions inventory, it is anticipated Mexicali would contribute a much higher share of overall PM2.5 emissions to the total airshed.

Staff also evaluated the relationship between wind direction and the resulting PM2.5 concentrations at Calexico. This analysis paired hourly wind direction data with hourly PM2.5 data to determine what the average PM2.5 impact was from winds that came from the north (Imperial County) versus winds that came from the south (Mexicali) (Figure 5). To determine the appropriate wind direction splits, the compass degrees were split into 16 equal sized bins and assigned as having a northern or southern component. The analysis showed that when the winds came from north, the average PM2.5 concentration measured at Calexico was under the annual PM2.5 standard at 11.7 $\mu g/m^3$. However, when the winds came from the south, the average PM2.5 measured concentration at Calexico increased to 20.2 $\mu g/m^3$. In addition, winds from the north occurred much more frequently (44 percent) than winds from the south (23 percent) yet the southern winds still had the strongest impact on annual PM2.5 levels at Calexico.

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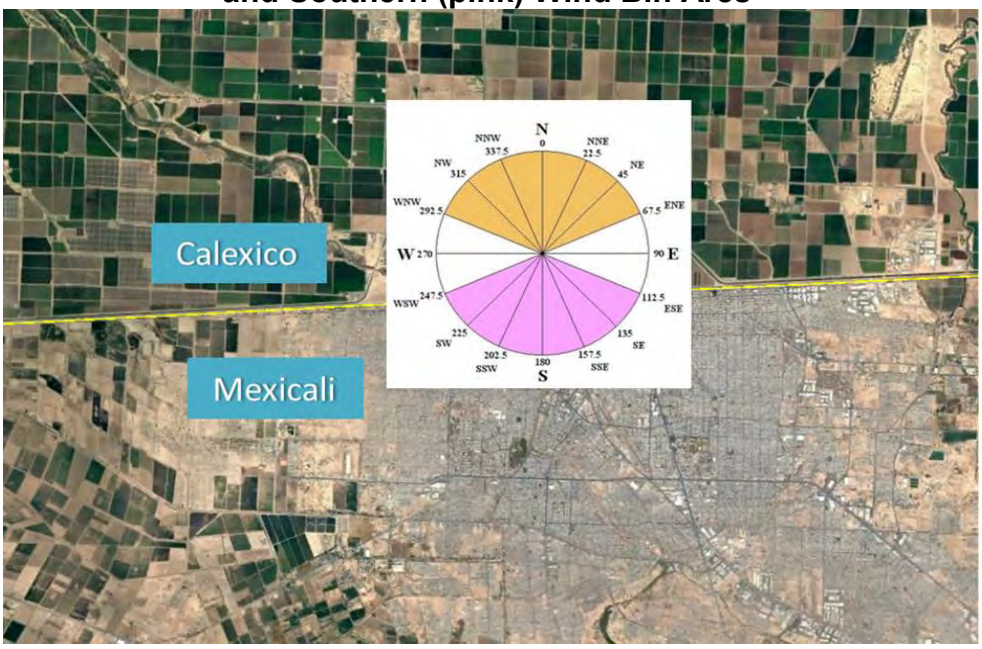
Figure 5. Compass Display of the Northern (orange) and Southern (pink) Wind Bin Arcs



Staff evaluated the chemical composition collected at CARB's Calexico air monitoring site to help identify the type of emissions that result in elevated PM2.5 levels. The chemical composition of the PM2.5 particles at Calexico indicated that combustion, such as produced from motor vehicles or wood and waste burning, is a major source of emissions. The analysis also indicated that elements such as chromium, lead, and zinc, normally measured at very low levels throughout Imperial County and the rest of the State were significantly higher at the Calexico air monitoring site. The potential sources of these elements include the combustion of refuse or other non-biomass materials and industry that does not exist in the Imperial County PM2.5 nonattainment area. Further evaluation of the correlations between wind direction and these source signatures indicated that the origin of these pollutants was south-southeast of the monitoring site in the direction of the border and Mexicali.

Staff conducted various analyses using monitoring data, meteorological conditions, and emissions in the border region to evaluate the impacts of emissions emanating from Mexicali on attainment of the annual PM2.5 standard in Imperial County. Staff assessed Calexico speciation data and conducted a source apportionment analysis which tied speciation data to sources that are present in both the Imperial County PM2.5 nonattainment area and Mexicali. This apportionment method enabled a hypothetical calculation of the annual PM2.5 design value if Mexicali sources were excluded from consideration. This analysis identified seven major sources of pollution (airborne soil, biomass burning, mobile, secondary sulfate, secondary nitrate, refuse burning, and industrial) that impact the Calexico site, with the source direction for the majority of these sources from Mexicali or the border crossing area (Figure 6).

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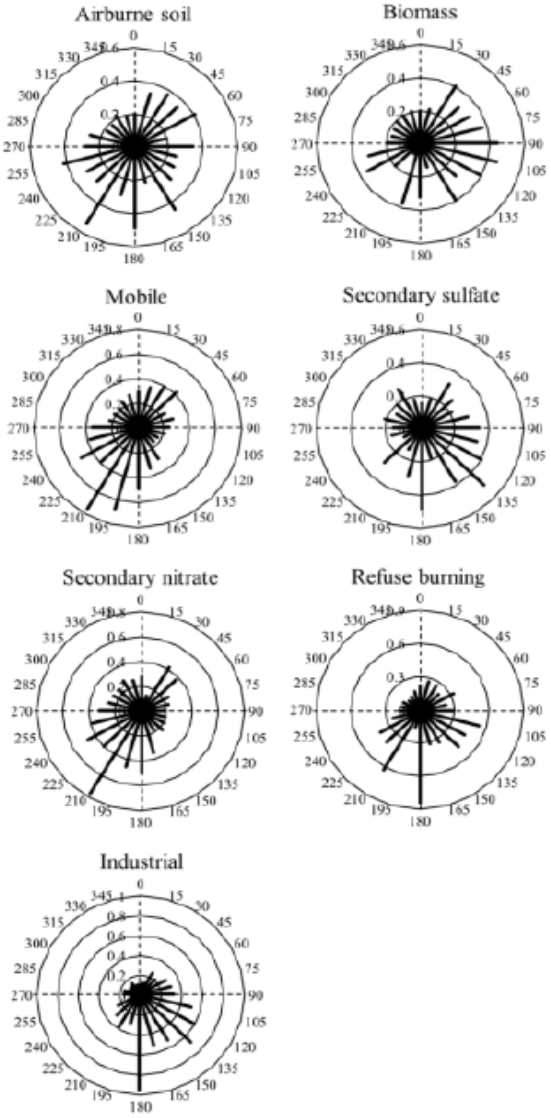
Figure 6. Conditional Probability Function Plots for the Highest 25 Percent of the Source Contributions



Air quality modeling demonstrated that the annual average PM2.5 design value would be 11.7 µg/m^3 at the Calexico PM2.5 monitor in 2021 if emissions from Mexicali were reduced or eliminated. Considered together with air quality data and meteorological influences, the analyses in Appendix A of the 2018 PM2.5 Plan demonstrate that, in 2021, the Imperial County PM2.5 nonattainment area would attain the annual PM2.5 standard of 12.0 µg/m^3 in the absence of emissions from Mexico.

Together with the proximity of Calexico to Mexicali, analysis of the emission inventory for the Imperial County PM2.5 nonattainment area and Mexicali, analysis of the meteorological conditions (wind speed and wind direction) at Calexico, and the chemical composition of samples at Calexico and other monitoring sites, the available evidence supports the international cross-border impact of Mexicali emissions on the Imperial County PM2.5 nonattainment area required under the Act.

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V. OTHER CONSIDERATIONS IN IMPERIAL COUNTY

A. Assembly Bill 617

Assembly Bill (AB) 617 (C. Garcia, Chapter 136, Statutes of 2017) provides a new community-focused action framework to improve air quality and reduce exposure to criteria air pollutants and toxic air contaminants in communities most impacted by air pollution. The bill recognizes that while California has seen tremendous improvement in air quality, some communities still suffer greater impacts and will require special attention along with accelerated action. AB 617 builds on the foundation of existing programs, providing additional tools to target actions in communities that bear the greatest burdens. Specifically the legislation sets out a framework that includes:

- Community-level air quality monitoring;
- A State strategy and community emissions reduction programs;
- Expedited schedule for the installation of the cleanest controls on industrial facilities
- Enhanced requirements for the reporting of emissions data including increased penalty provisions for polluters; and
- Grants to local community groups to support active engagement in developing solutions for their communities.

To implement AB 617, CARB has established the Community Air Protection Program (Program). The legislation sets out an ambitious implementation schedule, and CARB must set the overall direction of the Program by October 1, 2018. This includes identifying impacted communities, establishing the criteria for air monitoring and local emissions reduction programs, and developing statewide strategies for reducing emissions. The local air districts also have specific roles and responsibilities and successful implementation will require strong collaboration between CARB and the air districts, as well as with local communities.

B. Agricultural Burning

Imperial County residents have raised concerns about the level of agricultural burning that occurs in Imperial County and the impact it may have on their health. Agricultural burning is a source of PM2.5 emissions that can have localized impacts in the Imperial County PM2.5 nonattainment area. After crops are harvested, the fields and stubble are burned to prepare for the next planting. This burning helps prevent the spread of plant diseases and controls weeds and other pests. Title 17 of the California Code of Regulations (Title 17) provides agricultural and prescribed burning guidelines for each area in California with the goal of minimizing public health impacts. Title 17 specifically requires the District to have rules in place that minimize smoke from agricultural burning.[3] Title 17 also identifies the meteorological criteria for regulation of agricultural and prescribed burning by air basin in order to minimize smoke impacts.

[3] *Smoke Management Guidelines for Agricultural and Prescribed Burning*. Title 17 of the California Code of Regulations, Subchapter 2, March 14, 2001.

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On a daily basis, the District reviews meteorological reports from various airport operators, the National Weather Service, State fire agencies, and CARB to help determine whether the day is a "burn day". Burn/no burn days are declared for the entire county. The District uses a detailed map of Imperial County to ensure that burns are allocated correctly for minimal-to-no smoke impacts on the public. Daily burn authorizations specify the amount, timing, and location of each burn event. The burn authorization system considers the following factors before declaring a burn day: (1) air quality; (2) meteorological conditions expected during burning, including wind speeds and directions at the surface and aloft, and atmospheric stability; (3) types and amounts of materials to be burned; (4) location and timing of materials to be burned; (5) locations of nearby smoke sensitive areas (schools, residential neighborhoods, etc.); and (6) smoke from all burning activities, including burning in neighboring air districts or regions which may affect the District or region.

The District's Rule 701 prohibits agricultural burning on any day declared to be a no-burn day by CARB, a fire control agency, or the District's Air Pollution Control Officer. Residents may report illegal agricultural burning to the District enforcement office. If the burn is deemed to be illegal, the District will conduct an inspection to obtain information on the violation and fines will be assessed on the landowner. Rule 701 also specifies the type of waste material that is allowed for burning, along with appropriate drying times, and the hours when burning may be conducted.

The District's Rule 701 additionally requires that when a burn permit is applied for in which burning is within 1.5 miles of a residential area (three or more contiguous, inhabited dwellings), rural school, or adjacent to heavily traveled roads, an inspector must be present prior to, and at the time of ignition, and must give approval before the burn may be started. In addition, beginning in 2010, as part of the District's Good Neighbor Policy (Policy 37), farmers who conduct burning must notify and advise nearby neighbors (within a half mile) of a potential burn.[4] Overall, agricultural burning has been reduced 75 percent since 2003 in Imperial County.[5]

C. Salton Sea

Imperial County residents have raised concerns about future air quality in Imperial County as Salton Sea water levels decline due to the cessation of mitigation water flows. As the surface level of the Salton Sea drops over the next three decades, the lakebed – or playa – will become exposed and become a potential new source of PM2.5 in the north part of Imperial County. Unless prevented or controlled, windblown PM2.5 could reverse some of the air quality gains proposed in the 2018 PM2.5 Plan. To address this, CARB has been collaborating with other State, as well as federal and local agencies since 2003 in the monitoring, planning, and control of particulate matter (PM) emissions at the Salton Sea.

CARB staff were instrumental in the design and construction of a six-station network of shoreline PM and meteorological monitoring stations at the Salton Sea in 2009. These

[4] *Good Neighbor Policy-Neighbor Notification and Traffic Re-Routing Procedures for Agricultural Burning*. Policy No. 37. https://www.arb.ca.gov/smp/District/imp2010.pdf. April 7, 2010.
[5] Imperial County Air Pollution Control District agricultural burn reports (2003-2017)

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stations collect baseline air quality data and serve as an early warning system for changes in exposed playa dust emissivity. The continuous hourly data collected since February 2010 provide a rich database for assessment of air quality impacts and development of mitigation measures by researchers and regulatory agencies alike.

By requirement of the 2003 water transfer agreement, the Imperial Irrigation District (IID) has been the principal agency involved in Salton Sea windblown dust research and control measure testing for the past 15 years. The 2003 water transfer agreement allowed California to reduce diversions from the Colorado River and secure water for population growth in coastal regions, over the next 75 years. The agreement also provided a path for mitigation of adverse environmental impacts resulting from flow reductions to the Salton Sea. Using funds pooled by the water agencies involved in the transfer, IID has retained a team of air quality consultants who participate in control measure research and testing at Owens Lake to conduct similar activities at the Salton Sea. CARB staff is closely reviewing and advising a team of air quality consultants retained by the IID on technical aspects of windblown dust research at the Salton Sea. Research results are shared with the District, the South Coast Air Quality Management District, local environmental justice groups, and the Science and Air Quality Committees of the Governor's Salton Sea Task Force.

Analysis of the collected air quality monitoring data around the Salton Sea has shown that current high PM10 concentrations during high wind events are due to emissions from disturbed soil sources almost due west of communities near the Salton Sea. The windblown dust emissions from the playa will infrequently be transported south to Westmorland and Brawley. Niland, near the southeast corner of the Sea, is downwind of exposed playa during high wind events, but the hourly PM10 peaks recorded on high wind days at Niland and two nearby shoreline stations shows little relationship between the hourly profiles at the three locations.

In the past two years, new dust plume visualization systems have been utilized for ongoing analyses of playa emissions. These new systems include 360-degree images recorded during daylight hours at elevated locations at Red Hill Bay and Anza Borrego Desert State Park, as well as captured by new GOES-R geostationary satellites. This system is useful in identifying windblown dust source areas and dust plume density and trajectory. The team of air quality consultants has been researching the design, control effectiveness, and costs of alternative playa dust control measures since 2013. Information from this research includes a three-year lag between the playa first becoming exposed and the onset of windblown dust generation. Addition of the analysis indicates deep tilling can be a near-term control measure that requires the use of no water.

CARB staff will continue collaborative efforts with IID in playa dust control research and testing activities. Staff will also continue to communicate the findings and implications of these research activities to the affected air quality agencies and the many community groups concerned about future Salton Sea emissions. These research activities will help establish the most effective controls to mitigate playa dust.

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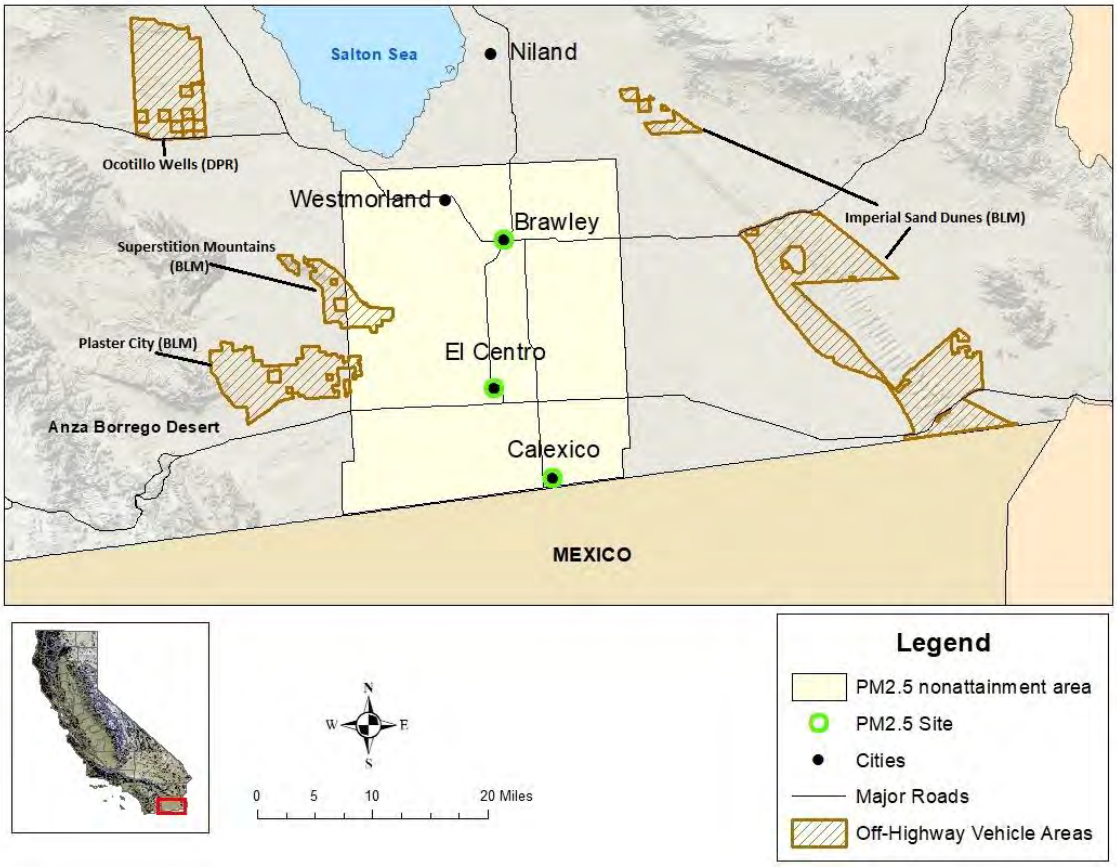
D. Off-Road Vehicles

Imperial County residents have raised concerns about how off-road recreational vehicles (OHV) impact the PM10 and PM2.5 air quality in Imperial County. PM2.5 emissions from off-road recreational vehicles (OHV) contributes approximately eight percent of the PM2.5 emissions in the Imperial County PM2.5 nonattainment area. The Bureau of Land Management (BLM) and Department of Parks and Recreation (DPR) are the only land managers of OHV-use areas on public lands in Imperial County. BLM and DPR have jurisdiction over five OHV-use areas in Imperial County, totaling over 209,000 acres of land. DPR manages Ocotillo Wells and Heber Dunes which encompass 38,660 and 340 acres, respectively. BLM manages the majority of the OHV-use areas in Imperial County. OHV-use areas under BLM management are the Imperial Sand Dunes, Plaster City, and Superstition Mountain which cover 127,416, 28,240, and 14,723 acres of land in Imperial County, respectively. The Imperial Sand Dunes contain the largest mass of sand dunes in California, covering an area more than 40 miles long and averaging 5 miles in width. Figure 7 displays the OHV areas in relation to the Imperial County PM2.5 nonattainment area.

Figure 7. OHV Areas in Imperial County



The District Rule 800 (General Requirements for Control of Fine Particulate Matter) includes requirements for OHV areas. Under Rule 800, BLM and DPR must submit a Dust Control Plan (DCP) to the District for review and approval that lays out the controls on these OHV use areas. After District comments are incorporated into the DCP, the

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District shall transmit the DCP to CARB and U.S. EPA for 45-day review and comment. BLM and DPR must implement all final DCP elements within six months of submittal and update the DCP every two calendar years. The DCP must include a summary of the total miles of paved and unpaved roads with 50 or more average vehicle trips per day, including the length and level of usage of each road. The DCP must also explain the plans for control of PM10 emissions from these roads. From June 15-August 15, BLM and DPR are required to submit a separate DCP to the District for approval in order to hold off-road events and/or competitions. The DCP shall include specific fugitive dust control measures and demonstrate that all control measures, including the requirements of Rule 800, can be implemented and enforced.

BLM and DPR are required to submit a recreational DCP to the District when off-road events and/or competitions take place. On each day of an off-road event and/or competition, in which 50 average vehicle daily trips per day will occur on an unpaved road segment or unpaved traffic area, BLM and DPR shall limit the visible dust emissions to 20 percent opacity and comply with the requirements of a stabilized unpaved road by application of various dust control measures (i.e., watering, restricting access, speed limit restriction, chemical dust suppressants).

During holiday weekends with increased OHV activity, BLM and DPR control road dust on the main entry roads by water application. In addition, a 15 mile per hour speed limit is enforced and posted on these aggregate roads. To deter illegal motorized recreation, route markers and signage identifying restricted use areas are maintained. BLM law enforcement rangers actively patrol illegal off-roading in undesignated areas to deter off-route illegal recreational use on these lands and will issue citations when illegal use is found. In addition, if any new OHV use areas are established within Imperial County that have PM10 emissions of 70 tons per year or above, the public agency must demonstrate in a federal- and/or state-required environmental assessment that these emissions would not cause or contribute to any new violations of any PM10 NAAQS in the area.

BLM and DPR have submitted complete DCP in 2013 and 2016 to the District that outline the measures they have taken and will continue to take to reduce PM10 emissions from OHV areas in the County. These DCP have been approved by the District and the requirements of Rule 800 will continue to be enforced by the District on these OHV use areas.

VI. COLLABORATIVE EFFORTS IN THE BORDER REGION

A. Mexico

Border 2020

The District, CARB, and the U.S. EPA are working together with Mexican federal, state, and local air quality agencies on many fronts to identify and implement programs that will improve air quality in the border region. In 2012, the U.S. and Mexico signed the Border 2020 Program, which is a joint effort between U.S. EPA, Secretariat of Environment and Natural Resources (SEMARNAT), Baja California's Environmental

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Protection Agency (SPA), CARB, the District, and other agencies to improve the border environment by cleaning the air, water, hazardous waste generators, and ensuring emergency preparedness along the U.S.-Mexico border region.

The Border 2020 Program includes the Imperial-Mexicali Air Quality Task Force (AQTF). The AQTF was organized to address issues unique to the border region known as the Mexicali/Imperial air shed, and focuses on reducing air pollution in this area. AQTF membership includes representatives from federal, state and local governments from both sides of the border, as well as representatives from academia, environmental organizations, and the general public. The AQTF meets quarterly, alternating between Imperial County and Mexicali.

The first goal of the Border 2020 Program is to reduce air pollution in the border communities. Emissions from electrical generation and other industrial sources, unpaved roads, diesel trucks, buses and cars, including those idling for long periods of time at ports-of-entry, are significant contributors to the poor air quality along the border. It is important that strategies and solutions to address air pollution along the border are developed and implemented with active participation from the community, as well as local, state, and federal authorities.

- Objective 1: By 2020, in accordance with the North American Free Trade Agreement (NAFTA), promote the reduction of the number of vehicles operating in the border region that do not comply with the respective vehicle emissions standards, and reduce vehicle emissions at ports-of-entry through anti-idling and other feasible reduction measures;
- Objective 2: By 2020, reduce pollutant emissions in order to approach attainment of respective national ambient air quality standards in the Imperial County/Mexicali airshed (and other areas);
- Objective 3: By 2018, maintain effective air monitoring networks and provide real-time access to air quality data in California/Baja California;
- Objective 4: By 2015, support completion of climate action plans in each of the six northern Mexican Border States (as appropriate), and build the necessary capacity to guarantee sustained implementation; and
- Objective 5: By 2020, reduce emissions and associated impacts through energy efficiency and/or alternative/renewable energy projects.

Following is a brief summary of some of the projects in which the District, in conjunction with the AQTF, CARB and U.S. EPA, participated in to address or evaluate emissions at the border and educate the communities on the impact of air pollution in this region.

Mexicali and Imperial County Educational Media Campaign

Elevated PM2.5 levels at the Calexico monitoring station occur during the months of December and January. It is during these months when continual stagnant conditions with light winds dominate the airshed. These conditions, coupled with the tradition in Mexicali of burning wood, tires, etc. for warmth during cold nights, lead to violations of the PM2.5 standards in Calexico.

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The U.S. EPA, and the Border Environmental Cooperation Commission (BECC), the District and the Imperial Valley-Mexicali AQTF, through the Border 2020 program, have been funding a “no burn” radio and television Environmental Educational Media Campaign (Campaign) to help educate the Mexicali community concerning the impacts from open burning on the regional air quality and public health. The Campaign encourages a “no burn” mentality and promotes awareness for the wellbeing of the region’s health and environment. The District is the lead agency for this Campaign, and the Secretariat of the State of Baja California is focused on the media portion of the project. The objectives of the radio and television Campaign are to:

- Educate the community regarding the status of air quality in the region and the consequences of open burning of tires, wood, fireworks, etc.;
- Educate young adults with the goal of creating environmental advocates who care for and respect the environment;
- Raise public awareness around the serious consequences of open burning of tires, wood, fireworks, etc. on regional air quality;
- Work towards creating a “no burn” mentality; and
- Improve community leadership involvement.

The Campaign is focused on days that are likely to violate the federal health standard for air quality, traditionally during the holiday season in December and January. Therefore, the media transmissions are aired in phases to capture the periods of highest pollution. There are three audience profiles the Campaign targets: children in kindergarten to sixth grade, young adults in junior high to high school, and the general public. The first step of the Campaign targeted the education of the health and air quality impacts resulting from the burning of fireworks, tires, and wood. The affected community can then begin to understand the long-term harm that will continue should these cultural traditional practices not change.

The District started implementing this Campaign in 2011. The Campaign media advertisements are broadcast on the television and radio, and the District is committed to yearly implementation, as funding allows. The Campaign has opened many avenues of communication with Mexicali’s community and it carries tremendous power to educate all audiences.

Mexicali Monitoring (2016-2018)

To better understand emissions occurring in Mexicali and impacting air quality on both sides of the border, CARB and officials from Baja California received U.S. EPA funding to conduct PM2.5 monitoring beginning in 2016 at two sites in Mexicali (UABC and COBACH) including chemical speciation. This bi-national, monitoring effort began in April of 2016 and will run through April of 2018. This study will produce high quality information on PM2.5 air quality and likely sources in Mexicali. The District is working closely with counterparts in Mexico to develop and implement emission reduction strategies and projects that will improve the air quality in the Mexicali-Imperial region.

At the end of the two years, the monitoring equipment will be donated to the Secretary of Environmental Protection of the State of Baja California. The Secretary of

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Environmental Protection will monitor for PM2.5 at Cobach and UABC but speciation will not be continued since the laboratory infrastructure to support analyzing speciated PM2.5 data is not available. CARB will analyze all of the air quality data from this project to assess the main PM2.5 sources and locations of pollution impacting the communities in Mexicali and Calexico.

California-Mexico Memorandum of Understanding

In 2014, the California-Mexico Memorandum of Understanding (MOU) was signed to enhance the cooperation on climate change and the environment between the State of California and the Ministry of Environment and Natural Resources and the National Forestry Commission of the United Mexican States.[6] The MOU establishes actions related to environmental issues such as climate change, human and environmental health, air quality, wildfires, and transportation between California and Mexico. In addition to other efforts in the MOU, to improve the air quality in these areas, the MOU seeks to: reduce emissions of criteria pollutants, and toxic air contaminants; Increase the cooperation related to air quality along the border, including air quality monitoring, audits of air quality monitoring equipment, the use of specialized equipment and, exchange of technical and policy information on air quality; support new and expanded markets for clean and efficient energy technologies in the industrial, electricity and transportation sectors; reduce vehicle emissions though strengthening vehicle standards, setting common standards, and supporting green freight initiatives; and strengthen technical and institutional capabilities on fire management.

U.S. EPA, CARB, SEMARNAT, SPA, the District, and many other organizations and the public are working together to meet the goals of the MOU to better the air quality in California and Mexico.

Program to Improve Air Quality in Mexicali 2011-2020 (ProAire)

The ProAire program represents a collaborative effort between the federal, State, and municipal governments in Mexico, along with industry and local communities to improve the quality of life in Mexicali and to reduce the risk of exposure to air pollution. This program identifies agricultural burning, paved and unpaved roads, and power generation as the main sources of direct PM2.5 emissions in Mexicali. The program includes the following actions to reduce air emissions in Mexicali:

- Regulating agricultural burning and developing a diagnosis of the current state of agricultural burning in Mexicali in order to establish the meteorological and size conditions under which agricultural burning can be allowed;
- Establishing a model to incentivize reduction of agricultural burning and identifying other alternatives to agricultural burning;

[6] 2014, July 28. Memorandum of Understanding to Enhance Cooperation on Climate Change and the Environment Between the State of California of the United States of America and the Ministry of Environment and Natural Resources and the National Forestry Commission of the United Mexican States. Retrieved from: https://www.gov.ca.gov/wp-content/uploads/2017/09/7.28_Climate_MOU_Eng.pdf.

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- Developing a strategy to reduce particulate emissions from paved and unpaved roads; and
- Establishing agreements with power generation facilities to evaluate the significance of their air emissions on air quality and public health and to identify new actions to reduce and control their air emissions.

As outlined in the programs above, the District has been and will continue to work cooperatively with counterparts from U.S. EPA, CARB, and Mexico to develop emission reductions strategies and projects for air quality improvement at the border and to provide public information and education to border residents.

B. District

Web-Based Air Quality and Health Information Center

The District and CARB, in cooperation with the U.S. EPA, operate a web-based air quality and health information center for Imperial County (available at: http://www.imperialvalleyair.org). Through this project, the community is able to take advantage of the real-time air quality data collected by CARB and District-operated monitoring stations, including data for ozone and particulate matter (PM2.5 and PM10). The website allows residents to sign up to receive email, text, or push notifications (via the Imperial Valley Air Quality mobile app) when air quality in the region reaches unhealthy levels. Features of the mobile app include a forecast discussion with related weather information, an explanation of the Air Quality Index (AQI), a “locate me” GPS-based notification, and an identification of the cities where air monitoring stations are located. The overall purpose of this project is to enable schools and after-school programs, as well as other residents and groups in the county, to make informed choices to reduce their exposure to air pollutants. The projects enable them to prepare to use prescribed treatments, such as inhalers, when air pollution reaches levels that could adversely affect their asthma or other respiratory ailments.

AQI Advertisement Campaign

Asthma is a common health issue in Imperial County, with education in daily air quality conditions being a great need for the community. In order to promote air quality awareness and protection, the District established an AQI Advertisement Campaign with the purpose of educating and alerting the community of the daily particulate risk levels. The campaign serves as a visual communication method by utilizing a marquee at a highly trafficked area of the county, the Imperial Valley Mall. The campaign also utilizes local radio and television stations which display and discuss the AQI alerts. The District received funding to contract with Entravision/Univision, a local high–rated and frequently-viewed television station. Viewers will be informed of the air quality forecast, the current AQI, and the AQI website. This information is broadcast twice a day during the morning and evening news. This contract also includes an agreement with a high-rated radio station which announces the AQI, air quality forecast, and Imperial County AQI website three times a day.

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Vehicle Idling Emissions Study at Calexico East and Calexico West Ports of Entry (POE)

Reducing emissions of PM and NOx from idling vehicles at the Calexico East and Calexico West Ports of Entry (POE) is one of the most important air quality challenges facing the Imperial County and Mexicali region. Even with new vehicle tailpipe emission standards taking effect over the next decade, millions of vehicles at the border will continue to emit large amounts of NOx, PM, and air toxics, which contribute to serious public health problems in the region.

It is important to understand the impacts and to evaluate the amount of air emissions generated by idling vehicles at the Calexico East and Calexico West POE. On behalf of the AQTF, in 2014, the District was selected as a grantee by BECC to study border idling. The District hired a consulting firm to develop an analysis with two essential elements. The first element was to determine the vehicle idling impacts at both POE. The second element, crucial to any air quality improvement program, was the identification of emission reduction strategies that U.S.-Mexican planning agencies could implement at both POE to reduce impacts on the general population. Estimating emissions from idling vehicles and identifying potential control strategies can be helpful in securing organizational support for federal, State, and local governments on both sides of the border. Overall, this project estimated PM and NOx emissions from northbound idling vehicles waiting at the two POE and identified emission reduction strategies (with accompanying PM and NOx reductions) that U.S. and Mexican planning agencies could implement at the POE.

The first phase of this study focused on the collection of real-world data to better characterize and understand the emissions associated with and causes of border crossing delays at the POE. The second and third phases of this study focused on estimating seasonal emissions of PM2.5, ROG, and NOx at the POE under existing (2014) conditions and assuming several strategies to reduce those emissions. In addition, to analyze existing conditions and an idealized no POE delay scenario, seven emission reduction scenarios were studied:

- Phase 1 of the Calexico West POE reconstruction project;
- Phase 2 of the Calexico West POE reconstruction project;
- Use of California fuel in Mexicali;
- A reduction in empty general-purpose truck trips;
- Replacing 10 percent of general-purpose truck trips to FAST truck trips;
- Streamlining commercial crossing by combining the Aduanas and U.S. Customs and Border Protection (CBP) primary inspections; and
- The Section 559 Proposal to expand the Calexico East POE.

The results indicate that border delay accounts for about 63 percent of the ROG emissions, 46 percent of the NOx emissions, and 53 percent of the PM2.5 emissions from northbound vehicles crossing into the United States on an annual basis. The emissions associated with border delay are equivalent to the TOG (Total Organic Gases which ROG is a subset of) emissions from 2,700 passenger vehicles in Imperial County, the NOx emissions from 4,400 passenger vehicles in Imperial County, and the PM2.5

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emissions from 3,450 passenger vehicles in Imperial County. These results provide a sense of the number of privately owned vehicles in Imperial County that would need to be removed from the vehicle fleet in order to achieve the same air quality emissions benefit as addressing border delays.

C. Community

CARB has been involved with the Environmental Group Comité Cívico del Valle Inc. (CCV) on their community monitoring effort which consists of 40 low-cost air quality sensors that measure PM2.5 and PM10 throughout Imperial County. One of these sensors have been collocated with the Calexico station to compare to the regulatory PM2.5 and PM10 measurements. This aides CCV in validating their sensor data as well as to fine tune their calibration algorithm for this monitoring effort. CARB and CCV partnered together to take a proactive role in promoting community science to assess local air quality. The partnership consists of a $160,000 contract to evaluate and improve the performance of CCV's existing community-led air monitoring network in Imperial Valley.

Other efforts to help assist community efforts have also taken place. In support of the CARB/Department of Pesticide Regulation pesticide study, CCV ran a pesticide field sampling site. CARB staff trained CCV on pesticide sampling in February of 2018 to help out with this effort. CARB also performed an EBAM PM2.5 collocation study in the spring 2016 (5 schools plus border crossing) with Dylos PM sensors to verify the Dylos calibration algorithm.

VII. ENVIRONMENTAL IMPACTS

The California Environmental Quality Act (CEQA) requires that State and local agency projects be assessed for potential environmental impacts. An air quality plan is a "project" that is potentially subject to CEQA requirements. The District found that the 2018 PM2.5 Plan will not result in any potentially significant adverse effects on the environment and released a Negative Declaration on March 11, 2018, which was certified at a public hearing on April 24, 2018.

CARB has determined that its review and approval of the 2018 PM2.5 Plan submitted by the District for inclusion in the California SIP is a ministerial activity by CARB for purposes of CEQA (14 CCR § 15268). A "ministerial" decision is one that involves fixed standards or objective measurements, and the agency has no discretion to shape the activity in response to environmental concerns (14 CCR § 15369; *San Diego Navy Broadway Complex Coalition v. City of San Diego* (2010) 185 Cal.App.4th 924, 934).

VIII. RECOMMENDATION

CARB staff recommends that the Board approve the Imperial County PM2.5 nonattainment area's 2018 PM2.5 Plan as a revision to the California SIP including the technical analysis of the impacts of international transport demonstrating the Imperial

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County PM2.5 nonattainment area will attain the 12.0 μg/m^3 annual PM2.5 standard in 2021 absent the impact of these international emissions.

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This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D1557 – 12$^{\varepsilon 1}$

Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))[1]

This standard is issued under the fixed designation D1557; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

ε[1] NOTE—Editorially corrected variable for Eq A1.2 in July 2015.

1. Scope*

1.1 These test methods cover laboratory compaction methods used to determine the relationship between molding water content and dry unit weight of soils (compaction curve) compacted in a 4- or 6-in. (101.6- or 152.4-mm) diameter mold with a 10.00-lbf. (44.48-N) rammer dropped from a height of 18.00 in. (457.2 mm) producing a compactive effort of 56 000 ft-lbf/ft^3 (2700 kN-m/m^3).

NOTE 1—The equipment and procedures are the same as proposed by the U.S. Corps of Engineers in 1945. The modified effort test (see 3.1.3) is sometimes referred to as the Modified Proctor Compaction Test.

1.1.1 Soils and soil-aggregate mixtures are to be regarded as natural occurring fine- or coarse-grained soils, or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as gravel or crushed rock. Hereafter referred to as either soil or material.

1.2 These test methods apply only to soils (materials) that have 30 % or less by mass of their particles retained on the ¾-in. (19.0-mm) sieve and have not been previously compacted in the laboratory; that is, do not reuse compacted soil.

1.2.1 For relationships between unit weights and molding water contents of soils with 30 % or less by weight of material retained on the ¾-in. (19.0-mm) sieve to unit weights and molding water contents of the fraction passing the ¾-in. (19.0-mm) sieve, see Practice D4718.

1.3 Three alternative methods are provided. The method used shall be as indicated in the specification for the material being tested. If no method is specified, the choice should be based on the material gradation.

1.3.1 *Method A:*

1.3.1.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*—Passing No. 4 (4.75-mm) sieve.

1.3.1.3 *Layers*—Five.

1.3.1.4 *Blows per layer*—25.

1.3.1.5 *Usage*—May be used if 25 % or less by mass of the material is retained on the No. 4 (4.75-mm) sieve. However, if 5 to 25 % by mass of the material is retained on the No. 4 (4.75-mm) sieve, Method A can be used but oversize corrections will be required (See 1.4) and there are no advantages to using Method A in this case.

1.3.1.6 *Other Use*—If this gradation requirement cannot be met, then Methods B or C may be used.

1.3.2 *Method B:*

1.3.2.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.2.2 *Material*—Passing ⅜-in. (9.5-mm) sieve.

1.3.2.3 *Layers*—Five.

1.3.2.4 *Blows per layer*—25.

1.3.2.5 *Usage*—May be used if 25 % or less by mass of the material is retained on the ⅜-in. (9.5-mm) sieve. However, if 5 to 25 % of the material is retained on the ⅜-in. (9.5-mm) sieve, Method B can be used but oversize corrections will be required (See 1.4). In this case, the only advantages to using Method B rather than Method C are that a smaller amount of sample is needed and the smaller mold is easier to use.

1.3.2.6 *Other Usage*—If this gradation requirement cannot be met, then Method C may be used.

1.3.3 *Method C:*

1.3.3.1 *Mold*—6-in. (152.4-mm) diameter.

1.3.3.2 *Material*—Passing ¾-in. (19.0-mm) sieve.

1.3.3.3 *Layers*—Five.

1.3.3.4 *Blows per layer*—56.

1.3.3.5 *Usage*—May be used if 30 % or less (see 1.4) by mass of the material is retained on the ¾-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Method A or B.

NOTE 2—Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds, with the

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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***A Summary of Changes section appears at the end of this standard**

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smaller mold size typically yielding larger values of unit weight and density (1).[2]

1.4 If the test specimen contains more than 5 % by mass of oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit weight and molding water content of the test specimen or to the appropriate field in-place unit weight (or density) test specimen using Practice D4718.

1.5 This test method will generally produce a well-defined maximum dry unit weight for non-free draining soils. If this test method is used for free-draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D4253.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by these test methods.

1.6.1 For purposes of comparing measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.6.2 The procedures used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analytical methods for engineering design.

1.7 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only, except for units of mass. The units for mass are given in SI units only, g or kg.

1.7.1 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. These test methods have been written using the gravitational system of units when dealing with the inch-pound system. In this system, the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm) or the recording of density in lbm/ft^3 shall not be regarded as a nonconformance with this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.9 **Warning**—Mercury has been designated by EPA and many state agencies as a hazardous material that can cause central nervous system, kidney, and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website (http://www.epa.gov/mercury/faq.htm) for additional information. Users should be aware that selling mercury or mercury containing products or both into your state may be prohibited by state law.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

D2168 Practices for Calibration of Laboratory Mechanical-Rammer Soil Compactors

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4220 Practices for Preserving and Transporting Soil Samples

D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

D4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D4914 Test Methods for Density and Unit Weight of Soil and Rock in Place by the Sand Replacement Method in a Test Pit

D5030 Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit

D6026 Practice for Using Significant Digits in Geotechnical Data

D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E319 Practice for the Evaluation of Single-Pan Mechanical Balances
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology D653 for general definitions.

3.1.2 *molding water content, n*—the water content of the soil (material) specimen in the mold after it has been reconstituted and compacted.

3.1.3 *modified effort*—in compaction testing, the term for the 56 000 ft-lbf/ft^3 (2700 kN-m/m^3) compactive effort applied by the equipment and methods of this test.

3.1.4 *modified maximum dry unit weight, $\gamma_{d,max}$ (lbf/ft^3 (kN/m^3))*—in compaction testing, the maximum value defined by the compaction curve for a compaction test using modified effort.

3.1.5 *modified optimum water content, w_{opt} (%)*—in compaction testing, the water content at which the soil can be compacted to the maximum dry unit weight using modified compactive effort.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *oversize fraction (coarse fraction), P_C (%)*—the portion of total specimen not used in performing the compaction test; it may be the portion of total specimen retained on the No. 4 (4.75-mm) sieve in Method A, ⅜-in. (9.5-mm) sieve in Method B, or ¾-in. (19.0-mm) sieve in Method C.

3.2.2 *test fraction (finer fraction), P_F (%)*—the portion of the total specimen used in performing the compaction test; it may be fraction passing the No. 4 (4.75-mm) sieve in Method A, passing the ⅜-in. (9.5-mm) sieve in Method B, or passing the ¾-in. (19.0-mm) sieve in Method C.

4. Summary of Test Method

4.1 A soil at a selected molding water content is placed in five layers into a mold of given dimensions, with each layer compacted by 25 or 56 blows of a 10.00-lbf (44.48-N) rammer dropped from a distance of 18.00 in. (457.2 mm), subjecting the soil to a total compactive effort of about 56 000 ft-lbf/ft^3 (2700 kN-m/m^3). The resulting dry unit weight is determined. The procedure is repeated for a sufficient number of molding water contents to establish a relationship between the dry unit weight and the molding water content for the soil. This data, when plotted, represent a curvilinear relationship known as the compaction curve. The values of optimum water content and modified maximum dry unit weight are determined from the compaction curve.

5. Significance and Use

5.1 Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as shear strength, compressibility, or permeability. In addition, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and molding water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved.

NOTE 3—The degree of soil compaction required to achieve the desired engineering properties is often specified as a percentage of the modified maximum dry unit weight as determined using this test method. If the required degree of compaction is substantially less than the modified maximum dry unit weight using this test method, it may be practicable for testing to be performed using Test Method D698 and to specify the degree of compaction as a percentage of the standard maximum dry unit weight. Since more energy is applied for compaction using this test method, the soil particles are more closely packed than when D698 is used. The general overall result is a higher maximum dry unit weight, lower optimum moisture content, greater shear strength, greater stiffness, lower compressibility, lower air voids, and decreased permeability. However, for highly compacted fine-grained soils, absorption of water may result in swelling, with reduced shear strength and increased compressibility, reducing the benefits of the increased effort used for compaction (2). Use of D698, on the other hand, allows compaction using less effort and generally at a higher optimum moisture content. The compacted soil may be less brittle, more flexible, more permeable, and less subject to effects of swelling and shrinking. In many applications, building or construction codes may direct which test method, D698 or this one, should be used when specifying the comparison of laboratory test results to the degree of compaction of the in-place soil in the field.

5.2 During design of an engineered fill, testing performed to determine shear, consolidation, permeability, or other properties requires test specimens to be prepared by compacting the soil at a prescribed molding water content to obtain a predetermined unit weight. It is common practice to first determine the optimum water content (w_{opt}) and maximum dry unit weight (γ_{dmax}) by means of a compaction test. Test specimens are compacted at a selected molding water content (w), either wet or dry of optimum (w_{opt}) or at optimum (w_{opt}), and at a selected dry unit weight related to a percentage of maximum dry unit weight (γ_{dmax}). The selection of molding water content (w), either wet or dry of optimum (w_{opt}) or at optimum (w_{opt}) and the dry unit weight (γ_{dmax}) may be based on past experience, or a range of values may be investigated to determine the necessary percent of compaction.

5.3 Experience indicates that the methods outlined in 5.2 or the construction control aspects discussed in 5.1 are extremely difficult to implement or yield erroneous results when dealing with some soils. The following subsections describe typical problem soils, the problems encountered when dealing with such soils and possible solutions for these problems.

5.3.1 *Oversize Fraction*—Soils containing more than 30 % oversize fraction (material retained on the ¾-in. (19-mm) sieve) are a problem. For such soils, there is no ASTM test method to control their compaction and very few laboratories are equipped to determine the laboratory maximum unit weight (density) of such soils (USDI Bureau of Reclamation, Denver, CO and U.S. Army Corps of Engineers, Vicksburg, MS). Although Test Methods D4914 and D5030 determine the "field" dry unit weight of such soils, they are difficult and expensive to perform.

5.3.1.1 One method to design and control the compaction of such soils is to use a test fill to determine the required degree of compaction and the method to obtain that compaction. Then

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use a method specification to control the compaction. Components of a method specification typically contain the type and size of compaction equipment to be used, the lift thickness, acceptable range of molding water content, and number of passes.

NOTE 4—Success in executing the compaction control of an earthwork project, especially when a method specification is used, is highly dependent upon the quality and experience of the contractor and inspector.

5.3.1.2 Another method is to apply the use of density correction factors developed by the USDI Bureau of Reclamation (3,4) and U.S. Corps of Engineers (5). These correction factors may be applied for soils containing up to about 50 to 70 % oversize fraction. Both agencies use a different term for these density correction factors. The USDI Bureau of Reclamation uses *D* ratio (or *D* – VALUE), while the U.S. Corps of Engineers uses Density Interference Coefficient (I_c).

5.3.1.3 The use of the replacement technique (Test Method D1557–78, Method D), in which the oversize fraction is replaced with a finer fraction, is inappropriate to determine the maximum dry unit weight, γ_{dmax}, of soils containing oversize fractions (5).

5.3.2 *Degradation*—Soils containing particles that degrade during compaction are a problem, especially when more degradation occurs during laboratory compaction than field compaction, the typical case. Degradation typically occurs during the compaction of a granular-residual soil or aggregate. When degradation occurs, the maximum dry-unit weight increases (1) so that the resulting laboratory maximum value is not representative of field conditions. Often, in these cases, the maximum dry unit weight is impossible to achieve in the field.

5.3.2.1 Again for soils subject to degradation, the use of test fills and method specifications may help. Use of replacement techniques is not correct.

5.3.3 *Gap Graded*—Gap-graded soils (soils containing many large particles with limited small particles) are a problem because the compacted soil will have larger voids than usual. To handle these large voids, standard test methods (laboratory or field) typically have to be modified using engineering judgement.

NOTE 5—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

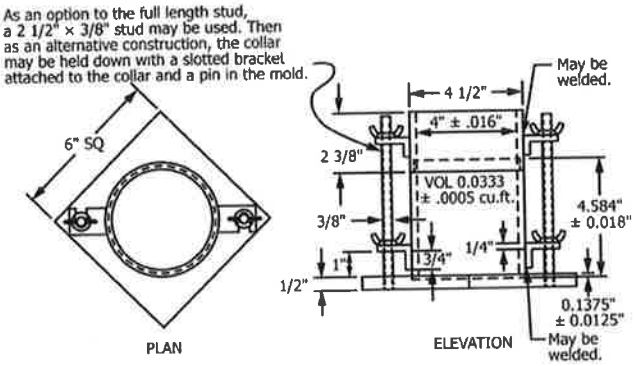
6. Apparatus

6.1 *Mold Assembly*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 6.1.1 or 6.1.2 and Fig. 1 and Fig. 2. See also Table 1. The walls of the mold may be solid, split, or tapered. The "split" type may consist of two half-round sections, or a section of pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The "tapered" type shall have an internal diameter taper that is uniform and not more than 0.200 in./ft (16.7 mm/m) of mold height. Each mold shall have a base plate and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached and easily detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2.0 in. (51 mm) which may include an upper section that flares out to form a funnel, provided there is at least a 0.75-in. (19-mm) straight cylindrical section beneath it. The extension collar shall align with the inside of the mold. The bottom of the base plate and bottom of the centrally recessed area that accepts the cylindrical mold shall be planar within ±0.005 in. (±0.1 mm).

6.1.1 *Mold, 4 in.*—A mold having a 4.000 ± 0.016-in. (101.6 ± 0.4-mm) average inside diameter, a height of 4.584 ± 0.018 in. (116.4 ± 0.5 mm) and a volume of 0.0333 ± 0.0005 ft^3 (943.0 ± 14.0 cm^3). A mold assembly having the minimum required features is shown in Fig. 1.

6.1.2 *Mold, 6 in.*—A mold having a 6.000 ± 0.026-in. (152.4 ± 0.7-mm) average inside diameter, a height of 4.584 ± 0.018 in. (116.4 ± 0.5 mm), and a volume of 0.0750 ± 0.0009 ft^3 (2124 ± 25 cm^3). A mold assembly having the minimum required features is shown in Fig. 2.

6.2 *Rammer*—A rammer, either manually operated as described further in 6.2.1 or mechanically operated as described in 6.2.2. The rammer shall fall freely through a distance of 18.00 ± 0.05 in. (457.2 ± 1.3 mm) from the surface of the specimen. The weight of the rammer shall be 10.00 ± 0.02 lbf



NOTE 1—See Table 1 for SI equivalents.

FIG. 1 Cylindrical Mold, 4.0-in.

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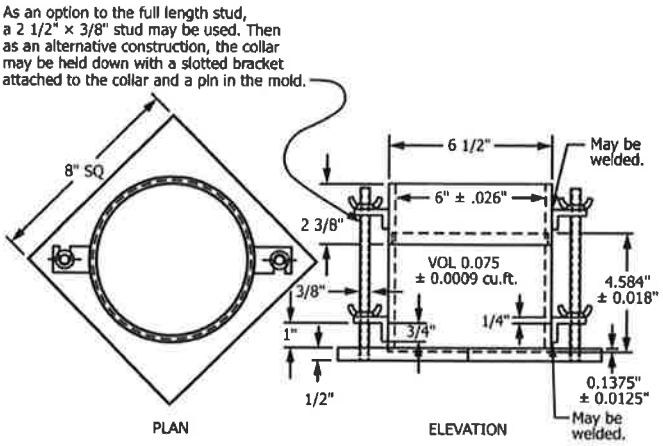

NOTE 1—See Table 1 for SI equivalents.

FIG. 2 Cylindrical Mold, 6.0-in.

TABLE 1 SI Equivalents for Figs. 1 and 2

in.	mm
0.016	0.41
0.026	0.66
0.032	0.81
0.028	0.71
½	12.70
2⅜	60.33
2½	63.50
2⅝	66.70
4	101.60
4½	114.30
4.584	116.43
4¾	120.60
6	152.40
6½	165.10
6⅝	168.30
6¾	171.40
8¼	208.60
ft^3	cm^3
1/30 (0.0333)	943
0.0005	14
1/13.333 (0.0750)	2,124
0.0011	31

(44.48 ± 0.09 N, or mass of 4.5364 ± 0.009 kg), except that the weight of the mechanical rammers may be adjusted as described in Practices D2168 (see Note 6). The striking face of the rammer shall be planar and circular, except as noted in 6.2.2.1, with a diameter when new of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be replaced if the striking face becomes worn or bellied to the extent that the diameter exceeds 2.000 ± 0.01 in. (50.80 ± 0.25 mm).

NOTE 6—It is a common and acceptable practice to determine the weight of the rammer using either a kilogram or pound balance and assume 1 lbf is equivalent to 0.4536 kg, 1 lbf is equivalent to 1 lbm, or 1 N is equivalent to 0.2248 lbf or 0.1020 kg.

6.2.1 *Manual Rammer*—The rammer shall be equipped with a guide sleeve that has sufficient clearance that the free fall of the rammer shaft and head is not restricted. The guide sleeve shall have at least four vent holes at each end (eight holes total) located with centers ¾ ± 1/16 in. (19 ± 2 mm) from each end and spaced 90° apart. The minimum diameter of the vent holes shall be ⅜ in. (9.5 mm). Additional holes or slots may be incorporated in the guide sleeve.

6.2.2 *Mechanical Rammer-Circular Face*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03-in. (2.5 ± 0.8-mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. The mechanical rammer shall meet the standardization/calibration requirements of Practices D2168. The mechanical rammer shall be equipped with a positive mechanical means to support the rammer when not in operation.

6.2.2.1 *Mechanical Rammer-Sector Face*—The sector face can be used with the 6.0-in. (152.4-mm) mold, as an alternative to the circular face mechanical rammer described in 6.2.2. The striking face shall have the shape of a sector of a circle of radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm) and an area about the same as the circular face (see 6.2). The rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen and follow the compaction pattern given in Fig. 3(b).

6.3 *Sample Extruder (optional)*—A jack, with frame or other device adapted for the purpose of extruding compacted specimens from the mold.

6.4 *Balance*—A Class GP5 balance meeting the requirements of Specification D4753 for a balance of 1-g readability. If the water content of the compacted specimens is determined using a representative portion of the specimen, rather than the whole specimen, and if the representative portion is less than 1000 g, a Class GP2 balance having a 0.1-g readability is needed in order to comply with Test Methods D2216 requirements for determining water content to 0.1 %.

NOTE 7—Use of a balance having an equivalent capacity and a readability of 0.002 lbm as an alternative to a class GP5 balance should not be regarded as nonconformance to this standard.

6.5 *Drying Oven*—Thermostatically controlled oven, capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C) throughout the drying chamber. These requirements typically require the use of a forced-draft type oven. Preferably the oven should be vented outside the building.

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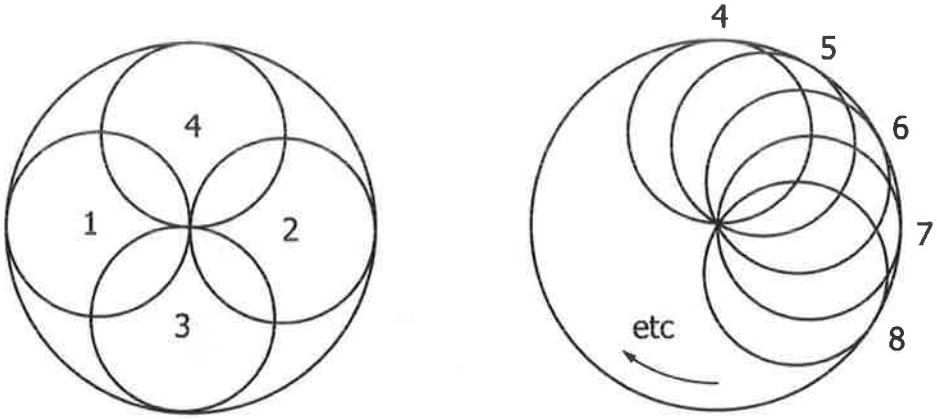

FIG. 3 Rammer Pattern for Compaction in 4-in. (101.6-mm) Mold

6.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10 in. (250 mm). The total length of the straightedge shall be machined straight to a tolerance of ±0.005 in. (±0.1 mm). The scraping edge shall be beveled if it is thicker than ⅛ in. (3 mm).

6.7 *Sieves*—¾ in. (19.0 mm), ⅜ in. (9.5 mm), and No. 4 (4.75 mm), conforming to the requirements of Specification E11.

6.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, spray device (to add water evenly), and (preferably, but optional) a suitable mechanical device for thoroughly mixing the subspecimen of soil with increments of water.

7. Standardization/Calibration

7.1 Perform standardizations before initial use, after repairs or other occurrences that might affect the test results, at intervals not exceeding 1000 test specimens, or annually, whichever occurs first, for the following apparatus:

7.1.1 *Balance*—Evaluate in accordance with Specification D4753 or Practice E319.

7.1.2 *Molds*—Determine the volume as described in Annex A1.

7.1.3 *Manual Rammer*—Verify the free fall distance, rammer weight, and rammer face are in accordance with 6.2. Verify the guide sleeve requirements in accordance with 6.2.1.

7.1.4 *Mechanical Rammer*—Verify and adjust if necessary that the mechanical rammer in accordance with Practices D2168. In addition, the clearance between the rammer and the inside surface of the mold shall be verified in accordance with 6.2.2.

8. Test Specimen

8.1 The minimum test specimen (test fraction) mass for Methods A and B is about 16 kg, and for Method C is about 29 kg of dry soil. Therefore, the field sample (see Practices D4220 for practices of preserving and transporting soil samples) should have a moist mass of at least 23 kg and 45 kg, respectively. Greater masses would be required if the oversize fraction is large (see 10.2 or 10.3) or an additional molding water content is taken during compaction of each point (see 10.4.1).

8.2 If gradation data is not available, estimate the percentage of material (by mass) retained on the No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve as appropriate for selecting Method A, B, or C, respectively. If it appears the percentage retained of interest is close to the allowable value for a given Method (A, B, or C), then either:

8.2.1 Select a Method that allows a higher percentage retained (B or C).

8.2.2 Using the sieve size designated for the Method of interest, process the specimen in accordance with 10.2 or 10.3 herein. This determines the percentage of material retained for that method. If the percentage retained is acceptable, proceed. If the percentage retained is not acceptable, go to Method B or C using the next larger sieve size.

8.2.3 Determine percentage retained values using a representative portion from the total sample, and performing a simplified or complete gradation analysis using the sieve(s) of interest and Test Method D6913 or C136. It is only necessary to calculate the retained percentage(s) for the sieve or sieves for which information is desired.

9. Preparation of Apparatus

9.1 Select the proper compaction mold(s), collar, and base plate in accordance with the Method (A, B, or C) being used. Check that the volume of the mold is known and whether the volume was determined with or without the base plate. Also, check that the mold is free of nicks or dents, and that the mold will fit together properly with the collar and base plate.

9.2 Check that the manual or mechanical rammer assembly is in good working condition and that parts are not loose or worn. Make any necessary adjustments or repairs. If adjustments or repairs are made, the rammer must be restandardized.

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10. Procedure

10.1 *Soils:*

10.1.1 Do not reuse soil that has been previously compacted in the laboratory. The reuse of previously compacted soil yields a significantly greater maximum dry unit weight (1).

10.1.2 When using this test method for soils containing hydrated halloysite, or in which past experience indicates that results will be altered by air-drying, use the moist preparation method (see Section 10.2). In referee testing, each laboratory has to use the same method of preparation, either moist (preferred) or air-dried.

10.1.3 Prepare the soil specimens for testing in accordance with 10.2 (preferred) or with 10.3.

10.2 *Moist Preparation Method (preferred)*—Without previously drying the sample/specimen, process it over a No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve, depending on the Method (A, B, or C) being used or required as covered in 8.2. For additional processing details, see Test Method D6913. Determine and record the mass of both the retained and passing portions (oversize fraction and test fraction, respectively) to the nearest g. Oven dry the oversize fraction and determine and record its dry mass to the nearest g. If it appears more than 0.5 % of the total dry mass of the specimen is adhering to the oversize fraction, wash that fraction. Then determine and record its oven dry mass to the nearest g. Determine and record the water content of the processed soil (test fraction). Using that water content, determine and record the oven dry mass of the test fraction to the nearest g. Based on these oven dry masses, the percent oversize fraction, P_C, and test fraction, P_F, shall be determined and recorded, unless a gradation analysis has already been performed. See Section 11 on Calculations.

10.2.1 From the test fraction, select and prepare at least four (preferably five) subspecimens having molding water contents such that they bracket the estimated optimum water content. A subspecimen having a molding water content close to optimum should be prepared first by trial additions or removals of water and mixing (see Note 8). Select molding water contents for the rest of the subspecimens to provide at least two subspecimens wet and two subspecimens dry of optimum, and molding water contents varying by about 2 %. At least two molding water contents are necessary on the wet and dry side of optimum to define the dry-unit-weight compaction curve (see 10.5). Some soils with very high optimum water content or a relatively flat compaction curve may require larger molding water content increments to obtain a well-defined maximum dry unit weight. Molding water content increments should not exceed about 4 %.

NOTE 8—With practice it is usually possible to visually judge a point near optimum water content. Typically, cohesive soils at the optimum water content can be squeezed into a lump that barely sticks together when hand pressure is released, but will break cleanly into two sections when "bent." They tend to crumble at molding water contents dry of optimum; they tend to stick together in a sticky cohesive mass wet of optimum. For cohesive soils, the optimum water content is typically slightly less than the plastic limit. For cohesionless soils, the optimum water content is typically close to zero or at the point where bleeding occurs.

10.2.2 Thoroughly mix the test fraction, then using a scoop select representative soil for each subspecimen (compaction point). Select about 2.3 kg when using Method A or B, or about 5.9 kg for Method C. Test Method D6913 section on Specimen and Annex A2 give additional details on obtaining representative soil using this procedure and the reason it is the preferred method. To obtain the subspecimen's molding water contents selected in 10.2.1, add or remove the required amounts of water as follows: To add water, spray it into the soil during mixing; to remove water, allow the soil to dry in air at ambient temperature or in a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Mix the soil frequently during drying to facilitate an even water content distribution. Thoroughly mix each subspecimen to facilitate even distribution of water throughout and then place in a separate covered container to stand (cure) in accordance with Table 2 prior to compaction. For selecting a standing time, the soil may be classified using Practice D2487, Practice D2488 or data on other samples from the same material source. For referee testing, classification shall be by Practice D2487.

10.3 *Dry Preparation Method*—If the sample/specimen is too damp to be friable, reduce the water content by air drying until the material is friable. Drying may be in air or by the use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Thoroughly break up the aggregations in such a manner as to avoid breaking individual particles. Process the material over the appropriate sieve: No. 4 (4.75 mm), ⅜ in. (9.5 mm), or ¾ in. (19.0 mm). When preparing the material by passing over the ¾-in. sieve for compaction in the 6-in. mold, break up aggregations sufficiently to at least pass the ⅜ in. sieve in order to facilitate the distribution of water throughout the soil in later mixing. Determine and record the water content of the test fraction and all masses covered in 10.2, as applicable to determine the percent oversize fraction, P_C, and test fraction, P_F.

10.3.1 From the test fraction, select and prepare at least four (preferably five) subspecimens in accordance with 10.2.1 and 10.2.2, except for the following: Use either a mechanical splitting or quartering process to obtain the subspecimens. As stated in Test Method D6913, both of these processes will yield non-uniform subspecimens compared to the moist procedure. Typically, only the addition of water to each subspecimen will be required.

10.4 *Compaction*—After standing (curing), if required, each subspecimen (compaction point) shall be compacted as follows:

10.4.1 Determine and record the mass of the mold or mold and base plate, see 10.4.7.

10.4.2 Assemble and secure the mold and collar to the base plate. Check the alignment of the inner wall of the mold and mold extension collar. Adjust if necessary. The mold shall rest without wobbling/rocking on a uniform rigid foundation, such as provided by a cylinder or cube of concrete with a weight or

TABLE 2 Required Standing Times of Moisturized Specimens

Classification	Minimum Standing Time, h
GW, GP, SW, SP	no requirement
GM, SM	3
All other soils	16

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mass of not less than 200 lb or 91 kg, respectively. Secure the base plate to the rigid foundation. The method of attachment to the rigid foundation shall allow easy removal of the assembled mold, collar and base plate after compaction is completed.

10.4.2.1 During the compaction procedure, it is advantageous but not required to determine the water content of each subspecimen immediately prior to compaction. This provides a check on the molding water content determined for each compaction point and the magnitude of bleeding. See 10.4.9. However, more soil will have to be selected for each subspecimen than stated in 10.2.2.

10.4.3 Compact the soil in five layers. After compaction, each layer should be approximately equal in thickness and the final layer shall extend slightly into the collar. Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a fluffy or loose state, using either the manual rammer or a cylinder approximately 2 in. (50 mm) in diameter. Following compaction of each of the first four layers, any soil that has not been compacted, such as adjacent to the mold walls, or extends above the compacted surface (up the mold walls) shall be trimmed. The trimmed soil shall be discarded. A knife or other suitable device may be used. The total amount of soil used shall be such that the fifth compacted layer slightly extends into the collar, but does not extend more than approximately ¼ in. (6 mm) above the top of the mold. If the fifth layer does extend above this limit, then the compaction point shall be discarded. In addition, the compaction point shall be discarded when the last blow on the rammer for the fifth layer results in the bottom of the rammer extending below the top of the compaction mold, unless the soil is pliable enough that this surface can easily be forced above the top of the compaction mold during trimming. See Note 9.

10.4.4 Compact each layer with 25 blows for the 4-in. (101.6-mm) mold or with 56 blows for the 6-in. (152.4-mm) mold. The manual rammer shall be used for referee testing.

10.4.5 In operating the manual rammer, take care to avoid lifting the guide sleeve during the rammer upstroke. Hold the guide sleeve steady and within 5° of vertical. Apply the blows at a uniform rate of about 25 blows/min and in such a manner as to provide complete, uniform coverage of the specimen surface. When using a 4-in. (101.6-mm) mold and manual rammer, follow the blow pattern given in Fig. 3(a) and Fig. 3(b) while for a mechanical rammer, follow the pattern in Fig. 3(b). When using a 6-in. (152.4-mm) mold and manual rammer, follow the blow pattern given in Fig. 4 up to the 9th blow, then systematically around the mold (Fig. 3(b)) and in the middle. When using a 6-in. (152.4-mm) mold and a mechanical rammer equipped with a sector face, the mechanical rammer shall be designed to follow the compaction pattern given in Fig. 3(b). When using a 6-in. (152.4-mm) mold and a mechanical rammer equipped with a circular face, the mechanical rammer shall be designed to distribute the blows uniformly over the surface of the specimen. If the surface of the compacted soil becomes highly uneven (see Note 9) then adjust the pattern to follow the logic given in Fig. 3(a) or Fig. 4. This will most likely void the use of a mechanical rammer for such compaction points.

NOTE 9—When compacting specimens wetter than optimum water content, uneven compacted surfaces can occur and operator judgment is required as to the average height of the specimen and rammer pattern during compaction.

10.4.6 Following compaction of the last layer, remove the collar and base plate (except as noted in 10.4.7) from the mold. A knife may be used to trim the soil adjacent to the collar to loosen the soil from the collar before removal to avoid disrupting the soil below the top of the mold. In addition, to prevent/reduce soil sticking to the collar or base plate, rotate them before removal.

10.4.7 Carefully trim the compacted specimen even with the top of the mold by means of the straightedge scraped across the top of the mold to form a plane surface even with the top of the

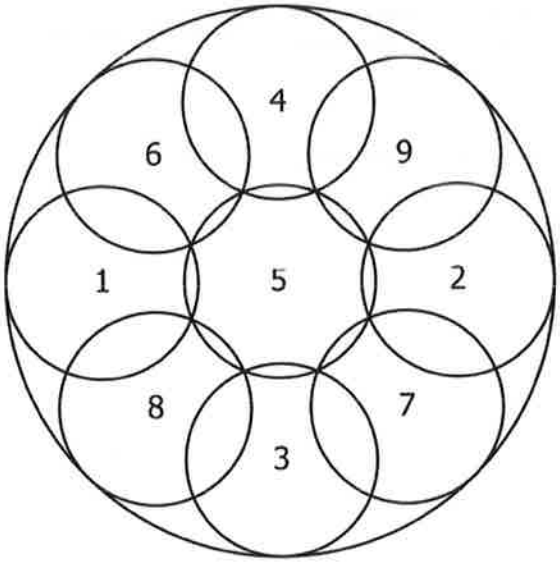

FIG. 4 Rammer Pattern for Compaction in 6-in. (152.4-mm) Mold

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mold. Initial trimming of the specimen above the top of the mold with a knife may prevent tearing out soil below the top of the mold. Fill any holes in either surface with unused or trimmed soil from the specimen, press in with the fingers, and again scrape the straightedge across the top of the mold. If gravel size particles are encountered, trim around them or remove them, whichever is the easiest and reduces the disturbance of the compacted soil. The estimated volume of particles above the surface of the compacted soil and holes in that surface shall be equal. Fill in remaining holes as mentioned above. Repeat the appropriate preceding operations on the bottom of the specimen when the mold volume was determined without the base plate. For very wet or dry soils, soil or water may be lost if the base plate is removed. For these situations, leave the base plate attached to the mold. When the base plate is left attached, the volume of the mold must be calibrated with the base plate attached to the mold rather than a plastic or glass plate as noted in Annex A1 (A1.4.1).

10.4.8 Determine and record the mass of the specimen and mold to the nearest g. When the base plate is left attached, determine and record the mass of the specimen, mold and base plate to the nearest g.

10.4.9 Remove the material from the mold. Obtain a specimen for molding water content by using either the whole specimen (preferred method) or a representative portion. When the entire specimen is used, break it up to facilitate drying. Otherwise, obtain a representative portion of the five layers, removing enough material from the specimen to report the water content to 0.1 %. The mass of the representative portion of soil shall conform to the requirements of Table 1, Method B, of Test Methods D2216. Determine the molding water content in accordance with Test Method D2216.

10.5 Following compaction of the last specimen, compare the wet unit weights to ensure that a desired pattern of obtaining data on each side of the optimum water content will be attained for the dry-unit-weight compaction curve. Plotting the wet unit weight and molding water content of each compacted specimen can be an aid in making the above evaluation. If the desired pattern is not obtained, additional compacted specimens will be required. Generally, for experienced plotters of compaction curves, one compaction point wet of the optimum water content is adequate to define the maximum wet unit weight. See 11.2.

11. Calculation and Plotting (Compaction Curve)

11.1 *Fraction Percentages*—If gradation data from Test Method D6913 is not available, calculate the dry mass of the test fraction, percentage of oversize fraction, and test fraction as covered below and using the data from 10.2 or 10.3:

11.1.1 *Test Fraction*—Determine the dry mass of the test fraction as follows:

$$M_{d,tf} = \frac{M_{m,tf}}{1 + \frac{w_{tf}}{100}} \quad (1)$$

where:

$M_{d,tf}$ = dry mass of test fraction, nearest g or 0.001 kg,
$M_{m,tf}$ = moist mass of test fraction, nearest g or 0.001 kg, and
w_{tf} = water content of test fraction, nearest 0.1 %.

11.1.2 *Oversize Fraction Percentage*—Determine the oversize (coarse) fraction percentage as follows:

$$P_C = \frac{M_{d,of}}{M_{d,of} + M_{d,tf}} \quad (2)$$

where:

P_C = percentage of oversize (coarse) fraction, nearest %,
$M_{d,of}$ = dry mass of oversize fraction, nearest g or 0.001 kg.

11.1.3 *Test Fraction Percentage*—Determine the test (finer) fraction percentage as follows:

$$P_F = 100 - P_C \quad (3)$$

where:

P_F = percentage of test (finer) fraction, nearest %

11.2 *Density and Unit Weight*—Calculate the molding water content, moist density, dry density, and dry unit weight of each compacted specimen as explained below.

11.2.1 *Molding Water Content, w*—Calculate in accordance with Test Method D2216 to nearest 0.1 %.

11.2.2 *Density and Unit Weights*—Calculate the moist (total) density (Eq 4), the dry density (Eq 5), and then the dry unit weight (Eq 6) as follows:

11.2.2.1 *Moist Density:*

$$\rho_m = K \times \frac{(M_t - M_{md})}{V} \quad (4)$$

where:

ρ_m = moist density of compacted subspecimen (compaction point), four significant digits, g/cm^3 or kg/m^3,
M_t = mass of moist soil in mold and mold, nearest g,
M_{md} = mass of compaction mold, nearest g,
V = volume of compaction mold, cm^3 or m^3 (see Annex A1), and
K = conversion constant, depending on density units and volume units. Use 1 for g/cm^3 and volume in cm^3. Use 1000 for g/cm^3 and volume in m^3. Use 0.001 for kg/cm^3 and volume in m^3. Use 1000 for kg/m^3 and volume in cm^3.

11.2.2.2 *Dry Density:*

$$\rho_d = \frac{\rho_m}{1 + \frac{w}{100}} \quad (5)$$

where:

ρ_d = dry density of compaction point, four significant digits, g/cm^3 or kg/m^3, and
w = molding water content of compaction point, nearest 0.1 %.

11.2.2.3 *Dry Unit Weight:*

$$\gamma_d = K_1 \times \rho_d \quad (6)$$

in lbf/ft^3, or,

$$\gamma_d = K_2 \times \rho_d \quad (7)$$

in kN/m^3,

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where:

γ_d = dry unit weight of compacted specimen, four significant digits, in lbf/ft^3 or kN/m^3,

K_1 = conversion constant, depending on density units. Use 62.428 for density in g/cm^3, or use 0.062428 for density in kg/m^3,

K_2 = conversion constant, depending on density units. Use 9.8066 for density in g/cm^3, or use 0.0098066 for density in kg/m^3.

11.3 *Compaction Curve*—Plot the dry unit weight and molding water content values, the saturation curve (see 11.3.2), and draw the compaction curve as a smooth curve through the points (see example, Fig. 5). For each point on the compaction curve, calculate, record, and plot dry unit weight to the nearest 0.1 lbf/ft^3 (0.02 kN/m^3) and molding water content to the nearest 0.1 %. From the compaction curve, determine the compaction results: optimum water content, to nearest 0.1 % and maximum dry unit weight, to the nearest 0.1 lbf/ft^3 (0.02 kN/m^3). If more than 5 % by mass of oversize material was removed from the sample/specimen, calculate the corrected optimum water content and maximum dry unit weight of the total material using Practice D4718. This correction may be made to the appropriate field in-place density test specimen rather than to the laboratory compaction results.

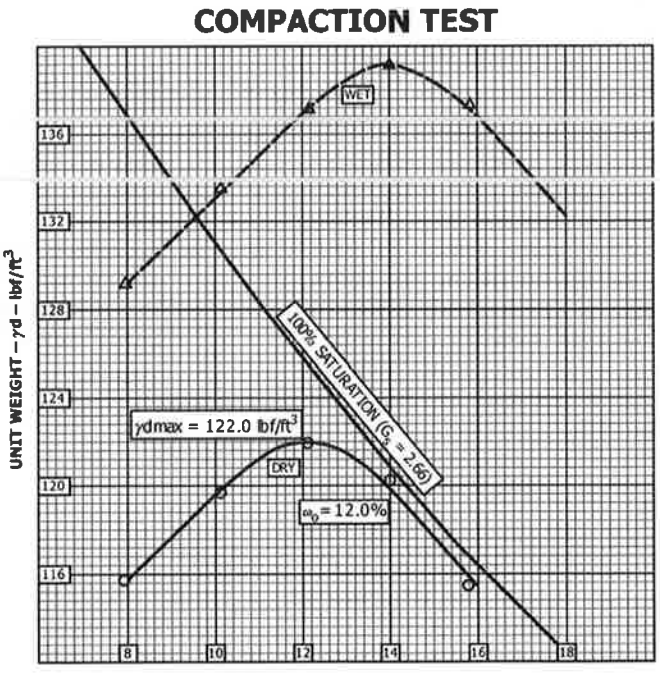
11.3.1 In these plots, the scale sensitivities should remain the same, that is, the change in molding water content or dry unit weight per division is constant between plots. Typically, the change in dry unit weight per division is twice that of molding water content's (2 lbf/ft^3 to 1 % w per major division). Therefore, any change in the shape of the compaction curve is a result of testing different material, not the plotting scale. However, a one to one ratio should be used for soils have a relatively flat compaction curve (see 10.2.1), such as highly plastic soils or relatively free draining ones up to the point of bleeding.

11.3.1.1 The shape of the compaction curve on the wet side on optimum should typically follow that of the saturation curve. The shape of the compaction curve on the dry side of optimum may be relatively flat or up and down when testing some soils, such as relatively free draining ones or plastic soils prepared using the moist procedure and having molding water contents close to or less than the shrinkage limit.

11.3.2 Plot the 100 % saturation curve, based on either an estimated or a measured specific gravity. Values of water content for the condition of 100 % saturation can be calculated as explained in 11.4 (see example, Fig. 5).

NOTE 10—The 100 % saturation curve is an aid in drawing the compaction curve. For soils containing more than about 10 % fines and molding water contents well above optimum, the two curves generally become roughly parallel with the wet side of the compaction curve between 92 % to 95 % saturation. Theoretically, the compaction curve cannot plot to the right of the 100 % saturation curve. If it does, there is an error in specific gravity, in measurements, in calculations, in testing, or in plotting. The 100 % saturation curve is sometimes referred to as the zero air voids curve or the complete saturation curve.

11.4 *Saturation Points*—To calculate points for plotting the 100 % saturation curve or zero air voids curve, select values of



NOTE 1—Wet Unit Weights are usually not plotted. They are plotted here for informational purposes only. Also notice that the compaction points may not all lie exactly on the compaction curve.

FIG. 5 Example Compaction Curve Plotting

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dry unit weight, calculate corresponding values of water content corresponding to the condition of 100 % saturation as follows:

$$w_{sat} = \frac{(\gamma_w)(G_s) - \gamma_d}{(\gamma_d)(G_s)} \times 100 \quad (8)$$

where:

w_{sat} = water content for complete saturation, nearest 0.1 %,
γ_w = unit weight of water, 62.32 lbf/ft^3 (9.789 kN/m^3) at 20°C,
γ_d = dry unit weight of soil, lbf/ft^3 (kN/m^3), three significant digits, and
G_s = specific gravity of soil (estimated or measured), to nearest 0.01 value, see 11.4.1.

11.4.1 Specific gravity may be estimated for the test fraction based on test data from other soils having the same soil classification and source or experience. Otherwise, a specific gravity test (Test Method C127, Test Method D854, or both) is necessary.

12. Report: Data Sheet(s)/Form(s)

12.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as described below, is covered in Section 1.6.

12.2 The data sheet(s)/form(s) shall contain as a minimum the following information:

12.2.1 Method used (A, B, or C).

12.2.2 Preparation method used (moist or dry).

12.2.3 As-received water content, if determined, nearest 1 %.

12.2.4 Modified optimum water content, Mod-w_{opt} to nearest 0.1 %.

12.2.5 Modified maximum (optimum) dry unit weight, Mod-$\gamma_{d,max}$ nearest 0.1 lbf/ft^3 or 0.02 kN/m^3.

12.2.6 Type of rammer (manual or mechanical).

12.2.7 Soil sieve data when applicable for selection of Method (A, B, or C) used.

12.2.8 Description of sample used in test (as a minimum, color and group name and symbol), by Practice D2488, or classification by Test Method D2487.

12.2.9 Specific gravity and method of determination, nearest 0.01 value.

12.2.10 Identification of sample used in test, for example, project number/name, location, depth, and the like.

12.2.11 Compaction curve plot showing compaction points used to establish compaction curve, and 100 % saturation curve, value or point of maximum dry unit weight and optimum water content.

12.2.12 Percentages for the fractions retained (P_C) and passing (P_F) the sieve used in Method A, B, or C, nearest 1 %. In addition, if compaction data (Mod-w_{opt} and Mod-$\gamma_{d,max}$) are corrected for the oversize fraction, include that data.

NOTE 11—The Data Sheet(s)/Form requirements in Section 12 are not intended as requirements for reporting final test results to the requesting agency. The requirements apply to testing records for measurements, for intermediate calculations and for compaction points used to plot the compaction curve. It has been attempted in this test method to determine all measurements and calculations to four significant figures. The purpose is to ensure that precision is not lost due to rounding prior to plotting the compaction curve and that data sheets and forms retained by the laboratory contain that same degree of precision.

13. Precision and Bias[4]

13.1 *Precision*—Criteria for judging the acceptability of maximum unit weight and optimum water content results obtained by this method are given in Table 3.

13.1.1 *Single-Operator Precision (Repeatability)*—The figures in Column 2 of Table 3 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the values given in Table 3, Column 3.

13.1.2 *Multilaboratory Precision (Reproducibility)*—The figures in Column 2 of Table 3 are the standard deviations that have been found to be appropriate for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the values given in Table 3, Column 3.

13.2 *Bias*—It is not possible to present information on bias because there is no other method of determining the values of modified maximum unit weight and modified optimum water content.

14. Keywords

14.1 compaction characteristics; density; impact compaction using modified effort; laboratory tests; modified proctor test; moisture-density curves; soil compaction

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D18-1017.

TABLE 3 Precision Estimates

Conditions of Test and Test Property	Standard Deviation (1s)[A]	Acceptable Range of Two Test Results (d2s)[A]
Single Operator Precision:		
Maximum Unit Weight (lbf/ft ^{3})	0.6	1.8
Optimum Water Content (percent)	0.4	1.0
Multilaboratory Precision:		
Maximum Unit Weight (lbf/ft ^{3})	1.6	4.4
Optimum Water Content (percent)	0.7	2.1

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670 for Preparing Precision and Bias Statements for Test Methods for Construction Materials.

NOTE 1—The precision estimates given in Table 3 are based on the analysis of test results from three pairs of AMRL proficiency samples. The data analyzed consisted of results from 144 to 253 laboratories for each of the three pairs of samples. The analysis included two classifications of fine grained soil (group symbol CL): lean clay with sand and sandy lean clay. Average maximum unit weights ranged from 125.8 lbf/ft^3 to 132.6 lbf/ft^3. Average optimum water contents ranged from 8.0 percent to 10.4 percent.

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ANNEX

(Mandatory Information)

A1. VOLUME OF COMPACTION MOLD

A1.1 Scope

A1.1.1 This annex describes the method for determining the volume of a compaction mold.

A1.1.2 The volume is determined by two methods, a water-filled method and a linear-measurement method.

A1.1.3 The water filling method for the 4-in. (106.5-mm) mold, when using a balance readable to nearest g, does not yield four significant figures for its volume, just three. Based on Practice D6026, this limits the density/unit weight determinations previously presented from four to three significant figures. To prevent this limitation, the water filling method has been adjusted from that presented in early versions of this test method.

A1.2 Apparatus

A1.2.1 In addition to the apparatus listed in Section 6, the following items are required:

A1.2.1.1 *Vernier or Dial Caliper,* having a measuring range of at least 0 to 6 in. (0 to 150 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.2 *Inside Micrometer (optional),* having a measuring range of at least 2 to 12 in. (50 to 300 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.3 *Depth Micrometer (optional),* having a measuring range of at least 0 to 6 in. (0 to 150 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.4 *Plastic or Glass Plates*—Two plastic or glass plates about 8 in. by 8 in. by ¼ in. thick (200 mm by 200 mm by 6 mm).

A1.2.1.5 *Thermometer or other Thermometric Device,* having a readability of 0.1°C and a maximum permissible error of 0.5°C.

A1.2.1.6 *Stopcock Grease* or similar sealant.

A1.2.1.7 *Distilled Water or De-ionized Water*—Either type of water may be used to fill the mold when determining the mold volume using the water-filling method. Distilled water or de-ionized water may be purchased and is available in most grocery stores. In the procedure for the water-filling method, distilled water, or de-ionized water, is referred to as water.

A1.2.1.8 *Miscellaneous equipment*—Bulb syringe, towels, etc.

A1.3 Precautions

A1.3.1 Perform this method in an area isolated from drafts or extreme temperature fluctuations.

A1.4 Procedure

A1.4.1 *Water-Filling Method:*

A1.4.1.1 Lightly grease the bottom of the compaction mold and place it on one of the plastic or glass plates. Lightly grease the top of the mold. Be careful not to get grease on the inside of the mold. If it is necessary to use the base plate, as noted in 10.4.7, place the greased mold onto the base plate and secure with the locking studs.

A1.4.1.2 Determine the mass of the greased mold and both plastic or glass plates to the nearest 1 g and record, M_{mp}. When the base plate is being used in lieu of the bottom plastic or glass plate determine the mass of the mold, base plate and a single plastic or glass plate to be used on top of the mold to the nearest 1 g and record.

A1.4.1.3 Place the mold and the bottom plate on a firm, level surface and fill the mold with water to slightly above its rim.

A1.4.1.4 Slide the second plate over the top surface of the mold so that the mold remains completely filled with water and air bubbles are not entrapped. Add or remove water as necessary with a bulb syringe.

A1.4.1.5 Completely dry any excess water from the outside of the mold and plates.

A1.4.1.6 Determine the mass of the mold, plates and water and record to the nearest 1 g, $M_{mp,w}$.

A1.4.1.7 Determine the temperature of the water in the mold to the nearest 0.1°C and record. Determine and record the density of water from the table given in D854 or as follows:

$$\rho_{w,c} = 1.00034038 - (7.77 \times 10^{-6}) \times T - (4.95 \times 10^{-6}) \times T^2 \quad \text{(A1.1)}$$

where:

$\rho_{w,c}$ = density of water, nearest 0.00001 g/cm^3, and
T = calibration test temperature, nearest 0.1°C.

A1.4.1.8 Calculate the mass of water in the mold by subtracting the mass determined in A1.4.1.2 from the mass determined in A1.4.1.6.

A1.4.1.9 Calculate the volume of water by dividing the mass of water by the density of water. Record this volume to the nearest 0.1 cm^3 for the 4-in.(101.6-mm) mold or nearest 1 cm^3 for the 6-in. (152.4-mm) mold. To determine the volume of the mold in m^3, multiply the volume in cm^3 by 1×10^{-6}. Record this volume, as prescribed.

A1.4.1.10 If the water-filling method is being used to determine the mold's volume and checked by linear measurement method, repeat this volume determination (A1.4.1.3 – A1.4.1.9) and determine and record the average value, V_w, as prescribed.

A1.4.2 *Linear Measurement Method:*

A1.4.2.1 Using either the vernier caliper or the inside micrometer (preferable), measure the inside diameter (ID) of the mold six times at the top of the mold and six times at the bottom of the mold spacing each of the six top and bottom measurements equally around the inside circumference of the mold. Record the values to the nearest 0.001 in. (0.02 mm). Determine and record the average ID to the nearest 0.001 in.

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(0.02 mm), d_{avg}. Verify that this ID is within specified tolerances, 4.000 ± 0.016 in. (101.6 ± 0.4 mm); if not, discard the mold.

A1.4.2.2 Using the vernier caliper or depth micrometer (preferably), measure the inside height of the mold to the base plate. In these measurements, make three or more measurements equally spaced around the inside circumference of the mold, and preferably one in the center of the mold, but not required (use the straightedge to facilitate the latter measurement and correct the measurement for the thickness of the straightedge). Record these values to the nearest 0.001 in. (0.02 mm). Determine and record the average of these height measurements to the nearest 0.001 in. (0.02 mm), h_{avg}. Verify that this height is within specified tolerances, 4.584 ± 0.018 in. (116.4 ± 0.5 mm); if not, discard the mold.

A1.4.2.3 Calculate the volume of the mold to four significant digits in cm^3 as follows:

$$V_{lm} = K_3 \frac{\pi \times h_{avg} \times (d_{avg})^2}{4} \quad \text{(A1.2)}$$

where:

V_{lm} = volume of mold by linear measurements, to four significant digits, cm^3,
K_3 = constant to convert measurements made in inch (in.) or mm. Use 16.387 for measurements in inches. Use 10^{-3} for measurements in mm.
π = 3.14159,
h_{avg} = average height, in. (mm), and
d_{avg} = average of the top and bottom diameters, in. (mm).

If the volume in m^3 is required, then multiply the above value by 10^{-6}.

A1.5 Comparison of Results and Standardized Volume of Mold

A1.5.1 The volume obtained by either method should be within the volume tolerance requirements of 6.1.1 and 6.1.2, using either or cm^3 or ft^3. To convert cm^3 to ft^3, divide cm^3 by 28 317, record to the nearest 0.0001 ft^3.

A1.5.2 The difference between the two methods should not exceed 0.5 % of the nominal volume of the mold, cm^3 or ft^3.

A1.5.3 Repeat the determination of volume which is most suspect, or both, if these criteria are not met.

A1.5.4 Failure to obtain satisfactory agreement between the two methods, even after several trials, is an indication that the mold is badly deformed and should be replaced.

A1.5.5 Use the volume of the mold determined using the water-filling method or linear method, or average of both methods as the standardized volume for calculating the moist density (see 11.2.2.1). This value (V) in cm^3 or m^3 shall have four significant digits. The use of a volume in ft^3, along with masses in lbm shall not be regarded as a nonconformance with this standard.

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SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to these test methods since the last issue, D1557–09, that may impact the use of these test methods. (Approved May 1, 2012)

(1) Revised 6.2.2.1 and 10.4.5.

(2) Added a mercury caveat in the Scope.

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California Ambient Air Quality Standards

California Ambient Air Quality Standards (CAAQS)

CATEGORIES

Topics Health, Air Pollution, Air Quality Monitoring

Programs Outdoor Air Quality Standards, Community Air Protection Program ,

Type Fact Sheet

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Hundreds of scientific studies published over the past 50 years point to the harmful effects of air pollution. Air pollution harms people's health, damages agricultural crops, forests, ornamental and native plants, and creates the haze that reduces visibility. Ambient air quality standards are designed to prevent these impacts on health and the environment.

What is a California ambient air quality standard?

Ambient air quality standards (AAQS) define clean air, and are established to protect the health of the most sensitive groups in our communities. An air quality standard defines the maximum amount of a pollutant averaged over a specified period of time that can be present in outdoor air without any harmful effects on people or the environment. In 1959 California enacted legislation requiring the state Department of Public Health to establish air quality standards and necessary controls for motor vehicle emissions. California law continues to mandate California ambient air quality standards (CAAQS), which are often more stringent than national standards. Learn more about our brief history of standard setting in California.

How are California ambient air quality standards developed?

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Air quality standard setting in California commences with a critical review of all relevant peer reviewed scientific literature. The Office of Environmental Health Hazard Assessment (OEHHA) uses the review of health literature to develop a recommendation for the standard. The recommendation can be for no change, or can recommend a new standard. The review, including the OEHHA recommendation, is summarized in a document called the draft Initial Statement of Reasons (ISOR), which is released for comment by the public, and also for public peer review by the Air Quality Advisory Committee (AQAC). AQAC members are appointed by the President of the University of California for their expertise in the range of subjects covered in the ISOR, including health, exposure, air quality monitoring, atmospheric chemistry and physics, and effects on plants, trees, materials, and ecosystems. The Committee provides written comments on the draft ISOR. ARB staff next revises the ISOR based on comments from AQAC and the public. The revised ISOR is then released for a 45-day public comment period prior to consideration by the Board at a regularly scheduled Board hearing.

When were California ambient air quality standards last updated?

In June of 2002, the Air Resources Board adopted revisions to the PM10 standard and established a new PM2.5 annual standard. The new standards became effective in June 2003. Visit our web page for more information regarding the PM and Sulfates Standards Review.

Subsequently, staff reviewed the published scientific literature on ground-level ozone and nitrogen dioxide and the Air Resources Board adopted revisions to the standards for these two pollutants. Revised standards for ozone and nitrogen dioxide went into effect on May 17, 2006 and March 20, 2008, respectively. Please follow these links for more information about the Ozone Standard Review and the Nitrogen Dioxide Standards Review.

What are the health and environmental effects of the air pollutants for which there are California ambient air quality standards?

Although there is some variability among the health effects of the CAAQS pollutants, each has been linked to multiple adverse health effects including, among others, premature death, hospitalizations and emergency department visits for exacerbated chronic disease, and increased symptoms such as coughing and wheezing.

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Below is the list of pollutants for which CAAQS were established and more information on the health and environmental effects specific to each pollutant.

- Particulate Matter (PM10 and PM2.5)
- Ozone (O_3)
- Nitrogen Dioxide (NO_2)
- Sulfate
- Carbon Monoxide (CO)
- Sulfur Dioxide (SO_2)
- Visibility Reducing Particles
- Lead
- Hydrogen Sulfide (H_2S)
- Vinyl Chloride

Download the PDF for more information on the current levels and averaging times for each California ambient air quality standard.

CAAQS vs. NAAQS

In 1959 the California Legislature directed the State Department of Public Health to develop CAAQS. The original CAAQS were established in 1962. The Air Resources Board was created by the legislature in 1967, and the CAAQS that had been set by the Department of Public Health were subsequently adopted by the Air Resources Board (ARB) in 1969. Thus, the CAAQS predate the national ambient air quality standards (NAAQS) set by the U.S. Environmental Protection Agency (U.S. EPA), which was created in 1970, and issued its first NAAQS in 1971. California law continues to mandate CAAQS, although attainment of the NAAQS has precedence over attainment of the CAAQS due to federal penalties for failure to meet federal attainment deadlines.

Attainment of Air Quality Standards

California law does not require that CAAQS be met by specified dates as is the case with NAAQS. Rather, it requires incremental progress toward attainment.

Additional Information

- View state and federal designation maps showing which geographical areas of California meet the NAAQS and/or CAAQS

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- California's State Implementation Plans and State Maintenance Plans for NAAQS
- An overview of the NAAQS

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Inhalable Particulate Matter and Health (PM2.5 and PM10)

CATEGORIES

Topics Health, Air Pollution, Indoor Air Quality & Exposure

Programs Outdoor Air Quality Standards, Exposure

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What is Particulate Matter?

Airborne particulate matter (PM) is not a single pollutant, but rather is a mixture of many chemical species. It is a complex mixture of solids and aerosols composed of small droplets of liquid, dry solid fragments, and solid cores with liquid coatings. Particles vary widely in size, shape and chemical composition, and may contain inorganic ions, metallic compounds, elemental carbon, organic compounds, and compounds from the earth's crust. Particles are defined by their diameter for air quality regulatory purposes. Those with a diameter of 10 microns or less (PM10) are inhalable into the lungs and can induce adverse health effects. Fine particulate matter is defined as particles that are 2.5 microns or less in diameter (PM2.5). Therefore, PM2.5 comprises a portion of PM10.

What is the Difference Between PM10 and PM2.5?

PM10 and PM2.5 often derive from different emissions sources, and also have different chemical compositions. Emissions from combustion of gasoline, oil, diesel fuel or wood produce much of the PM2.5 pollution found in outdoor air, as well as a significant proportion of PM10. PM10 also includes dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria.

PM may be either directly emitted from sources (primary particles) or formed in the

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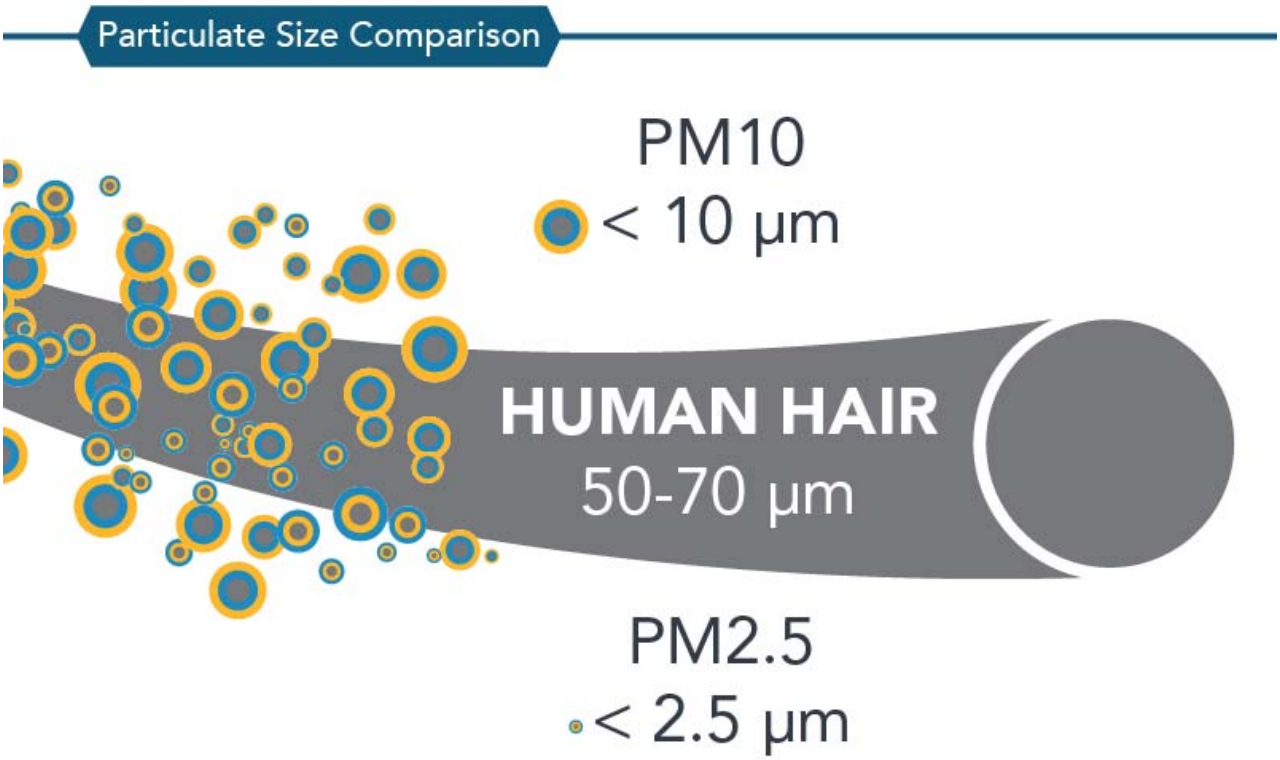
atmosphere through chemical reactions of gases (secondary particles) such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), and certain organic compounds. These organic compounds can be emitted by both natural sources, such as trees and vegetation, as well as from man-made (anthropogenic) sources, such as industrial processes and motor vehicle exhaust. The relative sizes of PM10 and PM2.5 particles are compared in the figure below.



Why is CARB Concerned about PM10 and PM2.5?

CARB is concerned about air-borne particles because of their effects on the health of Californians and the environment. Both PM2.5 and PM10 can be inhaled, with some depositing throughout the airways, though the locations of particle deposition in the lung depend on particle size. PM2.5 is more likely to travel into and deposit on the surface of

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the deeper parts of the lung, while PM10 is more likely to deposit on the surfaces of the larger airways of the upper region of the lung. Particles deposited on the lung surface can induce tissue damage, and lung inflammation.

What Kinds of Harmful Effects Can Particulate Matter Cause?

A number of adverse health impacts have been associated with exposure to both PM2.5 and PM10. For PM2.5, short-term exposures (up to 24-hours duration) have been associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms, and restricted activity days. These adverse health effects have been reported primarily in infants, children, and older adults with preexisting heart or lung diseases. In addition, of all of the common air pollutants, PM2.5 is associated with the greatest proportion of adverse health effects related to air pollution, both in the United States and world-wide based on the World Health Organization's Global Burden of Disease Project.

Short-term exposures to PM10 have been associated primarily with worsening of respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD), leading to hospitalization and emergency department visits.

Long-term (months to years) exposure to PM2.5 has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children. The effects of long-term exposure to PM10 are less clear, although several studies suggest a link between long-term PM10 exposure and respiratory mortality. The International Agency for Research on Cancer (IARC) published a review in 2015 that concluded that particulate matter in outdoor air pollution causes lung cancer.

Diesel PM: A special class of particulates. The solid material in diesel exhaust is known as diesel particulate matter (DPM). More than 90% of DPM is less than 1 µm in diameter (about 1/70th the diameter of a human hair), and thus is a subset of PM2.5. More Information

Who is at the Greatest Risk from Exposure to Particulate Matter?

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Research points to older adults with chronic heart or lung disease, children and asthmatics as the groups most likely to experience adverse health effects with exposure to PM10 and PM2.5. Also, children and infants are susceptible to harm from inhaling pollutants such as PM because they inhale more air per pound of body weight than do adults - they breathe faster, spend more time outdoors and have smaller body sizes. In addition, children's immature immune systems may cause them to be more susceptible to PM than healthy adults.

Research from the CARB-initiated Children's Health Study found that children living in communities with high levels of PM2.5 had slower lung growth, and had smaller lungs at age 18 compared to children who lived in communities with low PM2.5 levels.

CARB used the U.S. EPA's risk assessment methodology to conduct an assessment of premature mortality associated with exposure to PM2.5 (California Air Resources Board 2010). An update to this analysis using ambient air quality data from 2014-2016 indicated that PM2.5 exposure contributes to 5,400 (uncertainty range of 4,200 – 6,700) premature deaths due to cardiopulmonary causes per year in California. In addition, PM2.5 contributes to about 2,800 hospitalizations for cardiovascular and respiratory diseases (uncertainty range 350 – 5,100), and about 6,700 emergency room visits for asthma (uncertainty range 4,200 – 9,300) each year in California.

How Does Particulate Matter Affect the Environment?

Particulate matter has been shown in many scientific studies to reduce visibility, and also to adversely affect climate, ecosystems and materials. PM, primarily PM2.5, affects visibility by altering the way light is absorbed and scattered in the atmosphere. With reference to climate change, some constituents of the ambient PM mixture promote climate warming (e.g., black carbon), while others have a cooling influence (e.g., nitrate and sulfate), and so ambient PM has both climate warming and cooling properties. PM can adversely affect ecosystems, including plants, soil and water through deposition of PM and its subsequent uptake by plants or its deposition into water where it can affect water quality and clarity. The metal and organic compounds in PM have the greatest potential to alter plant growth and yield. PM deposition on surfaces leads to soiling of materials.

Is Particulate Matter a Problem Indoors?

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Some of the particulate matter found indoors originates from the outdoors, especially PM2.5. These particles enter indoor spaces through doors, windows, and “leakiness” in building structures. Particles can also originate from indoor sources. Particles of indoor origin include components derived from biological sources, many of which are known allergens, such as pollens, mold spores, dust mites and cockroaches. Indoor activities generate particles, as well, including smoking tobacco, cooking and burning wood, candles or incense. Particles also can form indoors from complex reactions of gaseous pollutants emitted from such sources as household cleaning products and air fresheners.

What are the Ambient Air Quality Standards for Particulate Matter?

Ambient air quality standards define the maximum amount of pollutant that can be present in outdoor air without harming human health. In 2002, after an extensive review of the scientific literature, the Board adopted a new annual average standard for PM2.5 ppm, and retained the existing annual and 24-hour standard average standards for PM10. The national annual average PM2.5 standard was most recently revised in 2012 following an exhaustive review of new literature pointed to evidence for increased risk of premature mortality at lower PM2.5 concentrations than the existing standard. The 2012 review resulted in retention of the existing 24-hour average PM2.5 and PM10 standards.

	PM2.5		**PM10**	
	Annual Average	**24-Hour Average**	**Annual Average**	**24-Hour Average**
National Ambient Air Quality Standard	12 µg/m^3	35 µg/m^3	None	150 µg/m^3
California Ambient Air Quality Standard	12 µg/m^3	None	20 µg/m^3	50 µg/m^3

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Vinyl Chloride & Health

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Programs Outdoor Air Quality Standards, Exposure

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What is vinyl chloride?

Vinyl chloride (chloroethene), a chlorinated hydrocarbon, is a colorless gas with a mild, sweet odor. Most vinyl chloride is used in the process of making polyvinyl chloride (PVC) plastic and vinyl products, thus may be emitted from industrial processes. Vinyl chloride has been detected near landfills, sewage treatment plants, and hazardous waste sites, due to microbial breakdown of chlorinated solvents, although levels above the standard have not been measured in California since the 1970's. Today, vinyl chloride exposure is primarily an occupational concern.

History of the vinyl chloride Ambient Air Quality Standard

The ambient air quality standard for vinyl chloride is unique among the California Ambient Air Quality Standards (CAAQS) in that it addressed a localized exposure risk, rather than a statewide risk. The standard for vinyl chloride was set in 1978 to address elevated cancer risk in three areas of California that were adjacent to industrial facilities that emitted vinyl chloride from their production processes. The level of the standard, 0.010 ppm as a 24 hour average was chosen because it was the lowest level that could be reliably measured at the time the standard was promulgated, and could thus function as an enforceable exposure limit.

Vinyl chloride is the only pollutant that has a CAAQS and is also listed as a toxic air

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contaminant because of its carcinogenicity. The Air Toxics Program, which lists and regulates cancer causing pollutants, had not yet been established at the time CARB determined there was a need to control vinyl chloride emissions. Consequently, CARB used the CAAQS process because it was the only means available at that time to regulate vinyl chloride emissions. Then in 1990, the Board identified vinyl chloride as a toxic air contaminant under the recently established Air Toxics Program, and established a cancer unit risk factor. As a carcinogen, no level of exposure to vinyl chloride is considered as being completely safe and without risk. Although the vinyl chloride CAAQS remains in force, current regulatory efforts are under CARB's Air Toxics Program.

What kinds of harmful effects can vinyl chloride cause?

Short-term exposure to high levels (10 ppm or above) of vinyl chloride in air causes central nervous system effects, such as dizziness, drowsiness, and headaches. The primary non-cancer health effect of long-term exposure to vinyl chloride through inhalation or oral exposure is liver damage. Inhalation exposure to vinyl chloride has been shown to increase the risk of angiosarcoma, a rare form of liver cancer in humans. Current Occupational Safety and Health Administration (OSHA) regulations allow occupational exposures of up to an 8-hour average of 1 ppm vinyl chloride.

There is little information available on possible environmental effects of vinyl chloride.

Who is at the greatest risk from exposure to vinyl chloride?

Most health data on vinyl chloride relate to carcinogenicity. Thus, the people most at risk are those who have long-term exposure to elevated levels. Today, this is more likely to occur in occupational or industrial settings. Control methodologies currently applied to industrial facilities prevent emissions to the ambient air.

Is vinyl chloride a problem indoors?

Outside of occupational and industrial settings, there are no known indoor sources of vinyl chloride emissions.

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What is the Ambient Air Quality Standard for vinyl chloride?

	24-Hour Average
National Ambient Air Quality Standard	None
California Ambient Air Quality Standard	0.01 ppm

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Hydrogen Sulfide & Health

CATEGORIES

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What is hydrogen sulfide?

Hydrogen sulfide (H_2S) is a colorless gas with the odor of rotten eggs. The most common sources of H_2S emissions are oil and natural gas extraction and processing, and natural emissions from geothermal fields. It is also formed during bacterial decomposition of human and animal wastes, and is present in emissions from sewage treatment facilities and landfills. Industrial sources include petrochemical plants, coke oven plants, and kraft paper mills.

Why does CARB focus on hydrogen sulfide?

The odor of H_2S is extremely strong and foul, and it can induce tearing of the eyes and symptoms related to overstimulation of the sense of smell, including headache, nausea, or vomiting. The odor of H_2S is detectable at a very low level. On a population basis, the average odor detection threshold is about 0.03 to 0.05 ppm, although some individuals can detect H_2S at lower concentrations. Additional health effects have only been reported with exposures greater than 50 ppm (eye irritation), considerably higher than the odor threshold based standard. Exposure to even higher levels of H_2S (over 300 ppm) can induce serious adverse health effects, although these exposures are typically only encountered in occupational or industrial accident situations. H_2S is regulated as a nuisance based on its odor detection level. If the standard were based on adverse health effects, it would be set at a much higher level.

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Who is at the greatest risk from exposure to hydrogen sulfide?

There are insufficient data available to determine whether or not some groups are at greater risk than others. A few studies suggest that asthmatics may be at increased risk of exacerbation of their asthma symptoms.

How does hydrogen sulfide affect the environment?

H_2S is a key participant in the global sulfur cycle. It is oxidized in the atmosphere to SO_2, which can then be converted to sulfate through three different chemical pathways. H_2S is somewhat soluble in water, resulting in formation of sulfhydric acid, which is corrosive to metals, and contributes to acidic deposition to soil and water. Additional information on the environmental effects of sulfur dioxide and sulfate can be found on the fact sheets for these two pollutants. H_2S is not a climate change gas, although because H_2S is converted in the atmosphere to sulfate, it contributes to the cooling influence provided by atmospheric sulfate.

Is hydrogen sulfide a problem indoors?

H_2S is rarely a problem indoors. There are few indoor emission sources of H_2S. Detection of H_2S indoors is generally related to spoiling and decomposition of some foodstuffs. Caution: odorants, which have an odor similar to H_2S, are added to natural gas as an aid to gas leak detection. If the odor of H_2S is present in your home, the local gas company should be notified and asked to investigate whether or not there is a gas leak.

What is the Ambient Air Quality Standard for hydrogen sulfide?

The H_2S standard was adopted for the purpose of odor control. The current standard, 0.03 ppm for a one hour average, was adopted by CARB in 1969. The California Department of Public Health reviewed the scientific literature in 1981 and concluded that

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the existing standard was adequate. Consequently, CARB did not undertake regulatory action on the standard. The standard has not been changed since it was first adopted.

	1-Hour Average
National Ambient Air Quality Standard	None
California Ambient Air Quality Standard	0.03 ppm

The U.S. Environmental Protection Agency has not established a standard for H_2S; however, the U. S. Occupational Safety and Health Administration has set an 8-hr average occupational standard of 20 ppm.

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CATEGORIES

Topics Health, Air Pollution, Indoor Air Quality & Exposure

Programs Outdoor Air Quality Standards, Exposure

Type Information

CONTACT

Research Division

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What is lead?

Lead is a relatively soft and chemically resistant metal. Lead forms compounds with both organic and inorganic substances. As an air pollutant, lead is present in small particles.

Why do CARB and U.S. EPA focus on lead?

It has been known for many years that lead can accumulate in the body, especially in the bones, and that a variety of adverse health effects can develop if the amount of lead in the body is sufficiently high. At the time the ambient air quality standard for lead was promulgated ambient air was the source of a significant portion of people's total lead exposure due to emissions from motor vehicles that ran on leaded gasoline. The Air Resources Board adopted an ambient air quality standard for lead to protect the public from these adverse health effects. In 1976 CARB passed a regulation that led to a phase-out of lead in gasoline over several years. Since 1993 lead has been regulated under the Toxic Air Contaminant Program, although the state ambient air quality standard remains in force.

What are the sources of lead in ambient air?

In the past, motor vehicle exhaust was the major source of lead emissions to the air. Since lead has been removed from gasoline air emissions of lead from the transportation sector, and particularly the automotive sector, have greatly declined. However, because it was

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emitted in large amounts from vehicles when leaded gasoline was used, lead is present in many soils (especially urban soils) and can get resuspended into the air. The major sources of lead emissions today are ore and metals processing, particularly lead smelters, and piston-engine aircraft operating on leaded aviation gasoline. Other stationary sources include waste incinerators, utilities, and lead-acid battery manufacturers.

What kinds of harmful effects can lead cause?

Once taken into the body, the blood carries lead throughout the body and it is deposited in the bones where it accumulates. Because lead is only slowly excreted, exposures to small amounts of lead from a variety of sources can accumulate to harmful levels. Lead can adversely affect multiple organ systems of the body and people of every age group. Young children are particularly at risk of lead poisoning. They are usually exposed to lead through the normal hand-to mouth behavior that occurs through crawling or playing on the floor, and putting their hands, toys, and other items in their mouths. In children, adverse health effects of lead exposure are often irreversible and include brain damage and mental retardation. Lead poisoning is often unrecognized in children, and if undetected, it may result in behavioral problems, reduced intelligence, anemia, and liver or kidney damage.

Lead is also harmful to adults. Excessive lead exposure in adults is most often the related to exposure in occupational settings or to unsafe home renovation procedures. Lead poisoning can cause reproductive problems in men and women, high blood pressure, kidney disease, digestive problems, nerve disorders, memory and concentration problems, and muscle and joint pain. There is also evidence that lead exposure can result in cancer in adults. If a pregnant woman is exposed to elevated levels of lead, it can cross the placenta into the baby's blood, increasing risk of adverse developmental effects, particularly in the brain and nervous system.

Who is at the greatest risk from exposure to lead?

Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits and lowered IQ.

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How does lead affect the environment?

Lead is persistent in the environment and accumulates in soils and sediments through deposition from air sources, direct discharge of waste streams to water bodies, mining, and erosion. Ecosystems near point sources of lead demonstrate a wide range of adverse effects including losses in biodiversity, changes in community composition, decreased growth and reproductive rates in plants and animals, and neurological effects in vertebrates.

Is lead a problem indoors?

The main source of lead pollution indoors is lead-based paint, which could arise, for example, from paint flecks or chips or sanding during home renovations. In these cases, the particles are generally too large to be inhaled. Instead, exposure is primarily through ingestion. Young children are at greatest risk in this case due to hand-to-mouth transfer of paint flecks or sanded paint that are then swallowed. This can lead to an elevated level of lead in the body, increasing risk of neurological, behavioral, and learning deficits. Care should be exercised when renovating older homes to prevent inhalation or ingestion of lead-based paint residue.

What are the Ambient Air Quality Standards for lead?

	30-Day Average	**Rolling 3-Month Average**
National Ambient Air Quality Standard	None	0.15 µg/m^3
California Ambient Air Quality Standard	1.5 µg/m^3	None

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Carbon Monoxide & Health

CATEGORIES

Topics Health, Air Pollution, Indoor Air Quality & Exposure

Programs Outdoor Air Quality Standards, Exposure

Type Information

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What is carbon monoxide?

Carbon monoxide (CO) is a colorless, odorless gas. It results from the incomplete combustion of carbon-containing fuels such as natural gas, gasoline, or wood, and is emitted by a wide variety of combustion sources, including motor vehicles, power plants, wildfires, and incinerators. Nationally and, particularly in urban areas, the majority of outdoor CO emissions to ambient air come from mobile sources. Carbon monoxide can also be formed through photochemical reactions in the atmosphere from methane and non-methane hydrocarbons, other volatile organic hydrocarbons in the atmosphere, and organic molecules in surface waters and soils. There are also a number of indoor sources of CO that contribute to total exposure.

Why do CARB and U.S. EPA focus on carbon monoxide?

Air quality regulators are concerned about air pollutants which may reasonably be anticipated to endanger public health and welfare. There is substantial evidence that CO can adversely affect health, participate in atmospheric chemical reactions that result in formation of ozone air pollution, and contribute to climate change.

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What kinds of harmful effects can carbon monoxide cause?

Carbon monoxide is harmful because it binds to hemoglobin in the blood, reducing the ability of blood to carry oxygen. This interferes with oxygen delivery to the body's organs. The most common effects of CO exposure are fatigue, headaches, confusion, and dizziness due to inadequate oxygen delivery to the brain. For people with cardiovascular disease, short-term CO exposure can further reduce their body's already compromised ability to respond to the increased oxygen demands of exercise, exertion, or stress. Inadequate oxygen delivery to the heart muscle leads to chest pain and decreased exercise tolerance. Unborn babies whose mothers experience high levels of CO exposure during pregnancy are at risk of adverse developmental effects.

Who is at the greatest risk from exposure to carbon monoxide?

Unborn babies, infants, elderly people, and people with anemia or with a history of heart or respiratory disease are most likely to experience health effects with exposure to elevated levels of CO.

How does carbon monoxide affect the environment?

U.S. EPA conducted an extensive literature search as part of the review of the National Ambient Air Quality Standard for Carbon Monoxide that was completed in 2011, and did not identify any evidence for ecological effects of CO at levels at or near ambient. Consequently, there is no secondary (welfare) standard for CO.

CO contributes indirectly to climate change because it participates in chemical reactions in the atmosphere that produce ozone, which is a climate change gas. CO also has a weak direct effect on climate. For these reasons, CO is classified as a short-lived climate forcing agent, prompting CO emission reductions to be considered as a possible strategy to mitigate effects of global warming.

Is carbon monoxide a problem indoors?

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Indoor CO levels can be considerably higher than outdoors. There are a number of potential sources of CO indoors, including gas stoves, malfunctioning or improperly vented gas appliances (i.e., water heaters, furnaces, clothes dryers), space heaters, fireplaces, tobacco smoke, and car or truck exhaust that enters from attached garages.

> ### WARNING
>
> During the cold season CO poisoning cases tend to increase. These are most often related to elevated indoor CO levels resulting from use of improperly vented space heaters and use of gas ranges to heat the house. Over 400 people die each year in the U.S., due to CO poisoning. Of these, 13 to 36 individuals have died each year since 2000 from non-fire-related CO poisoning in California. Because of the health risk of CO poisoning, California has mandated installation of CO detectors in all housing units in the state.

What is the Ambient Air Quality Standard for carbon monoxide?

	1-Hour Average	8-Hour Average
National Ambient Air Quality Standard	35 ppm	9 ppm
California Ambient Air Quality Standard	20 ppm	9.0 ppm

Additional Information

- Carbon monoxide in the home

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Ozone & Health

Health Effects of Ozone

CATEGORIES

Topics Health, Air Pollution, Research, Indoor Air Quality & Exposure

Programs Outdoor Air Quality Standards, Exposure, Indoor Air Quality, Air Cleaners & Ozone Generating Products

Type Information

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What is ozone (O_3)?

Ozone, an important component of smog, is a highly reactive and unstable gas capable of damaging living cells, such as those present in the linings of the human lungs. This pollutant forms in the atmosphere through complex reactions between chemicals directly emitted from vehicles, industrial plants, consumer products and many other sources. Ozone is a powerful oxidant – its actions can be compared to household bleach, which can kill living cells (such as germs or human skin cells) upon contact. It forms in greater quantities on hot, sunny, calm days. In metropolitan areas of California, ozone concentrations frequently exceed existing health-protective standards in the summertime.

Where does ozone come from?

Ozone is formed in the atmosphere through chemical reactions between pollutants emitted from vehicles, factories and other industrial sources, fossil fuels, combustion, consumer products, evaporation of paints, and many other sources. Hydrocarbons and nitrogen oxide gases react in the presence of sunlight to form ozone. Hot, sunny, and calm weather promotes ozone formation. Ozone has a very characteristic pungent odor, and it

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can sometimes be detected after lightning strikes or during electrical discharges. Individual humans vary in their ability to smell ozone; some people can smell it at levels as low as 0.05 ppm.

What is the difference between ground-level and stratospheric ozone?

The ozone that CARB regulates as an air pollutant is produced close to the ground level, where people live, exercise and breathe. A layer of ozone high up in the atmosphere is called stratospheric ozone. This layer, far away from where people live, reduces the amount of ultraviolet light entering the earth's atmosphere. Without the protection of the stratospheric ozone layer, plant and animal life would be seriously harmed.

Why do CARB and U.S. EPA focus on ozone?

Air quality regulators are concerned about ozone pollution because of its effects on public health and the environment. Ozone can damage the tissues of the respiratory tract, causing inflammation and irritation, and result in symptoms such as coughing, chest tightness and worsening of asthma symptoms. In addition, ozone causes substantial damage to crops, forests and native plants. Ozone can also damage materials such as rubber and plastics.

What kinds of harmful effects can ozone cause?

Inhalation of ozone causes inflammation and irritation of the tissues lining human airways, causing and worsening a variety of symptoms. Exposure to ozone can reduce the volume of air that the lungs breathe in and cause shortness of breath. Ozone in sufficient doses increases the permeability of lung cells, rendering them more susceptible to toxins and microorganisms. The occurrence and severity of health effects from ozone exposure vary widely among individuals, even when the dose and the duration of exposure are the same.

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Who is at the greatest risk from exposure to ozone?

Research shows adults and children who spend more time outdoors participating in vigorous physical activities are at greater risk from the harmful health effects of ozone exposure. While there are relatively few studies of ozone's effects on children, the available studies show that children are no more or less likely to suffer harmful effects than adults. However, there are a number of reasons why children may be more susceptible to ozone and other pollutants. Children and teens spend nearly twice as much time outdoors and engaged in vigorous activities as adults. Children breathe more rapidly than adults and inhale more pollution per pound of their body weight than adults. Also, children are less likely than adults to notice their own symptoms and avoid harmful exposures. Further research may be able to better distinguish between health effects in children and adults.

Children, adolescents and adults who exercise or work outdoors, where ozone concentrations are the highest, are at the greatest risk of harm from this pollutant.

How does ozone affect the environment?

Ozone's effect on plant life

Ozone exposure reduces the overall productivity of plants, damaging cells and causing destruction of leaf tissue. As a result, ozone exposure reduces the plants' ability to photosynthesize and produce their own food. Plants respond by growing more leaves thereby reducing the amounts of stored carbohydrates in roots and stems. This weakens plants, making them susceptible to disease, pests, cold and drought. Ozone also reduces crop and timber yields, resulting in millions of dollars in economic losses. Additionally, ozone disturbs the stability of ecosystems, leading to sensitive species dying out. Furthermore, ozone exposure reduces the production of roots, seeds, fruit and other plant constituents, reducing the amount of food available for wildlife.

Ozone's effect on materials

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Ozone can cause substantial damage to a variety of materials such as rubber, plastics, fabrics, paint and metals. Exposure to ozone progressively damages both the functional and aesthetic qualities of materials and products, and shortens their life spans. Damage from ozone exposure can result in significant economic losses as a result of the increased costs of maintenance, upkeep and replacement of these materials.

Is ozone a problem indoors?

Ozone reacts with surfaces as it penetrates the indoor environment, usually resulting in lower levels indoors than outdoors. However, levels of ozone indoors can approach outdoor levels when windows or doors are open. Moreover, equipment such as photocopiers, laser printers and certain air purifiers can emit ozone indoors as well. Air purifiers that purposely emit ozone, called ozone generators, should not be used in occupied spaces as they can emit unsafe levels of ozone. Once inside, ozone can cause harmful health effects and damage materials, depending on its concentration.

> **CAUTION REGARDING OZONE GENERATORS**
>
> The Air Resources Board and the California Department of Health Services advise the public not to use ozone generators in homes or offices. These devices are often marketed for the purposes of aiding allergy sufferers, but actually emit harmful ozone gas.

What are the Ambient Air Quality Standards for ozone?

In 2005, after an extensive review of the scientific literature, CARB approved an eight-hour standard for ozone of 0.070 ppm and retained the one-hour 0.09 ppm standard previously established in 1987. Evidence from the reviewed studies indicates that significant harmful health effects could occur among both adults and children if exposed to levels above these standards. On October 1, 2015, the U.S. EPA lowered the national eight-hour standard from 0.075 ppm to 0.070 ppm.

	1-Hour Average	Annual Average
National Ambient Air Quality Standard	--	0.070 ppm*

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California Ambient Air Quality Standard	0.09 ppm*	0.070 ppm*

* A part per million (ppm) refers to one part of a substance dissolved into a million parts of another substance.

RELATED RESOURCES

Harbor Communities Monitoring Study - Ultrafine Particle (UFP) Network

Harbor Communities Monitoring Study - Mobile Monitoring Platform

Harbor Communities Monitoring Study - Saturation Monitoring Project

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Nitrogen Dioxide & Health

CATEGORIES

Topics Health, Air Pollution, Indoor Air Quality & Exposure

Programs Outdoor Air Quality Standards, Exposure

Type Information

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What is nitrogen dioxide (NO_2)?

Nitrogen Dioxide (NO_2) is a pungent gas that, along with fine airborne particulate matter, contributes to the reddish-brown haze characteristic of smoggy air in California. NO_2 is comprised of one atom of nitrogen and two atoms of oxygen, and is a gas at ambient temperatures. It has a pungent smell, and is brownish red in color. NO_2 is a member of a family of chemicals comprised of nitrogen and oxygen that are collectively known as nitrogen oxides. The two most prevalent nitrogen oxides are NO_2 and nitric oxide (NO), and the combination is often referred to as NO_X.

Where does nitrogen dioxide come from?

Although NO_2 can be directly emitted from combustion sources, much of the NO_2 in the ambient air is formed in the atmosphere through reactions between nitric oxide (NO) and other air pollutants that require the presence of sunlight (photochemical reactions). NO_2 contributes to formation of several other air pollutants, including ozone (O_3), nitric acid (HNO_3), and nitrate (NO_3^-) -containing particles that also form through photochemical reactions. NO_2 levels in air vary with direct emission levels, as well as with changing atmospheric conditions, particularly the amount of sunlight.

Why do CARB and U.S. EPA focus on nitrogen dioxide?

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Air quality regulators have selected NO_2 as the marker for controlling ambient levels of NO_X for several reasons. Much of the information on oxides of nitrogen is specifically for NO_2. This includes information on the distribution in air, human exposure and dose, and health effects. There is only limited information for NO and NO_X, as well as large uncertainty in relating health effects to NO or NO_X exposure. In addition, emissions of NO_2 are highly correlated with those of other oxides of nitrogen and with several other traffic-related pollutants. Consequently, control measures that reduce emissions of NO_2 will also reduce emissions of other NO_X species, as well. NO_2 is an important precursor of anthropogenic O_3, and it is the key agent in the formation of several airborne toxic substances, including nitric acid (HNO_3), fine particles, peroxyacetyl nitrate, nitrosamines, and nitro-polycyclic aromatic hydrocarbons (nitro-PAHs).

It should be noted that the California ambient air quality standard is specifically for NO_2, while the national ambient air quality standard is for NO_X as a group, with NO_2 the marker for determining attainment. In both cases, however, the intent is to control NO_X emissions as a group.

What kinds of harmful effects can nitrogen dioxide cause?

A large body of health science literature indicates that exposure to NO_2 can induce adverse health effects. The strongest health evidence, and the health basis for the ambient air quality standard for NO_2, is results from controlled human exposure studies that show that NO_2 exposure can intensify responses to allergens in allergic asthmatics. In addition, a number of epidemiological studies have demonstrated associations between NO_2 exposure and premature death, cardiopulmonary effects, decreased lung function growth in children, respiratory symptoms, emergency room visits for asthma, and intensified allergic responses.

Who is at the greatest risk from exposure to nitrogen dioxide?

Infants and children are particularly at risk because they have disproportionately higher exposure to NO_2 than adults due to their greater breathing rate for their body weight and their typically greater outdoor exposure duration. Several studies have shown that long-term NO_2 exposure during childhood, the period of rapid lung growth, can lead to smaller

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lungs at maturity in children with higher compared to lower levels of exposure. In addition, children with asthma have a greater degree of airway responsiveness compared with adult asthmatics. In adults, the greatest risk is to people who have chronic respiratory diseases, such as asthma and chronic obstructive pulmonary disease.

How does nitrogen dioxide affect the environment?

With few exceptions, NO_2 can injure vegetation, including trees, forests and crops. This has only been reported when the cumulative duration of exposures was at least 0.2 ppm for 100 hours or longer during the growing season. Also, NO_2 can contribute to the reduction of visibility both directly, by selectively absorbing the shorter blue wavelengths of visible light, and indirectly by contributing to the formation of nitrate aerosol haze that decreases visibility.

Is nitrogen dioxide a problem indoors?

Indoor levels of NO_2 are determined primarily by the presence of NO_2-emitting appliances, the indoor-outdoor air exchange rate, (i.e., whether or not windows are open), and the effects of season. Gas stoves and space heaters are the most common indoor sources of NO_2 emissions. Other possible sources include improperly vented furnaces, water heaters, and clothes dryers. Winter levels are typically higher than those in summer, due to greater use of gas appliances in winter, and reduced use of windows for ventilation.

What are the Ambient Air Quality Standards for nitrogen dioxide?

Ambient air quality standards define the maximum amount of pollutant that can be present in outdoor air without harming human health. In 2007, after an extensive review of the scientific literature, the Board lowered the state one-hour standard for NO_2 to 0.18 ppm and retained the annual average standard of 0.030 ppm based on evidence for adverse health effects at the level of the existing one-hour standard. The national standard was more recently revised in 2010 following an exhaustive review of new

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literature pointed to evidence for adverse effects in asthmatics at lower NO_2 concentrations than the existing national standard.

	1-Hour Average	Annual Average
National Ambient Air Quality Standard	0.100 ppm*	0.053 ppm
California Ambient Air Quality Standard	0.18 ppm	0.030 ppm

* The official level of the 1-hour NO_2 standard is 100 ppb, equal to 0.100ppm, which is shown here for the purpose of clearer comparison to the other standards.

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Sulfate & Health

CATEGORIES

Topics Health, Air Pollution

Programs Outdoor Air Quality Standards, Exposure

Type Information

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What are sulfates?

Sulfates are a family of chemicals that contain the fully oxidized ionic form of sulfur (SO_4^{2-}), in combination with metal and/or hydrogen ions. In California, emissions of sulfur-containing compounds occur primarily from the combustion of petroleum-derived fuels (e.g., gasoline and diesel fuel) that contain sulfur. A small amount of sulfate is directly emitted from combustion of sulfur-containing fuels, but most ambient sulfate is formed in the atmosphere. First, emitted sulfur in the fuel is oxidized to sulfur dioxide (SO_2) during the combustion process and subsequently converted to sulfate particulate matter through chemical reactions in the atmosphere. Thus, sulfates are a sub-fraction of ambient particulate matter. The conversion of SO_2 to sulfates takes place comparatively rapidly and completely in urban areas of California due to regional meteorological characteristics.

Why does CARB focus on sulfates?

Sulfates can be a significant portion of fine particulate matter (particles that are equal to or less than 2.5 microns in diameter, called PM2.5), and they can induce a wide range of adverse health effects, as described below. In addition, sulfates contribute to acidification of surface water and soil, and contribute to acid rain and fog that damage ecosystems, forests and plants. Because sulfates are light colored, they reflect energy from sunlight back into space. This means that sulfates have a cooling influence on climate change.

What kinds of harmful effects can sulfates cause?

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Sulfate particles are part of PM2.5, and so they have health effects similar to those from exposure to PM2.5. These include reduced lung function, aggravated asthmatic symptoms, and increased risk of emergency department visits, hospitalizations, and death in people who have chronic heart or lung diseases.

Who is at the greatest risk from exposure to sulfates?

Groups having higher risk of experiencing adverse health effects with sulfates exposure include children, asthmatics, and older adults who have chronic heart or lung diseases.

How do sulfates affect the environment?

Sulfates are particularly effective in degrading visibility by scattering light before it reaches an observer. This light scattering reduces visual clarity, mutes colors, and reduces the distance one can see. Sulfate particles are usually acidic and when dissolved in water they form sulfuric acid. Deposition of this sulfuric acid is usually through acid rain or snow, which damages a variety of ecosystems and materials. Acid rain can increase the acidity of waterways and lakes, inhibiting fertility, growth, and development of fish and other aquatic species, strip aluminum from the soil and alter essential nutrient availability to trees and plants, thereby inhibiting tree and plant growth. Acid rain can also physically damage tree leaves and needles so that they have reduced capacity for photosynthesis. Dry deposition of acidic sulfates can cause acid damage to buildings, paint, metals and stone that leads to premature deterioration.

Are sulfates a problem indoors?

There are no significant sulfates emissions sources indoors. Indoor sulfate levels are related to infiltration of sulfate from outdoor air.

What is the Ambient Air Quality Standard for sulfates?

24-Hour Average

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	24-Hour Average
National Ambient Air Quality Standard	None
California Ambient Air Quality Standard	25 µg/m^3

Additional Information

- CARB's acid deposition research program
- U.S. EPA information on acid rain

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Sulfur Dioxide & Health

CATEGORIES

Topics Health, Air Pollution

Programs Outdoor Air Quality Standards, Exposure

Type Information

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What is sulfur dioxide (SO_2)?

Sulfur dioxide (SO_2) is comprised of one atom of sulfur and two atoms of oxygen, and is a gas at ambient temperatures. It has a pungent, irritating odor. SO_2 is a member of a family of chemicals comprised of sulfur and oxygen that are collectively known as sulfur oxides (SO_X).

Where does sulfur dioxide come from?

SO_X, including SO_2, are emitted when sulfur-containing fuel is burned. Some examples of sources include motor vehicles, locomotives, ships, and off-road diesel equipment that are operated with fuels that contain high levels of sulfur. In addition, SO_2 and the other SO_X are emitted from some industrial processes, such as natural gas and petroleum extraction, oil refining, and metal processing. They are also released during volcanic activity and from geothermal fields.

Why do CARB and U.S. EPA focus on sulfur dioxide as a marker for sulfur oxides?

SO_2 is the most prevalent species of gaseous SO_X in the atmosphere, with other species not present at concentrations relevant for human exposures. Because of this, most health studies have focused on SO_2. Many human and animal exposure studies, as well as

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epidemiological studies, have reported adverse health effects specifically attributable to SO_2 exposure. For this reason SO_2 is used as the indicator for the group of gaseous SO_X. However, it should be noted that emissions of the SO_X family of air pollutants are involved in a number of chemical reactions in the atmosphere where they are transformed into acids and particulate sulfates, and these pollutants can also contribute to adverse human health and environmental effects. Because the various SO_X species arise from the same sources, control measures that focus on SO_2 also reduce emissions of the other SO_X species.

It should be noted that the California ambient air quality standard is specifically for SO_2 while the national ambient air quality standard is for SO_X as a group, with SO_2 the marker for determining attainment. In both cases, however, the intent is to control SO_X emissions as a group.

What kinds of harmful effects can sulfur dioxide cause?

Controlled human exposure and epidemiological studies show that children and adults with asthma are more likely to experience adverse responses with SO_2 exposure, compared with the non-asthmatic population. Effects at levels near the one-hour standard are those of asthma exacerbation, including bronchoconstriction accompanied by symptoms of respiratory irritation such as wheezing, shortness of breath and chest tightness, especially during exercise or physical activity. Also, exposure at elevated levels of SO_2 (above 1 ppm) results in increased incidence of pulmonary symptoms and disease, decreased pulmonary function, and increased risk of mortality. The elderly and people with cardiovascular disease or chronic lung disease (such as bronchitis or emphysema) are most likely to experience these adverse effects.

How does sulfur dioxide affect the environment?

SO_2 deposition, along with that of other SO_X, species, contributes to soil and surface water acidification and acid rain. This acidification causes a variety of effects that harm susceptible aquatic and terrestrial ecosystems, including slower growth and injury to forests and localized extinction of fish and other aquatic species. SO_2 deposition also

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promotes chemical reactions that facilitate the accumulation of mercury in water and soil. This can lead to elevated mercury levels in food, which in turn increases risk of adverse health effects in human populations due to mercury ingestion.

Is sulfur dioxide a problem indoors?

The level of SO_2 indoors is largely driven by outdoor concentrations, and is typically lower that outdoors levels. The only known significant indoor source of SO_2 in the U.S. is unvented kerosene heaters, although this is not a common means of indoor heating in most of the country.

What are the Ambient Air Quality Standards for sulfur dioxide?

	1-Hour Average	**24-Hour Average**	**Annual Average**
National Ambient Air Quality Standard (SO_X with SO_2 as the marker)	0.075 ppm	0.14 ppm	0.030 ppm
California Ambient Air Quality Standard (SO_2)	0.25 ppm	0.04 ppm	None

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Visibility-Reducing Particles & Health

CATEGORIES

Topics Health, Air Pollution

Programs Outdoor Air Quality Standards, Exposure

Type Information

CONTACT

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What are visibility-reducing particles?

Particulate matter (PM) pollution impacts the environment by decreasing visibility (haze). These particles vary greatly in shape, size and chemical composition, and come from a variety of natural and manmade sources. Some haze-causing particles are directly emitted to the air such as windblown dust and soot. Others are formed in the air from the chemical transformation of gaseous pollutants (e.g., sulfates, nitrates, organic carbon particles) which are the major constituents of fine PM. These fine particles, caused largely by combustion of fuel, can travel hundreds of miles causing visibility impairment.

How do particles reduce visibility?

Visibility reduction is probably the most apparent symptom of air pollution. Visibility degradation is caused by the absorption and scattering of light by particles and gases in the atmosphere before it reaches the observer. As the number of fine particles increases, more light is absorbed and scattered, resulting in less clarity, color, and visual range. Light absorption by gases and particles is sometimes the cause of discolorations in the atmosphere but usually does not contribute very significantly to visibility degradation. Scattering by particulates impairs visibility much more readily. Particles that are the most effective at reducing visibility (per unit aerosol mass) have diameters in the range of 0.1-1.0 µm. Some types of particles such as sulfates scatter more light, particularly during humid conditions. Visibility standards are based on extinction coefficients, which is a measure of the light attenuation due to both absorption and scattering.

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What are the health effects of visibility-reducing particles?

Haze not only impacts visibility, but some haze-causing pollutants have been linked to serious health problems and environmental damage as well. Exposure to particles up to 2.5 (PM2.5) and 10 microns (PM10) in diameter in the ambient air can contribute to a broad range of adverse health effects, including premature death, hospitalizations and emergency department visits for worsened heart and lung diseases. These effects are described in CARB's webpage for PM2.5 and PM10.

What is the purpose of the Ambient Air Quality Standard for visibility-reducing particles?

The Ambient Air Quality Standard for visibility-reducing particles is intended to limit the frequency and severity of visibility impairment due to regional haze, which is largely caused by ambient particles. The visibility standard is unique among the California ambient air quality standards in that it is not based on health effects, but rather on what is termed a welfare effect. Welfare effects indirectly impact the public through effects that are not related to health, for example reduced visibility, and damage to materials, plants, forests, and ecosystems. Haze also has economic consequences. Each year, millions of visitors travel to our national parks and wilderness areas. Haze affecting these areas obscures the spectacular views the public expects to experience. Over time, this could lead to fewer visitors or shorter visits.

What are the standards for visibility-reducing particles?

Secondary standards set limits to protect public welfare, including protection against decreased visibility. Originally, the State visibility standard was based on the distance a person could see, 10 miles in most of the State, and 30 miles at Lake Tahoe. In 1989, CARB converted both the general statewide 10-mile visibility standard and the Lake Tahoe 30-mile visibility standard to instrumental equivalents, which are "extinction of 0.23 per kilometer" and "extinction of 0.07 per kilometer" for the statewide and Lake Tahoe Air Basin standards, respectively.

Regional Haze Program

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RELATED RESOURCES

Mobile Monitoring Research Studies

Verification Procedure: Installers & Distributors

Car & Bus Exposure Studies

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Chair, California Air Resources Board
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SciName	ComName	TaxonGrou	ElmCode	FedList	CalList	GRank	SRank	RPlantRank	OthrStatus
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Polioptila n	black-taile	Birds	ABPBJ0803	None	None	G5	S3S4		CDFW_WL-
Polioptila n	black-taile	Birds	ABPBJ0803	None	None	G5	S3S4		CDFW_WL-
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Ditaxis clar	glandular d	Dicots	PDEUP080I	None	None	G3G4	S2	2B.2	
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1		BLM_S-Sen
Icteria virei	yellow-bre	Birds	ABPBX240:	None	None	G5	S3		CDFW_SSC
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Accipiter c	Cooper's h	Birds	ABNKC120	None	None	G5	S4		CDFW_WL-
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2		
Gelochelid	gull-billed t	Birds	ABNNM08(	None	None	G5	S1		CDFW_SSC
Gelochelid	gull-billed t	Birds	ABNNM08(	None	None	G5	S1		CDFW_SSC
Crucifixion	Crucifixion	Woodland	CTT75200C	None	None	G3	S1.2		
Astragalus	Peirson's m	Dicots	PDFAB0F5:	Threatenec	Endangere	G3G4T1	S1	1B.2	SB_RSABG-
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Helianthus	Algodones	Dicots	PDAST4N0	None	Endangere	G4T2T3	S1	1B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Palafoxia a	giant spani	Dicots	PDAST6T01	None	None	G5T3?	S2	1B.3	BLM_S-Sen
Castela em	Emory's cr	Dicots	PDSIM030:	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Pilostyles t	Thurber's p	Dicots	PDRAF010:	None	None	G5	S4	4.3	
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Ipomopsis	Baja Califo	Dicots	PDPLM060	None	None	G3?	SH	2B.1	SB_RSABG-

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Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Falco mexi	prairie falc	Birds	ABNKD060	None	None	G5	S4		CDFW_WL-
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Icteria virei	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Sonoran Cc	Sonoran Cc	Riparian	CTT61810(	None	None	G2	S1.1		
Castela em	Emory's cru	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Castela em	Emory's cru	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Hulsea me	Mexican hu	Dicots	PDAST4Z0	None	None	G3G4	S1	2B.3	SB_RSABG-
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1		BLM_S-Sen
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3		CDFW_WL-
Toxostoma	Le Conte's	Birds	ABPBK061(	None	None	G4	S3		BLM_S-Sen
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Ovis canad	desert bigh	Mammals	AMALE040	None	None	G4T4	S3		BLM_S-Sen
Ovis canad	desert bigh	Mammals	AMALE040	None	None	G4T4	S3		BLM_S-Sen
Ovis canad	desert bigh	Mammals	AMALE040	None	None	G4T4	S3		BLM_S-Sen
Ovis canad	Peninsular	Mammals	AMALE040	Endangere	Threatenec	G4T3Q	S1		CDFW_FP-I
Ovis canad	Peninsular	Mammals	AMALE040	Endangere	Threatenec	G4T3Q	S1		CDFW_FP-I
Piranga rut	summer ta	Birds	ABPBX450	None	None	G5	S1		CDFW_SSC
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Icteria virei	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Polioptila n	black-taile	Birds	ABPBJ0803	None	None	G5	S3S4		CDFW_WL-
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3		CDFW_WL-
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3		CDFW_WL-
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1		BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1		BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1		BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1		BLM_S-Sen
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I

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Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Mesquite E	Mesquite E	Riparian	CTT61820C	None	None	G3	S2.1		
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1		
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1		
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1		
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1		
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1		
Transmont	Transmont	Marsh	CTT52320C	None	None	G3	S2.1		
Palafoxia a	giant spani	Dicots	PDAST6T01	None	None	G5T3?	S2	1B.3	BLM_S-Sen
Palafoxia a	giant spani	Dicots	PDAST6T01	None	None	G5T3?	S2	1B.3	BLM_S-Sen
Palafoxia a	giant spani	Dicots	PDAST6T01	None	None	G5T3?	S2	1B.3	BLM_S-Sen
Nemacauli	slender cot	Dicots	PDPGN0G(	None	None	G3G4T3?	S2	2B.2	
Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Castela em	Emory's cr	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Castela em	Emory's cr	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Bursera mi	little-leaf e	Dicots	PDBUR010	None	None	G4	S2	2B.3	SB_RSABG-
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3		BLM_S-Sen
Lupinus alb	Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Lupinus alb	Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3		BLM_S-Sen
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1		AFS_EN-En
Selaginella	desert spik	Ferns	PPSEL010G	None	None	G4	S2S3	2B.2	
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	

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Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Opuntia wi	Wiggins' ch	Dicots	PDCAC0D1	None	None	G3?Q	S1?	3.3	
Opuntia wi	Wiggins' ch	Dicots	PDCAC0D1	None	None	G3?Q	S1?	3.3	
Stabilized a	Stabilized a	Dune	CTT22200C	None	None	G4	S3.2		
Active Des	Active Des	Dune	CTT22100C	None	None	G4	S2.2		
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Pilostyles t	Thurber's p	Dicots	PDRAF010	None	None	G5	S4	4.3	
Gelochelid	gull-billed t	Birds	ABNNM08(	None	None	G5	S1		CDFW_SSC
Gelochelid	gull-billed t	Birds	ABNNM08(	None	None	G5	S1		CDFW_SSC
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Nama sten	mud nama	Dicots	PDHYD0A0	None	None	G4G5	S1S2	2B.2	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1		

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Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Pseudocot	Andrew's d	Insects	IICOL3702(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala h	Hardy's dui	Insects	IICOL3006(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1	
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2	CDFW_SSC
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	

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Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Corynorhin	Townsend'	Mammals	AMACC08(	None	None	G3G4	S2		BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08(	None	None	G3G4	S2		BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08(	None	None	G3G4	S2		BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08(	None	None	G3G4	S2		BLM_S-Sen
Piranga rut	summer ta	Birds	ABPBX450	None	None	G5	S1		CDFW_SSC
Piranga rut	summer ta	Birds	ABPBX450	None	None	G5	S1		CDFW_SSC
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3		BLM_S-Sen
Junco hyen	gray-heade	Birds	ABPBXA50	None	None	G5T5	S1		CDFW_WL-
Setophaga	Sonoran ye	Birds	ABPBX030	None	None	G5T2T3	S2		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3		CDFW_SSC
Setophaga	yellow war	Birds	ABPBX030	None	None	G5	S3S4		CDFW_SSC
Setophaga	yellow war	Birds	ABPBX030	None	None	G5	S3S4		CDFW_SSC
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen

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Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2	BLM_S-Sen
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Polioptila n	black-tailec	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3	CDFW_WL-
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3	CDFW_WL-
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3	CDFW_WL-
Pyrocephal	vermilion f	Birds	ABPAE360	None	None	G5	S2S3	CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360	None	None	G5	S2S3	CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360	None	None	G5	S2S3	CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360	None	None	G5	S2S3	CDFW_SSC
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen
Asio flamm	short-eare	Birds	ABNSB130	None	None	G5	S3	CDFW_SSC
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Rynchops r	black skimr	Birds	ABNNM14	None	None	G5	S2	CDFW_SSC
Rynchops r	black skimr	Birds	ABNNM14	None	None	G5	S2	CDFW_SSC
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Rallus obsc	Yuma Ridg	Birds	ABNME05	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I

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Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I

Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3	CDFW_SSC
Piranga rut	summer ta	Birds	ABPBX450	None	None	G5	S1	CDFW_SSC
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Ptychochei	Colorado p	Fish	AFCJB3502	Endangere	Endangere	G1	SX	CDFW_FP-I
Desert Fan	Desert Fan	Riparian	CTT62300C	None	None	G3	S3.2	
Desert Fan	Desert Fan	Riparian	CTT62300C	None	None	G3	S3.2	
Desert Fan	Desert Fan	Riparian	CTT62300C	None	None	G3	S3.2	
Desert Fan	Desert Fan	Riparian	CTT62300C	None	None	G3	S3.2	
Desert Fan	Desert Fan	Riparian	CTT62300C	None	None	G3	S3.2	
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1	
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1	
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1	
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1	
Sonoran Cc	Sonoran Cc	Riparian	CTT61810C	None	None	G2	S1.1	
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Piranga rut	summer ta	Birds	ABPBX450	None	None	G5	S1	CDFW_SSC
Myiarchus	brown-cres	Birds	ABPAE430	None	None	G5	S3	CDFW_WL-
Polioptila n	black-taile	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Icteria vire	yellow-bre	Birds	ABPBX240	None	None	G5	S3	CDFW_SSC
Polioptila n	black-taile	Birds	ABPBJ0803	None	None	G5	S3S4	CDFW_WL-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Carnegiea	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2 SB_RSABG-
Carnegiea	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2 SB_RSABG-
Carnegiea	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2 SB_RSABG-
Carnegiea	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2 SB_RSABG-
Carnegiea	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2 SB_RSABG-
Eucnide ru	annual rocl	Dicots	PDLOA020	None	None	G3	S1	2B.2
Eucnide ru	annual rocl	Dicots	PDLOA020	None	None	G3	S1	2B.2
Eucnide ru	annual rocl	Dicots	PDLOA020	None	None	G3	S1	2B.2
Eucnide ru	annual rocl	Dicots	PDLOA020	None	None	G3	S1	2B.2
Geraea visc	sticky gera	Dicots	PDAST420	None	None	G2G3	S2	2B.2 SB_RSABG-
Herissantia	curly heriss	Dicots	PDMAL0F0	None	None	G5	S1	2B.3
Ipomopsis	slender-lea	Dicots	PDPLM060	None	None	G4	S2	2B.3 SB_RSABG-
Ipomopsis	slender-lea	Dicots	PDPLM060	None	None	G4	S2	2B.3 SB_RSABG-

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Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3	
Mentzelia l	hairy stickl	Dicots	PDLOA030	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030	None	None	G4?	S3	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Rynchops r	black skimr	Birds	ABNNM14(	None	None	G5	S2		CDFW_SSC
Hydroprog	Caspian ter	Birds	ABNNM08(	None	None	G5	S4		IUCN_LC-Le
Gelochelid	gull-billed t	Birds	ABNNM08(	None	None	G5	S1		CDFW_SSC
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Myotis cilic	western sm	Mammals	AMACC011	None	None	G5	S3		BLM_S-Sen
Sigmodon a	Colorado R	Mammals	AMAFF070	None	None	G5T2T3	S1S2		CDFW_SSC
Scaphiopus	Couch's spa	Amphibian	AAABF010	None	None	G5	S2		BLM_S-Sen
Incilius alva	Sonoran de	Amphibian	AAABB010	None	None	G5	SH		CDFW_SSC
Incilius alva	Sonoran de	Amphibian	AAABB010	None	None	G5	SH		CDFW_SSC
Incilius alva	Sonoran de	Amphibian	AAABB010	None	None	G5	SH		CDFW_SSC
Incilius alva	Sonoran de	Amphibian	AAABB010	None	None	G5	SH		CDFW_SSC
Incilius alva	Sonoran de	Amphibian	AAABB010	None	None	G5	SH		CDFW_SSC
Abronia vil	chaparral s	Dicots	PDNYC010	None	None	G5T2?	S2	1B.1	BLM_S-Sen
Xylorhiza o	Orcutt's wo	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Eryngium a	San Diego l	Dicots	PDAPI0Z04	Endangere	Endangere	G5T1	S1	1B.1	SB_CRES-Sa
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En

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Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Plegadis ch	white-face	Birds	ABNGE020	None	None	G5	S3S4		CDFW_WL-
Myotis yun	Yuma myot	Mammals	AMACC01(	None	None	G5	S4		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Plegadis ch	white-face	Birds	ABNGE020	None	None	G5	S3S4		CDFW_WL-
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061(	None	None	G4	S3		BLM_S-Sen
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Buteo rega	ferruginou	Birds	ABNKC191	None	None	G4	S3S4		CDFW_WL-
Buteo rega	ferruginou	Birds	ABNKC191	None	None	G4	S3S4		CDFW_WL-
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Euphorbia	flat-seeded	Dicots	PDEUP0D1	None	None	G3	S1	1B.2	SB_RSABG-
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Vireo bellii	least Bell's	Birds	ABPBW011	Endangere	Endangere	G5T2	S2		IUCN_NT-N
Nemacauli	slender cot	Dicots	PDPGN0G(	None	None	G3G4T3?	S2	2B.2	
Senna cove	Cove's cass	Dicots	PDFAB491)	None	None	G5	S3	2B.2	SB_RSABG-
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC

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Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Acmispon h	pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Anomala h	Hardy's du	Insects	IICOL3006(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Anomala c	Carlson's d	Insects	IICOL3005(	None	None	G1	S1		
Oliarces cl	cheesewee	Insects	IINEU0401(	None	None	G1G3	S2		
Onychomy	southern g	Mammals	AMAFF060	None	None	G5T3	S3		CDFW_SSC
Colubrina c	Las Animas	Dicots	PDRHA050	None	None	G4	S2S3	2B.3	SB_RSABG-
Colubrina c	Las Animas	Dicots	PDRHA050	None	None	G4	S2S3	2B.3	SB_RSABG-
Colubrina c	Las Animas	Dicots	PDRHA050	None	None	G4	S2S3	2B.3	SB_RSABG-
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Lasiurus xa	western ye	Mammals	AMACC05(	None	None	G5	S3		CDFW_SSC
Puma conc	Yuma mou	Mammals	AMAJH040	None	None	G5T1T2Q	S1		CDFW_SSC
Nyctinomo	big free-tai	Mammals	AMACD04(	None	None	G5	S3		CDFW_SSC
Myotis occ	Arizona My	Mammals	AMACC011	None	None	G4	S1		CDFW_SSC
Chaetodipu	pallid San I	Mammals	AMAFD05(	None	None	G5T34	S3S4		CDFW_SSC
Chaetodipu	pallid San I	Mammals	AMAFD05(	None	None	G5T34	S3S4		CDFW_SSC
Chaetodipu	pallid San I	Mammals	AMAFD05(	None	None	G5T34	S3S4		CDFW_SSC
Oreothlypi	Lucy's warl	Birds	ABPBX010	None	None	G5	S2S3		BLM_S-Sen
Melitta cali	California r	Insects	IIHYM7401	None	None	G4?	S2?		
Melitta cali	California r	Insects	IIHYM7401	None	None	G4?	S2?		
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Calliandra	pink fairy-d	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra	pink fairy-d	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra	pink fairy-d	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-

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Calliandra (	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-

Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Lupinus alb	Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3 BLM_S-Sen
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Ptychochei	Colorado p	Fish	AFCJB3502	Endangere	Endangere	G1	SX	CDFW_FP-I
Xylorhiza o	Orcutt's wo	Dicots	PDASTA10	None	None	G3?	S2	1B.2 BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Scaphiopus	Couch's spa	Amphibian	AAABF010	None	None	G5	S2	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lithobates	lowland lec	Amphibian	AAABH012	None	None	G4	SX	BLM_S-Sen
Lepismado	Algodones	Insects	IICOLX111(	None	None	G1	S1	
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4	BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3	BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3	BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3	BLM_S-Sen

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Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Myotis veli	cave myoti	Mammals	AMACC01(	None	None	G5	S1		BLM_S-Sen
Larus califc	California g	Birds	ABNNM03:	None	None	G5	S4		CDFW_WL-
Nyctinomo	pocketed fi	Mammals	AMACD04(	None	None	G4	S3		CDFW_SSC
Nyctinomo	pocketed fi	Mammals	AMACD04(	None	None	G4	S3		CDFW_SSC
Lasiurus cir	hoary bat	Mammals	AMACC05(	None	None	G5	S4		IUCN_LC-Le
Lasiurus cir	hoary bat	Mammals	AMACC05(	None	None	G5	S4		IUCN_LC-Le
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Nyctinomo	pocketed fi	Mammals	AMACD04(	None	None	G4	S3		CDFW_SSC
Myotis yun	Yuma myot	Mammals	AMACC01(	None	None	G5	S4		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3		BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3		BLM_S-Sen
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Nyctinomo	pocketed fi	Mammals	AMACD04(	None	None	G4	S3		CDFW_SSC
Macrotus c	California l	Mammals	AMACB01(	None	None	G4	S3		BLM_S-Sen
Antrozous	pallid bat	Mammals	AMACC10(	None	None	G5	S3		BLM_S-Sen
Nyctinomo	pocketed fi	Mammals	AMACD04(	None	None	G4	S3		CDFW_SSC
Eumops pe	western m	Mammals	AMACD02(	None	None	G5T4	S3S4		BLM_S-Sen
Imperata b	California s	Monocots	PMPOA3D(	None	None	G4	S3	2B.1	SB_RSABG-
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Perognath	Palm Sprin	Mammals	AMAFD01(	None	None	G5T2	S2		BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360:	None	None	G5	S2S3		CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360:	None	None	G5	S2S3		CDFW_SSC
Pyrocephal	vermilion f	Birds	ABPAE360:	None	None	G5	S2S3		CDFW_SSC
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100:	None	None	G4	S3		BLM_S-Sen
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Falco colun	merlin	Birds	ABNKD060	None	None	G5	S3S4		CDFW_WL-
Heloderma	banded Gil	Reptiles	ARACE010:	None	None	G4T4	S1		BLM_S-Sen
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-

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Calliandra (	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Teucrium c	dwarf germ	Dicots	PDLAM200	None	None	G4G5T3T4	S2	2B.2	
Teucrium c	dwarf germ	Dicots	PDLAM200	None	None	G4G5T3T4	S2	2B.2	
Abronia vil	chaparral s	Dicots	PDNYC010	None	None	G5T2?	S2	1B.1	BLM_S-Sen
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2	
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Hymenoxy	bitter hym	Dicots	PDAST530	None	None	G5	S2	2B.1	
Hymenoxy	bitter hym	Dicots	PDAST530	None	None	G5	S2	2B.1	
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V

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Scaphiopus	Couch's sp	Amphibian	AAABF010	None	None	G5	S2		BLM_S-Sen
Lithobates	northern le	Amphibian	AAABH011	None	None	G5	S2		CDFW_SSC
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3		BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3		BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen

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Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Ixobrychus least bitter		Birds	ABNGA020	None	None	G4G5	S2	CDFW_SSC
Ixobrychus least bitter		Birds	ABNGA020	None	None	G4G5	S2	CDFW_SSC
Ixobrychus least bitter		Birds	ABNGA020	None	None	G4G5	S2	CDFW_SSC
Ixobrychus least bitter		Birds	ABNGA020	None	None	G4G5	S2	CDFW_SSC
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2 SB_RSABG-
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2 SB_RSABG-

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Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Chaenactis	Peirson's p	Dicots	PDAST200	None	None	G5T2	S2	1B.3	BLM_S-Sen
Palafoxia a	giant spani	Dicots	PDAST6T0	None	None	G5T3?	S2	1B.3	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Salvia grea	Orocopia s	Dicots	PDLAM1S0	None	None	G2G3	S2S3	1B.3	BLM_S-Sen
Salvia grea	Orocopia s	Dicots	PDLAM1S0	None	None	G2G3	S2S3	1B.3	BLM_S-Sen
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Pseudocot	Andrew's d	Insects	IICOL3702	None	None	G1	S1		
Pseudocot	Andrew's d	Insects	IICOL3702	None	None	G1	S1		
Mentzelia	Darlington'	Dicots	PDLOA031	None	None	G5	S2	2B.2	SB_RSABG-
Mentzelia	Darlington'	Dicots	PDLOA031	None	None	G5	S2	2B.2	SB_RSABG-
Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3	
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2	
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Symphyotr	San Bernar	Dicots	PDASTE80	None	None	G2	S2	1B.2	SB_CRES-S
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Matelea pa	spear-leaf	Dicots	PDASC0A0	None	None	G5	S3	2B.3	USFS_S-Ser
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020	Endangere	Endangere	G1	S1		AFS_EN-En
Streptanth	southern je	Dicots	PDBRA2G0	None	None	G3	S3	1B.3	BLM_S-Sen
Mentzelia	hairy stickl	Dicots	PDLOA030	None	None	G4?	S3	2B.3	SB_RSABG-
Xylorhiza o	Orcutt's wo	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen

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Xylorhiza o	Orcutt's wc	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen

Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Astragalus	Harwood's	Dicots	PDFAB0F4	None	None	G5T4	S2	2B.2	SB_RSABG-
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen

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Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen

Lanius ludc	loggerhead	Birds	ABPBR010	None	None	G4	S4		CDFW_SSC
Lanius ludc	loggerhead	Birds	ABPBR010	None	None	G4	S4		CDFW_SSC
Lanius ludc	loggerhead	Birds	ABPBR010	None	None	G4	S4		CDFW_SSC
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2		CDFW_SSC
Macrotus c	California l	Mammals	AMACB01C	None	None	G4	S3		BLM_S-Sen
Bursera mi	little-leaf e	Dicots	PDBUR010	None	None	G4	S2	2B.3	SB_RSABG-
Ixobrychus least	bitter	Birds	ABNGA020	None	None	G4G5	S2		CDFW_SSC
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen

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Athene cur burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen

Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2	CDFW_SSC
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Sigmodon l	Yuma hispi	Mammals	AMAFF070	None	None	G5T2T3	S2	CDFW_SSC
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen

Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Koeberlinia	slender-spi	Dicots	PDCPP050	None	None	G4T4?	S2	2B.2	
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2		CDFW_FP-I
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Rallus obsc	Yuma Ridg	Birds	ABNME05(	Endangere	Threatenec	G5T3	S1S2	CDFW_FP-I
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V

Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010:	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Mentzelia p	Darlington'	Dicots	PDLOA031I	None	None	G5	S2	2B.2	SB_RSABG-
Astragalus	gravel milk	Dicots	PDFAB0F7F	None	None	G4G5	S2	2B.2	
Astragalus	gravel milk	Dicots	PDFAB0F7F	None	None	G4G5	S2	2B.2	
Astragalus	gravel milk	Dicots	PDFAB0F7F	None	None	G4G5	S2	2B.2	
Astragalus	gravel milk	Dicots	PDFAB0F7F	None	None	G4G5	S2	2B.2	
Astragalus	gravel milk	Dicots	PDFAB0F7F	None	None	G4G5	S2	2B.2	
Pholisma s	sand food	Dicots	PDLNN020:	None	None	G2	S2	1B.2	BLM_S-Sen
Acmispon h	pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Acmispon h	pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3		BLM_S-Sen
Mentzelia t	spiny-hair b	Dicots	PDLOA031	None	None	G4	S2	2B.1	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	
Lycium par	Parish's de	Dicots	PDSOL0G0I	None	None	G4	S1	2B.3	

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Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Linanthus r	Jacumba M	Dicots	PDPLM041	None	None	G2T1	S1	1B.1
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Charadrius	mountain p	Birds	ABNNB031	None	None	G3	S2S3	BLM_S-Sen
Crotalus ru	red-diamor	Reptiles	ARADE020	None	None	G4	S3	CDFW_SSC
Crotalus ru	red-diamor	Reptiles	ARADE020	None	None	G4	S3	CDFW_SSC
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatened	Endangere	G5T2T3	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatened	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatened	G3G4T1	S1	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatened	G3G4T1	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen
Penstemor	desert bea	Dicots	PDSCR1L5(	None	None	G4G5T4	S3	2B.2
Penstemor	desert bea	Dicots	PDSCR1L5(	None	None	G4G5T4	S3	2B.2
Penstemor	desert bea	Dicots	PDSCR1L5(	None	None	G4G5T4	S3	2B.2
Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Colaptes ch	gilded flick	Birds	ABNYF100	None	Endangere	G5	S1	BLM_S-Sen
Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen

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Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Melanerpe	Gila woodp	Birds	ABNYF041	None	Endangere	G5	S1	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Vireo bellii	Arizona bel	Birds	ABPBW011	None	Endangere	G5T4	S1S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Empidonax	southweste	Birds	ABPAE330	Endangere	Endangere	G5T2	S1	NABCI_RW
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3	BLM_S-Sen
Laterallus j	California b	Birds	ABNME03(	None	Threatenec	G3G4T1	S1	BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3	BLM_S-Sen
Pelecanus	California b	Birds	ABNFC010	Delisted	Delisted	G4T3T4	S3	BLM_S-Sen
Micrathene	elf owl	Birds	ABNSB090	None	Endangere	G5	S1	BLM_S-Sen

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Charadrius western sn	Birds	ABNNB030	Threatened	None	G3T3	S2S3		CDFW_SSC
Charadrius western sn	Birds	ABNNB030	Threatened	None	G3T3	S2S3		CDFW_SSC
Malperia te brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Malperia te brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Calliandra (pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra (pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Calliandra (pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3	SB_RSABG-
Malperia te brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3	SB_RSABG-
Xylorhiza o Orcutt's wo	Dicots	PDASTA10	None	None	G3?	S2	1B.2	BLM_S-Sen
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Lupinus alb Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Lupinus alb Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Lupinus alb Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Lupinus alb Mountain S	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3	BLM_S-Sen
Acmispon h pygmy lotu	Dicots	PDFAB2A0I	None	None	G3	S3	1B.3	SB_USDA-L
Pholistoma Arizona ph	Dicots	PDHYD0D0	None	None	G5T4?	S3	2B.3	SB_RSABG-
Pholistoma Arizona ph	Dicots	PDHYD0D0	None	None	G5T4?	S3	2B.3	SB_RSABG-
Pholistoma Arizona ph	Dicots	PDHYD0D0	None	None	G5T4?	S3	2B.3	SB_RSABG-
Mentzelia h hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Linanthus r Jacumba M	Dicots	PDPLM041	None	None	G2T1	S1	1B.1	BLM_S-Sen
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Euphorbia Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2	SB_RSABG-
Aquila chry golden eag	Birds	ABNKC220	None	None	G5	S3		BLM_S-Sen
Ipomopsis slender-lea	Dicots	PDPLM060	None	None	G4	S2	2B.3	SB_RSABG-
Ipomopsis slender-lea	Dicots	PDPLM060	None	None	G4	S2	2B.3	SB_RSABG-
Selaginella desert spik	Ferns	PPSEL010G	None	None	G4	S2S3	2B.2	
Aquila chry golden eag	Birds	ABNKC220	None	None	G5	S3		BLM_S-Sen
Castela em Emory's cr	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2	SB_RSABG-
Haliaeetus bald eagle	Birds	ABNKC100	Delisted	Endangere	G5	S3		BLM_S-Sen
Gila elegan bonytail	Fish	AFCJB1310	Endangere	Endangere	G1	SH		AFS_EN-En
Gila elegan bonytail	Fish	AFCJB1310	Endangere	Endangere	G1	SH		AFS_EN-En
Xyrauchen razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xyrauchen razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xyrauchen razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En
Xyrauchen razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2		AFS_EN-En

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Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Xyrauchen	razorback s	Fish	AFCJC1101	Endangere	Endangere	G1	S1S2	AFS_EN-En
Toxostoma	Crissal thra	Birds	ABPBK060	None	None	G5	S3	BLM_S-Sen
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3	BLM_S-Sen
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2 SB_RSABG-
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3	IUCN_VU-V
Toxostoma	Le Conte's	Birds	ABPBK061	None	None	G4	S3	BLM_S-Sen
Falco mexi	prairie falc	Birds	ABNKD060	None	None	G5	S4	CDFW_WL-
Acmispon	pygmy lotu	Dicots	PDFAB2A0	None	None	G3	S3	1B.3 SB_USDA-L
Panicum hi	roughstalk	Monocots	PMPOA4K1	None	None	G5T5	S2	2B.1 SB_RSABG-
Panicum hi	roughstalk	Monocots	PMPOA4K1	None	None	G5T5	S2	2B.1 SB_RSABG-
Panicum hi	roughstalk	Monocots	PMPOA4K1	None	None	G5T5	S2	2B.1 SB_RSABG-
Lupinus alb	Mountain s	Dicots	PDFAB2B1J	None	None	G4T2	S2	1B.3 BLM_S-Sen
Kinosterno	Sonoran m	Reptiles	ARAAE010	None	None	G4	SH	CDFW_SSC
Kinosterno	Sonoran m	Reptiles	ARAAE010	None	None	G4	SH	CDFW_SSC
Kinosterno	Sonoran m	Reptiles	ARAAE010	None	None	G4	SH	CDFW_SSC
Chylismia a	sand eveni	Dicots	PDONA030	None	None	G4?	S2S3	2B.2
Acmispon	pygmy lotu	Dicots	PDFAB2A0	None	None	G3	S3	1B.3 SB_USDA-L
Kinosterno	Sonoran m	Reptiles	ARAAE010	None	None	G4	SH	CDFW_SSC
Kinosterno	Sonoran m	Reptiles	ARAAE010	None	None	G4	SH	CDFW_SSC
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2 BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08	None	None	G3G4	S2	BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08	None	None	G3G4	S2	BLM_S-Sen
Corynorhin	Townsend'	Mammals	AMACC08	None	None	G3G4	S2	BLM_S-Sen
Palafoxia a	giant spani	Dicots	PDAST6T01	None	None	G5T3?	S2	1B.3 BLM_S-Sen
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Calliandra	pink fairy-c	Dicots	PDFAB0N0	None	None	G5	S3	2B.3 SB_RSABG-
Castela em	Emory's cr	Dicots	PDSIM030	None	None	G3G4	S2S3	2B.2 SB_RSABG-
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2 SB_RSABG-
Euphorbia	Abrams' sp	Dicots	PDEUP0D0	None	None	G4	S2	2B.2 SB_RSABG-
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2
Ditaxis clar	glandular d	Dicots	PDEUP080	None	None	G3G4	S2	2B.2
Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3
Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3
Lycium par	Parish's de	Dicots	PDSOL0G0	None	None	G4	S1	2B.3
Malperia te	brown turb	Dicots	PDAST6701	None	None	G4?	S2?	2B.3 SB_RSABG-
Panicum hi	roughstalk	Monocots	PMPOA4K1	None	None	G5T5	S2	2B.1 SB_RSABG-
Bursera mi	little-leaf e	Dicots	PDBUR010	None	None	G4	S2	2B.3 SB_RSABG-
Pholisma s	sand food	Dicots	PDLNN020	None	None	G2	S2	1B.2 BLM_S-Sen
Coccyzus a	western ye	Birds	ABNRB020	Threatenec	Endangere	G5T2T3	S1	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen

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Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen

Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Bombus cr	Crotch bun	Insects	IIHYM2448	None	Candidate	G3G4	S1S2	
Bombus oc	western bu	Insects	IIHYM2425	None	Candidate	G2G3	S1	USFS_S-Ser
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3	BLM_S-Sen
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Neotoma a	Colorado V	Mammals	AMAFF080	None	None	G5T3T4	S1S2	
Perognath	Palm Sprin	Mammals	AMAFD01(	None	None	G5T2	S2	BLM_S-Sen
Perognath	Palm Sprin	Mammals	AMAFD01(	None	None	G5T2	S2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2	BLM_S-Sen
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Cyprinodor	desert pup	Fish	AFCNB020(	Endangere	Endangere	G1	S1	AFS_EN-En
Coleonyx s	barefoot g	Reptiles	ARACD010	None	Threatene	G4	S1	BLM_S-Sen

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Toxostoma	Le Conte's	Birds	ABPBK061(	None	None	G4	S3		BLM_S-Sen
Coleonyx s	barefoot g	Reptiles	ARACD010	None	Threatenec	G4	S1		BLM_S-Sen
Arizona ele	California g	Reptiles	ARADB010	None	None	G5T2	S2		CDFW_SSC
Arizona ele	California g	Reptiles	ARADB010	None	None	G5T2	S2		CDFW_SSC
Laterallus j	California l	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Heloderma	banded Gil	Reptiles	ARACE010	None	None	G4T4	S1		BLM_S-Sen
Laterallus j	California l	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Heloderma	banded Gil	Reptiles	ARACE010	None	None	G4T4	S1		BLM_S-Sen
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Petalonyx l	narrow-lea	Dicots	PDLOA040	None	None	G4	S3?	2B.3	
Laterallus j	California l	Birds	ABNME03(	None	Threatenec	G3G4T1	S1		BLM_S-Sen
Athene cur	burrowing	Birds	ABNSB100	None	None	G4	S3		BLM_S-Sen
Selaginella	desert spik	Ferns	PPSEL010G	None	None	G4	S2S3	2B.2	
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Mentzelia l	hairy stickl	Dicots	PDLOA030I	None	None	G4?	S3	2B.3	SB_RSABG-
Galium ang	Borrego be	Dicots	PDRUB0N0	None	Rare	G5T3?	S3?	1B.3	BLM_S-Sen
Eriastrum h	Harwood's	Dicots	PDPLM030	None	None	G2	S2	1B.2	BLM_S-Sen
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Cylindropu	Munz's chc	Dicots	PDCAC0D0	None	None	G3	S1	1B.3	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Tidestromi	Eliasson's v	Dicots	PDAMA0J0	None	None	G5	S2	2B.2	
Gopherus a	desert tort	Reptiles	ARAAF010	Threatenec	Threatenec	G3	S2S3		IUCN_VU-V
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Taxidea tax	American b	Mammals	AMAJF040	None	None	G5	S3		CDFW_SSC
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Uma notat	Colorado D	Reptiles	ARACF150	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Croton wig	Wiggins' cr	Dicots	PDEUP0H1	None	Rare	G2G3	S2	2B.2	BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Carnegiea g	saguaro	Dicots	PDCAC120	None	None	G5	S1	2B.2	SB_RSABG-
Phrynosom	flat-tailed h	Reptiles	ARACF120	None	None	G3	S2		BLM_S-Sen
Agrilus har	Harenus je	Insects	IICOLV006(	None	None	G1G2	S1S2		

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Cyclocepha	Wandae du	Insects	IICOL3302(	None	None	G1G2	S1S2
Apiocera w	Glamis san	Insects	IIDIP54020	None	None	G1G2	S1S2
Efferia mac	Glamis rob	Insects	IIDIP07040	None	None	G1G2	S1S2
Euparagia ı	Algodones	Insects	IIHYMBC01	None	None	G1G2	S1S2
Microbemł	Algodones	Insects	IIHYM9001	None	None	G1G2	S1S2
Perdita alg	Algodones	Insects	IIHYM0113	None	None	G1G2	S1S2

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OccNumbe	EOndx	Mapndx	ElmDate	SiteDate	Sensitive	OccRank	Presence	Accuracy	AccuracyO
1	387	34623	19350420	19350420	N	U-Unknow	Presumed	Circular fea	90
12	3601	33091	19980105	19980105	N	B-Good	Presumed	Specific bo	10
15	3602	33094	19920504	19920504	N	B-Good	Presumed	Circular fea	50
13	3603	33092	199901XX	199901XX	N	A-Excellent	Presumed	Specific bo	10
14	3604	33093	19931214	19931214	N	B-Good	Presumed	Circular fea	50
16	3605	33095	19960703	19960703	N	B-Good	Presumed	Circular fea	50
17	3606	33096	20060115	20060115	N	B-Good	Presumed	Specific bo	10
18	3607	33097	19921012	19921012	N	B-Good	Presumed	Circular fea	50
33	4091	26363	19950112	19950112	N	B-Good	Presumed	Specific bo	10
32	4092	26362	19950112	19950112	N	B-Good	Presumed	Specific bo	10
3	4093	26366	19930703	19930703	N	U-Unknow	Presumed	Circular fea	90
5	4094	26365	19931211	19931211	N	U-Unknow	Presumed	Circular fea	70
4	4095	26334	19930628	19930628	N	U-Unknow	Presumed	Circular fea	60
11	4123	30609	19960630	19960630	N	A-Excellent	Presumed	Specific bo	10
40	4888	30148	19910516	19910516	N	U-Unknow	Presumed	Non-specif	30
41	4889	30147	19910510	19910510	N	U-Unknow	Presumed	Non-specif	30
48	4970	26220	19910604	19910604	N	U-Unknow	Presumed	Non-specif	30
43	4971	26225	20050811	20061016	N	D-Poor	Presumed	Non-specif	30
44	4972	26224	19910604	20061016	N	U-Unknow	Presumed	Non-specif	30
45	4973	26223	19910604	19910604	N	U-Unknow	Presumed	Specific bo	10
47	4974	26221	19910604	19910604	N	U-Unknow	Presumed	Specific bo	10
46	4975	26222	19910604	20061016	N	U-Unknow	Presumed	Non-specif	30
1	5532	35287	19780315	19780315	N	U-Unknow	Presumed	Circular fea	90
65	5664	6674	19450602	19450602	N	U-Unknow	Presumed	Circular fea	90
15	5665	6674	19450603	19450603	N	U-Unknow	Presumed	Circular fea	90
5	5666	6674	19170112	19170112	N	U-Unknow	Presumed	Circular fea	90
7	5667	6674	19491212	19491212	N	U-Unknow	Presumed	Circular fea	90
1	5668	6674	19170117	19170117	N	U-Unknow	Presumed	Circular fea	90
5	5966	75962	199408XX	199408XX	N	D-Poor	Presumed	Circular fea	50
3	5967	6266	199408XX	199408XX	N	A-Excellent	Presumed	Specific bo	20
1	6460	24620	19920412	19920412	N	A-Excellent	Presumed	Specific bo	20
1	6539	71505	20180418	20180418	N	B-Good	Presumed	Specific bo	20
11	6540	76078	2000XXXX	2000XXXX	N	U-Unknow	Presumed	Specific bo	20
1	6541	76052	20180418	20180418	N	B-Good	Presumed	Specific bo	20
2	6543	76077	20190222	20190222	N	B-Good	Presumed	Specific bo	20
1	6544	77872	20130420	20130420	N	U-Unknow	Presumed	Specific bo	20
17	6783	24779	19891105	20110308	N	X-None	Possibly Ex	Specific bo	10
66	6829	26201	19910607	19910607	N	U-Unknow	Presumed	Non-specif	30
65	6830	26202	19910607	19910607	N	U-Unknow	Presumed	Non-specif	30
67	8060	26200	19910607	20061013	N	U-Unknow	Presumed	Specific bo	10
68	8061	26199	20081021	20081021	N	D-Poor	Presumed	Specific bo	10
107	12220	17289	19901211	19901211	N	C-Fair	Presumed	Circular fea	50
3	12381	6387	20170301	20170301	N	U-Unknow	Presumed	Non-specif	30
21	12383	6117	19850702	19850702	N	A-Excellent	Presumed	Specific bo	20
14	12440	6715	20090530	20090530	N	B-Good	Presumed	Specific bo	20
1	12599	6156	1987XXXX	2004XXXX	N	U-Unknow	Presumed	Circular fea	50

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74	12720	26195	20050805	20061012	N	D-Poor	Presumed	Non-specif	30
5	12782	6480	1981XXXX	1981XXXX	N	U-Unknow	Presumed	Non-specif	30
13	12783	6000	1983XXXX	1983XXXX	N	U-Unknow	Presumed	Non-specif	30
44	13010	16018	19770726	20100629	N	C-Fair	Presumed	Non-specif	30
2	13038	6364	19750513	198904XX	N	U-Unknow	Presumed	Circular fea	50
17	13041	6440	20080422	20080508	N	U-Unknow	Presumed	Non-specif	30
9	13042	6599	20100527	20100527	N	U-Unknow	Presumed	Circular fea	90
166	13073	6475	19770529	19770529	Y	U-Unknow	Presumed	Circular fea	50
9	13138	6717	197303XX	1981XXXX	N	U-Unknow	Presumed	Circular fea	90
86	13176	76169	20050717	20060619	N	D-Poor	Presumed	Non-specif	30
23	13341	6637	19870504	19870504	N	B-Good	Presumed	Specific bo	20
75	13476	26196	20060713	20081018	N	D-Poor	Presumed	Non-specif	30
7	13564	6606	19830815	19870112	N	X-None	Extirpated	Circular fea	50
2	13787	17008	20090318	20090318	N	B-Good	Presumed	Non-specif	30
1	13788	6058	20131018	20131018	N	D-Poor	Presumed	Specific bo	20
32	14018	6562	20020609	20020609	N	A-Excellent	Presumed	Circular fea	40
33	14019	23027	20130428	20130428	N	U-Unknow	Presumed	Circular fea	60
34	14020	6544	19790427	19800620	N	U-Unknow	Presumed	Non-specif	30
2	14141	6054	19220401	19220401	N	U-Unknow	Presumed	Circular fea	90
1	14143	28131	19700412	19700412	N	U-Unknow	Presumed	Circular fea	90
4	14144	6628	19850415	20101226	N	X-None	Possibly Ex	Specific bo	20
2	14242	85577	20110611	20110611	N	U-Unknow	Presumed	Non-specif	30
1	14243	28322	19830715	19830715	N	U-Unknow	Presumed	Specific bo	20
36	14248	6054	19090327	19090327	N	U-Unknow	Presumed	Circular fea	90
30	14283	6169	19850701	19850701	N	U-Unknow	Presumed	Non-specif	30
28	14284	6165	19850701	19850701	N	U-Unknow	Presumed	Specific bo	20
22	14285	6129	19850702	19850702	N	U-Unknow	Presumed	Specific bo	20
27	14286	6172	19850701	19850701	N	U-Unknow	Presumed	Non-specif	30
16	14289	6036	1983XXXX	1983XXXX	N	U-Unknow	Presumed	Specific bo	20
46	14487	6497	1986XXXX	1986XXXX	N	U-Unknow	Presumed	Specific bo	20
38	14492	6591	1986XXXX	1986XXXX	N	U-Unknow	Presumed	Specific bo	20
37	14493	6351	1986XXXX	1986XXXX	N	U-Unknow	Presumed	Specific bo	20
5	14520	6007	1986XXXX	1986XXXX	N	U-Unknow	Presumed	Specific bo	20
1	14522	5874	2016XXXX	2016XXXX	N	B-Good	Presumed	Specific bo	20
8	14634	6637	19830715	19860602	N	U-Unknow	Presumed	Specific bo	20
39	14635	6637	19870405	19870405	N	C-Fair	Presumed	Specific bo	20
6	14640	6682	19860623	198608XX	N	U-Unknow	Presumed	Specific bo	20
52	14667	6682	19860603	198608XX	N	U-Unknow	Presumed	Specific bo	20
1	14684	6637	19770727	19860622	N	U-Unknow	Presumed	Specific bo	20
17	14685	6682	19860603	198608XX	N	U-Unknow	Presumed	Specific bo	20
2	14691	6637	19860622	19860622	N	U-Unknow	Presumed	Specific bo	20
23	14698	53056	20030712	20030712	N	U-Unknow	Presumed	Non-specif	30
3	14703	6637	2009XXXX	2009XXXX	N	A-Excellent	Presumed	Specific bo	20
127	14707	6682	19860623	198608XX	N	U-Unknow	Presumed	Specific bo	20
51	14712	85618	20120720	20130707	N	C-Fair	Presumed	Specific bo	20
33	14734	6268	20070315	20070522	N	B-Good	Presumed	Non-specif	30
31	14736	77093	20090603	20090603	N	C-Fair	Presumed	Non-specif	30

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20	14738	6638	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Non-specif	30
16	14739	6716	20090602	20090602	N	C-Fair	Presumed	Non-specif	30
15	14740	6626	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Non-specif	30
7	14741	28321	20080527	20080527	N	U-Unknow	Presumed	Non-specif	30
10	14742	6578	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Specific bo	20
59	14777	6137	20000710	20000710	N	U-Unknow	Presumed	Non-specif	30
61	14778	6122	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
28	14779	6438	20140520	20140520	N	U-Unknow	Presumed	Non-specif	30
1	14781	6154	20130620	20130620	N	B-Good	Presumed	Non-specif	30
4	14803	6371	1987XXXX	1987XXXX	N	B-Good	Presumed	Specific bo	20
2	14829	6065	19940518	19940518	N	B-Good	Presumed	Specific bo	20
4	14841	6586	1977XXXX	1977XXXX	N	U-Unknow	Presumed	Specific bo	20
2	15221	5966	1983XXXX	1983XXXX	N	U-Unknow	Presumed	Specific bo	20
22	15223	6010	1983XXXX	1983XXXX	N	U-Unknow	Presumed	Specific bo	20
6	15569	5917	19851228	19851228	N	U-Unknow	Presumed	Specific bo	20
17	15576	6682	19870111	19870111	N	C-Fair	Presumed	Specific bo	20
13	15579	6697	198501XX	198501XX	N	U-Unknow	Presumed	Specific bo	20
6	15583	6710	19830714	19830714	N	D-Poor	Presumed	Specific bo	20
5	15585	6601	1983XXXX	19870110	N	X-None	Extirpated	Specific bo	20
2	15586	6625	19870111	19870111	N	C-Fair	Presumed	Specific bo	20
9	16087	6061	19800412	19800412	N	U-Unknow	Presumed	Specific bo	20
50	16471	6595	19410303	19410303	N	U-Unknow	Presumed	Non-specif	30
53	16472	46724	19310315	19310315	N	U-Unknow	Presumed	Non-specif	30
54	16476	6410	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Non-specif	30
11	16506	26102	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
24	16541	5994	19400127	19400127	N	U-Unknow	Presumed	Non-specif	30
15	16543	6001	1978XXXX	1978XXXX	N	U-Unknow	Presumed	Circular fea	50
16	16546	5978	1978XXXX	1978XXXX	N	U-Unknow	Presumed	Circular fea	40
1	17711	28142	20080320	20080320	N	U-Unknow	Presumed	Non-specif	30
7	17831	28137	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	50
15	18572	6125	19560603	19560603	N	U-Unknow	Presumed	Circular fea	90
1	18573	6428	19820425	19820425	N	U-Unknow	Presumed	Specific bo	20
16	18574	6086	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Non-specif	30
11	18586	5991	19860324	19860324	N	C-Fair	Presumed	Circular fea	50
21	18838	66500	19980613	19980613	N	B-Good	Presumed	Circular fea	70
44	19068	6006	19850422	19850422	N	U-Unknow	Presumed	Circular fea	40
43	19069	5980	20010316	20010316	N	U-Unknow	Presumed	Circular fea	40
20	19226	30609	19960630	19960630	N	A-Excellent	Presumed	Specific bo	10
70	20585	26198	20080413	20090417	N	D-Poor	Presumed	Non-specif	30
71	20586	26192	20060713	20060713	N	U-Unknow	Presumed	Non-specif	30
73	20588	26194	20080712	20090416	N	D-Poor	Presumed	Non-specif	30
72	20590	26193	19910614	19910614	N	U-Unknow	Presumed	Non-specif	30
69	20593	26197	19910515	19910515	N	U-Unknow	Presumed	Non-specif	30
39	20595	30145	20090426	20090426	N	D-Poor	Presumed	Circular fea	50
49	20596	30171	20080112	20081017	N	D-Poor	Presumed	Specific bo	20
1	20674	35229	19220408	19220408	N	U-Unknow	Presumed	Circular fea	90
7	20837	6404	19890927	19890927	N	U-Unknow	Presumed	Circular fea	50

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8	20838	6430	198XXXXX	198XXXXX	N	U-Unknow	Presumed	Non-specif	30
3	20839	6377	198XXXXX	198XXXXX	N	U-Unknow	Presumed	Circular fea	60
5	20840	82529	198XXXXX	198XXXXX	N	U-Unknow	Presumed	Non-specif	30
1	20841	6469	198003XX	198003XX	N	U-Unknow	Presumed	Non-specif	30
5	21458	78123	19370219	19370219	N	U-Unknow	Presumed	Circular fea	90
6	21459	78124	1980XXXX	1980XXXX	N	U-Unknow	Presumed	Non-specif	30
3	21461	20105	193XXXXX	193XXXXX	N	U-Unknow	Presumed	Non-specif	30
2	21464	20105	193XXXXX	193XXXXX	N	U-Unknow	Presumed	Non-specif	30
34	21534	6133	19850701	19850701	N	U-Unknow	Presumed	Circular fea	50
31	21537	6167	19850701	19850701	N	U-Unknow	Presumed	Specific bo	20
29	21538	6188	19850701	19850701	N	U-Unknow	Presumed	Circular fea	50
26	21539	6077	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	50
25	21540	6134	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	50
24	21541	6115	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	50
23	21542	6092	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	40
19	21544	6104	19850702	19850702	N	U-Unknow	Presumed	Specific bo	20
15	21547	6014	1983XXXX	1983XXXX	N	U-Unknow	Presumed	Specific bo	20
9	21550	6082	19570324	19570324	N	U-Unknow	Presumed	Non-specif	30
5	21553	5989	19650127	19650127	N	U-Unknow	Presumed	Non-specif	30
7	21554	6156	19660305	19660305	N	U-Unknow	Presumed	Circular fea	50
4	21555	6075	19670324	19670324	N	U-Unknow	Presumed	Circular fea	50
2	21556	6119	19631129	19631129	N	U-Unknow	Presumed	Circular fea	50
1	21558	6097	19670324	19670324	N	U-Unknow	Presumed	Circular fea	40
1	21970	22124	199206XX	199206XX	N	C-Fair	Presumed	Circular fea	50
2	22120	22125	199408XX	199408XX	N	C-Fair	Presumed	Circular fea	50
39	22417	6564	19470726	19470726	N	U-Unknow	Presumed	Circular fea	60
1	22627	27990	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
27	22685	6502	197904XX	197904XX	N	U-Unknow	Presumed	Circular fea	50
26	22686	6496	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
25	22687	6490	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
24	22688	6488	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
23	22689	6476	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
22	22690	6494	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
21	22691	6427	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
20	22692	6495	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
19	22693	6486	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
18	22694	6484	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
17	22695	6479	19790414	19790414	N	U-Unknow	Presumed	Circular fea	50
16	22696	17492	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
15	22697	6540	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
14	22698	6397	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
13	22699	6530	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
12	22700	6510	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
11	22701	6520	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
10	22702	6504	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
9	22703	6511	19790420	19790420	N	U-Unknow	Presumed	Circular fea	50
8	22704	6402	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50

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7	22705	6431	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
6	22706	6409	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
5	22707	6478	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
4	22708	6489	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
3	22709	6483	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
2	22710	6491	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
1	22711	6481	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
15	22751	6409	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
16	22752	6511	19790420	19790420	N	U-Unknow	Presumed	Circular fea	50
14	22753	6431	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
13	22754	6434	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
12	22755	6427	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
11	22756	6397	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
10	22757	6473	19790417	19790417	N	U-Unknow	Presumed	Circular fea	50
9	22758	6452	19790415	19790415	N	U-Unknow	Presumed	Circular fea	50
8	22759	6489	19790610	19790610	N	U-Unknow	Presumed	Circular fea	50
7	22760	6491	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
6	22761	6510	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
5	22762	6540	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
4	22763	6530	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
3	22764	6520	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
2	22765	6502	197904XX	197904XX	N	U-Unknow	Presumed	Circular fea	50
1	22766	6483	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
17	22767	6439	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
16	22768	6409	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
15	22769	6431	19790419	19790419	N	U-Unknow	Presumed	Circular fea	50
14	22770	6434	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
13	22771	6427	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
12	22772	6397	19790418	19790418	N	U-Unknow	Presumed	Circular fea	50
11	22773	6460	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
10	22774	6513	19790416	19790416	N	U-Unknow	Presumed	Circular fea	90
9	22775	6473	19790417	19790417	N	U-Unknow	Presumed	Circular fea	50
8	22776	6452	19790415	19790415	N	U-Unknow	Presumed	Circular fea	50
7	22777	6489	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
6	22778	6491	19790410	19790410	N	U-Unknow	Presumed	Circular fea	50
5	22779	6510	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
4	22780	6530	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
3	22781	6520	19790412	19790412	N	U-Unknow	Presumed	Circular fea	50
2	22782	6502	197904XX	197904XX	N	U-Unknow	Presumed	Circular fea	50
1	22783	6483	19790413	19790413	N	U-Unknow	Presumed	Circular fea	50
42	22827	30146	19910614	19910614	N	U-Unknow	Presumed	Non-specif	30
23	23791	6696	19100421	19100421	N	U-Unknow	Presumed	Circular fea	90
6	23803	6596	19100512	19100512	N	U-Unknow	Presumed	Circular fea	90
22	23804	6231	19090508	19090508	N	U-Unknow	Presumed	Circular fea	90
7	23807	6072	19800207	19800207	N	U-Unknow	Presumed	Circular fea	50
1	23809	6691	19401227	19401227	N	U-Unknow	Presumed	Non-specif	30
9	23810	5970	19581106	19581106	N	U-Unknow	Presumed	Circular fea	50

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3	23815	59733	19100503	19100503	N	U-Unknow	Presumed	Non-specif	30
6	24258	6424	19890926	19890926	N	U-Unknow	Presumed	Non-specif	30
23	24321	6571	191911XX	191911XX	N	U-Unknow	Presumed	Circular fea	90
5	24335	6622	19430301	19430301	N	U-Unknow	Presumed	Circular fea	50
1	24337	6676	19210506	19210506	N	U-Unknow	Presumed	Non-specif	30
2	24338	6712	19180514	1991XXXX	N	U-Unknow	Presumed	Circular fea	50
20	24385	6613	19860621	19860621	N	U-Unknow	Presumed	Circular fea	50
7	24390	6701	19160519	19160519	N	U-Unknow	Presumed	Circular fea	90
47	24395	6541	19770607	19770607	N	U-Unknow	Presumed	Circular fea	90
44	24398	6555	19770607	19770607	N	U-Unknow	Presumed	Circular fea	50
42	24401	16014	19870421	19870421	N	C-Fair	Presumed	Circular fea	90
38	24403	6587	19860621	19860621	N	U-Unknow	Presumed	Non-specif	30
40	24404	16017	19860623	19860623	N	U-Unknow	Presumed	Circular fea	90
18	24406	6299	19101225	19101225	N	U-Unknow	Presumed	Circular fea	90
21	24410	6273	19691004	19691004	N	U-Unknow	Presumed	Circular fea	90
19	24411	6701	19160401	19160401	N	U-Unknow	Presumed	Circular fea	90
8	24413	6191	19521128	19521128	N	U-Unknow	Presumed	Circular fea	90
9	24417	6647	19711209	19711209	N	U-Unknow	Presumed	Circular fea	90
10	24421	28885	19250101	19250101	N	U-Unknow	Presumed	Circular fea	90
7	24422	6262	19481023	19481023	N	U-Unknow	Presumed	Circular fea	90
88	24493	6541	19770607	19770607	N	U-Unknow	Presumed	Circular fea	90
85	24498	6555	19770607	19770607	N	U-Unknow	Presumed	Circular fea	50
81	24501	6470	19750405	19750405	N	U-Unknow	Presumed	Circular fea	90
75	24504	6095	19330514	19330514	N	U-Unknow	Presumed	Circular fea	90
33	24524	6163	19520914	19520914	N	U-Unknow	Presumed	Circular fea	90
37	24525	6076	19090331	19090331	N	U-Unknow	Presumed	Circular fea	90
34	24531	6063	19331127	19331127	N	U-Unknow	Presumed	Circular fea	90
35	24533	6550	18960316	18960316	N	U-Unknow	Presumed	Circular fea	90
32	24534	6074	19331208	19331208	N	U-Unknow	Presumed	Circular fea	90
22	24546	5999	19340122	19340122	N	U-Unknow	Presumed	Circular fea	90
9	24667	6256	19570209	19570209	N	U-Unknow	Presumed	Circular fea	50
3	24802	6701	19160510	19160510	N	U-Unknow	Presumed	Circular fea	90
68	24859	6607	19870505	19870505	N	B-Good	Presumed	Circular fea	50
61	24865	6600	19870505	19870505	N	B-Good	Presumed	Circular fea	90
60	24866	6624	19870503	19870503	N	B-Good	Presumed	Circular fea	50
59	24868	6593	19870505	19870505	N	B-Good	Presumed	Circular fea	90
51	24873	16017	19860623	19860623	N	U-Unknow	Presumed	Circular fea	90
50	24875	6587	19860621	19860621	N	U-Unknow	Presumed	Non-specif	30
49	24877	6592	19860604	198608XX	N	U-Unknow	Presumed	Circular fea	50
19	24887	6177	19600508	19600508	N	U-Unknow	Presumed	Circular fea	60
18	24891	6258	19610507	19610507	N	U-Unknow	Presumed	Circular fea	90
14	24898	6701	19300429	19300429	N	U-Unknow	Presumed	Circular fea	90
32	24911	6328	19210508	19210508	N	U-Unknow	Presumed	Circular fea	90
28	24915	6282	19521004	19521004	N	U-Unknow	Presumed	Circular fea	90
12	24922	6583	19100402	19100402	N	U-Unknow	Presumed	Circular fea	90
3	24924	6709	20110706	20110706	N	U-Unknow	Presumed	Circular fea	50
6	24925	59733	19100430	19100430	N	U-Unknow	Presumed	Non-specif	30

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5	24928	6701	19100427	19100427	N	U-Unknow	Presumed	Circular fea	90
31	25005	6541	19770607	19770607	N	U-Unknow	Presumed	Circular fea	90
28	25007	6555	19770607	19770607	N	U-Unknow	Presumed	Circular fea	50
7	25014	6273	19681014	19681014	N	U-Unknow	Presumed	Circular fea	90
8	25015	6301	19220402	19220402	N	U-Unknow	Presumed	Circular fea	90
4	25018	6568	19711206	19711206	N	U-Unknow	Presumed	Circular fea	90
12	25021	6701	19160407	19160407	N	U-Unknow	Presumed	Circular fea	90
6	25022	6262	19480314	19480314	N	U-Unknow	Presumed	Circular fea	90
3	25024	6571	19360322	19360322	N	U-Unknow	Presumed	Circular fea	90
20	25260	16017	19860623	19860623	N	U-Unknow	Presumed	Circular fea	90
19	25261	6587	19860621	19860621	N	U-Unknow	Presumed	Non-specif	30
16	25262	6592	19830715	198308XX	N	U-Unknow	Presumed	Circular fea	50
28	25269	6717	19640605	19640605	N	U-Unknow	Presumed	Circular fea	90
1	25278	6701	19160425	19160425	N	U-Unknow	Presumed	Circular fea	90
13	25279	6583	19100402	19100402	N	U-Unknow	Presumed	Circular fea	90
12	25285	59733	19100502	19100502	N	U-Unknow	Presumed	Non-specif	30
3	25376	6701	19301231	19301231	N	U-Unknow	Presumed	Circular fea	90
26	25401	6590	19870410	19870410	N	C-Fair	Presumed	Circular fea	50
24	25403	6644	19870418	19870418	N	B-Good	Presumed	Circular fea	50
22	25404	85627	20110621	20110621	N	U-Unknow	Presumed	Non-specif	30
20	25405	6592	19860604	198608XX	N	U-Unknow	Presumed	Circular fea	50
21	25406	6587	19860621	19860621	N	C-Fair	Presumed	Non-specif	30
43	25467	6189	20060704	20060704	N	U-Unknow	Presumed	Specific bo	20
44	25468	6267	19830331	19830331	N	U-Unknow	Presumed	Circular fea	90
12	25492	16014	19870409	200905XX	N	C-Fair	Presumed	Circular fea	90
2	25539	6262	19560222	19560222	N	U-Unknow	Presumed	Circular fea	90
155	25556	6587	19860621	19860621	N	U-Unknow	Presumed	Non-specif	30
126	25576	6606	19830815	19830815	N	U-Unknow	Presumed	Circular fea	50
125	25577	77723	20090804	20100719	N	D-Poor	Presumed	Non-specif	30
103	25579	6602	19770728	20100622	N	U-Unknow	Presumed	Circular fea	80
50	25600	6616	19770728	19770728	N	U-Unknow	Presumed	Circular fea	50
49	25601	6608	19770804	19770804	N	U-Unknow	Presumed	Non-specif	30
47	25602	6620	19770805	20010801	N	U-Unknow	Presumed	Non-specif	30
48	25603	6604	19770805	19770805	N	U-Unknow	Presumed	Circular fea	50
46	25605	6700	19860623	20010801	N	U-Unknow	Presumed	Circular fea	60
43	25607	6618	XXXXXXXX	19770726	N	U-Unknow	Presumed	Circular fea	50
1	25776	6198	19750712	19750712	N	U-Unknow	Presumed	Circular fea	90
2	25778	6266	19730815	19730815	N	U-Unknow	Presumed	Specific bo	20
72	25791	6627	19720422	19720422	N	U-Unknow	Presumed	Circular fea	50
17	25811	6352	19750514	198904XX	N	U-Unknow	Presumed	Circular fea	50
15	25815	6353	19750514	198904XX	N	U-Unknow	Presumed	Non-specif	30
13	25818	6398	19750512	198904XX	N	U-Unknow	Presumed	Circular fea	60
7	25819	6379	19750513	198904XX	N	U-Unknow	Presumed	Circular fea	50
5	25822	6372	19750513	198904XX	N	U-Unknow	Presumed	Circular fea	50
3	25824	6370	198404XX	198404XX	N	U-Unknow	Presumed	Circular fea	60
1	25825	6390	19750515	198904XX	N	U-Unknow	Presumed	Non-specif	30
37	25892	6360	19870518	19870518	N	U-Unknow	Presumed	Circular fea	50

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32	25895	6249	1978XXXX	1978XXXX	N	U-Unknow	Presumed	Circular fea	40
30	25897	6308	2000XXXX	2000XXXX	N	U-Unknow	Presumed	Non-specif	30
21	25902	83076	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Non-specif	30
18	25904	6417	19820520	19820520	N	U-Unknow	Presumed	Circular fea	90
19	25905	6199	2000XXXX	2000XXXX	N	U-Unknow	Presumed	Circular fea	90
11	25906	6579	1985XXXX	1985XXXX	N	U-Unknow	Presumed	Non-specif	30
5	25944	6597	19870410	19870410	N	U-Unknow	Presumed	Circular fea	50
9	25972	6597	19870410	19870410	N	U-Unknow	Presumed	Circular fea	50
6	25974	6679	19870405	19870405	N	U-Unknow	Presumed	Circular fea	50
5	25976	6675	19870405	19870405	N	U-Unknow	Presumed	Circular fea	50
411	26015	5988	19760605	19760605	Y	U-Unknow	Presumed	Circular fea	60
408	26018	5983	19760622	19760622	Y	U-Unknow	Presumed	Circular fea	90
167	26242	83856	197403XX	197403XX	Y	U-Unknow	Presumed	Circular fea	60
164	26245	6614	19770531	19770531	Y	U-Unknow	Presumed	Circular fea	50
44	26445	72661	1980XXXX	1980XXXX	Y	U-Unknow	Presumed	Circular fea	70
85	26532	76190	20120703	20120703	N	B-Good	Presumed	Non-specif	30
8	27350	6701	19100429	19100429	N	U-Unknow	Presumed	Circular fea	90
6	27358	6670	19100503	19100503	N	U-Unknow	Presumed	Circular fea	90
63	27915	6121	20000710	20000710	N	U-Unknow	Presumed	Non-specif	30
62	27917	6090	19790517	19840626	N	U-Unknow	Presumed	Non-specif	30
57	27918	6471	19690506	19690506	N	U-Unknow	Presumed	Circular fea	90
52	27919	5995	20080507	20080507	N	B-Good	Presumed	Specific bo	10
60	27920	6450	19790703	19790703	N	U-Unknow	Presumed	Circular fea	90
58	27921	6296	19710514	19710514	N	X-None	Possibly Ex	Circular fea	50
48	27924	6374	19280722	19280722	N	X-None	Possibly Ex	Circular fea	90
56	27925	6072	19380420	19380420	N	U-Unknow	Presumed	Circular fea	50
41	27926	6064	20120326	20120326	N	U-Unknow	Presumed	Non-specif	30
51	27927	6241	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
43	27928	6251	19331130	19331130	N	X-None	Possibly Ex	Circular fea	90
31	27929	6507	19790503	19790503	N	U-Unknow	Presumed	Circular fea	90
49	27930	6432	20070524	20070524	N	U-Unknow	Presumed	Non-specif	30
37	27932	6045	197806XX	197806XX	N	U-Unknow	Presumed	Specific bo	20
36	27933	6405	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
23	27934	6139	19950828	19950828	N	C-Fair	Presumed	Circular fea	60
21	27936	6080	20141001	20141001	N	B-Good	Presumed	Specific bo	20
19	27937	6085	19790522	19790522	N	U-Unknow	Presumed	Circular fea	60
22	27941	6046	20060802	20060802	N	B-Good	Presumed	Specific bo	20
20	27942	6048	20020723	20020723	N	B-Good	Presumed	Specific bo	10
27	27945	6493	19790502	19790502	N	U-Unknow	Presumed	Circular fea	90
5	27948	6068	19790519	19790519	N	U-Unknow	Presumed	Non-specif	30
8	27951	6057	19790508	19790508	N	U-Unknow	Presumed	Non-specif	30
9	27954	6022	19790607	19790607	N	U-Unknow	Presumed	Circular fea	90
6	28151	5996	20010605	20010605	Y	U-Unknow	Presumed	Circular fea	60
1	28152	6017	19760106	19760106	Y	U-Unknow	Presumed	Circular fea	70
3	28156	72537	19761009	19761009	Y	U-Unknow	Presumed	Circular fea	60
5	28157	6030	19870605	19870605	Y	U-Unknow	Presumed	Circular fea	90
2	28160	6028	19760102	19760102	Y	U-Unknow	Presumed	Circular fea	70

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38	28484	28322	19870502	19870502	N	B-Good	Presumed	Specific bo	20
14	28485	28322	19830601	19830601	N	U-Unknow	Presumed	Specific bo	20
19	28606	6570	1975XXXX	1975XXXX	N	X-None	Extirpated	Circular fea	50
11	28612	6598	19750612	1981XXXX	N	U-Unknow	Presumed	Circular fea	50
16	28613	6317	1974XXXX	1974XXXX	N	U-Unknow	Presumed	Circular fea	90
1	28614	88450	200407XX	200407XX	N	U-Unknow	Presumed	Specific bo	20
1	28647	6705	1910XXXX	1910XXXX	N	U-Unknow	Presumed	Circular fea	50
24	28864	5987	197709XX	197709XX	N	U-Unknow	Presumed	Circular fea	90
25	28865	5992	194607XX	194607XX	N	U-Unknow	Presumed	Circular fea	90
26	28866	6008	194607XX	194607XX	N	U-Unknow	Presumed	Circular fea	90
23	28867	5997	197709XX	197709XX	N	U-Unknow	Presumed	Circular fea	50
18	28870	5973	197709XX	19801111	N	U-Unknow	Presumed	Circular fea	90
18	28889	6612	19870111	19870111	N	C-Fair	Presumed	Circular fea	50
16	28890	6618	19870112	19870112	N	C-Fair	Presumed	Circular fea	50
3	28894	6639	19870111	19870111	N	D-Poor	Presumed	Circular fea	50
4	28895	6693	1983XXXX	198511XX	N	X-None	Extirpated	Circular fea	50
1	28896	6698	198511XX	198511XX	N	U-Unknow	Presumed	Circular fea	50
1	29377	85699	19500324	19500324	N	U-Unknow	Presumed	Circular fea	90
5	29449	85546	201107XX	201107XX	N	C-Fair	Presumed	Non-specif	30
10	29450	28321	19770804	19770804	N	U-Unknow	Presumed	Non-specif	30
4	29451	28321	19770804	19770804	N	U-Unknow	Presumed	Non-specif	30
2	29452	28321	19770804	19770804	N	U-Unknow	Presumed	Non-specif	30
25	29453	28321	19770804	19770804	N	U-Unknow	Presumed	Non-specif	30
11	29454	28322	19770726	19770726	N	U-Unknow	Presumed	Specific bo	20
1	31273	36276	1990XXXX	1990XXXX	N	U-Unknow	Presumed	Non-specif	30
3	31275	36278	19580320	20130310	N	U-Unknow	Presumed	Non-specif	30
5	31279	36282	19870110	19870110	N	U-Unknow	Presumed	Non-specif	30
2	31280	36283	19790429	19790429	N	U-Unknow	Presumed	Non-specif	30
6	31281	36284	19320405	19320405	N	U-Unknow	Presumed	Circular fea	70
4	31282	36285	19640412	19640412	N	U-Unknow	Presumed	Non-specif	30
7	31283	36286	19761110	19761110	N	U-Unknow	Presumed	Circular fea	90
9	31284	36287	20120330	20120330	N	C-Fair	Presumed	Specific bo	20
10	31285	36288	19620318	19620318	N	U-Unknow	Presumed	Circular fea	90
8	31288	36291	19870414	19870414	N	U-Unknow	Presumed	Non-specif	30
1	31381	36384	20130309	20130309	N	D-Poor	Presumed	Specific bo	20
2	31382	36385	19840614	19840614	N	U-Unknow	Presumed	Circular fea	90
3	31383	84075	20110427	20110427	N	B-Good	Presumed	Specific bo	10
4	31384	36387	19840614	19840614	N	U-Unknow	Presumed	Circular fea	90
5	31385	36388	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
4	31729	6034	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
5	31730	6029	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
6	31731	36734	19780510	20110213	N	U-Unknow	Presumed	Circular fea	70
3	31732	36735	19560129	20090316	N	U-Unknow	Presumed	Circular fea	90
7	31814	A8232	20150506	20150506	N	C-Fair	Presumed	Specific bo	10
1	31899	35229	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
1	31999	81359	19620419	19620419	N	U-Unknow	Presumed	Circular fea	60
3	32001	81354	20030511	20030511	N	U-Unknow	Presumed	Non-specif	30

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1	32018	78478	19860309	19860309	N	U-Unknow	Presumed	Non-specif	30
1	32022	37025	19610304	19610304	N	U-Unknow	Presumed	Circular fea	90
2	32023	35229	19270416	19270416	N	U-Unknow	Presumed	Circular fea	90
2	32034	37037	19920308	19920308	N	U-Unknow	Presumed	Circular fea	100
3	32035	6029	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
5	32037	78478	19860309	19860309	N	U-Unknow	Presumed	Non-specif	30
7	32039	37042	19260410	19260410	N	U-Unknow	Presumed	Circular fea	100
76	32918	37911	19860619	19860619	N	U-Unknow	Presumed	Specific bo	20
20	34095	39088	19870408	19870825	N	B-Good	Presumed	Specific bo	10
22	34099	39092	19870409	19870826	N	B-Good	Presumed	Non-specif	30
23	34102	39095	19870406	19870416	N	B-Good	Presumed	Non-specif	30
65	34612	39610	20020806	20020806	N	B-Good	Presumed	Circular fea	40
73	34660	6054	19150814	19150814	N	U-Unknow	Presumed	Circular fea	90
76	34667	6059	20150331	20150331	N	U-Unknow	Presumed	Specific bo	10
77	34673	39671	19660521	19660521	N	U-Unknow	Presumed	Non-specif	30
78	34685	39683	19840517	19840517	N	U-Unknow	Presumed	Non-specif	30
79	34692	39690	19840517	19840517	N	U-Unknow	Presumed	Non-specif	30
4	35257	40255	199808XX	199808XX	N	C-Fair	Presumed	Circular fea	50
3	35258	40255	199808XX	199808XX	N	C-Fair	Presumed	Circular fea	50
6	35259	40255	199808XX	199808XX	N	C-Fair	Presumed	Circular fea	50
26	40808	26333	199901XX	199901XX	N	B-Good	Presumed	Circular fea	60
27	40809	26334	199901XX	199901XX	N	B-Good	Presumed	Circular fea	60
4	40812	30609	199307XX	19930704	N	A-Excellent	Presumed	Specific bo	10
2	41031	6571	19100403	19100403	N	U-Unknow	Presumed	Circular fea	90
2	42999	42999	19890813	19890813	N	U-Unknow	Presumed	Circular fea	40
1	43419	43419	19160513	19160513	N	X-None	Possibly Ex	Circular fea	90
2	43446	6374	19120601	19120601	N	X-None	Possibly Ex	Circular fea	90
3	43447	43447	19120618	19120618	N	X-None	Possibly Ex	Circular fea	90
5	43449	43449	19500722	19500722	N	X-None	Possibly Ex	Circular fea	90
6	43450	43450	19100411	19100411	N	U-Unknow	Presumed	Non-specif	30
1	45033	6328	19121019	19121019	N	U-Unknow	Presumed	Circular fea	90
29	45395	36087	20090310	20090310	N	U-Unknow	Presumed	Specific bo	10
1	45963	6328	19030725	19030725	N	U-Unknow	Presumed	Circular fea	90
3	45965	45965	190406XX	190406XX	N	U-Unknow	Presumed	Circular fea	70
4	45966	6299	19121016	19121016	N	X-None	Possibly Ex	Circular fea	90
6	45968	80483	19121019	19121019	N	U-Unknow	Presumed	Circular fea	90
2	46437	46437	20180422	20180422	N	B-Good	Presumed	Specific bo	20
12	46458	6550	190205XX	190205XX	N	U-Unknow	Presumed	Circular fea	90
26	46503	43447	1915XXXX	1915XXXX	N	U-Unknow	Presumed	Circular fea	90
27	46513	46513	19810427	19810427	N	U-Unknow	Presumed	Non-specif	30
46	46673	46673	19800624	19800624	N	U-Unknow	Presumed	Non-specif	30
50	46714	46714	1986XXXX	1986XXXX	N	U-Unknow	Presumed	Non-specif	30
53	46724	46724	19540411	19540411	N	U-Unknow	Presumed	Non-specif	30
5	46958	35229	191704XX	191704XX	N	U-Unknow	Presumed	Circular fea	90
81	47082	47082	20010629	20010629	N	C-Fair	Presumed	Circular fea	40
82	47471	47471	20020611	20020611	N	A-Excellent	Presumed	Circular fea	50
78	47478	47478	20090416	20090416	N	D-Poor	Presumed	Non-specif	30

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83	47785	47785	20140925	20140925	N	B-Good	Presumed	Specific bo	20
84	47786	47786	20030410	20030410	N	B-Good	Presumed	Specific bo	20
17	48050	48050	1997XXXX	1997XXXX	N	U-Unknow	Presumed	Non-specif	30
12	48233	48233	200205XX	200205XX	N	U-Unknow	Presumed	Specific bo	20
85	48639	48639	20020728	20020728	N	A-Excellent	Presumed	Non-specif	30
86	48648	48648	20020714	20020714	N	D-Poor	Presumed	Specific bo	10
476	49011	49011	20020612	20020612	N	C-Fair	Presumed	Specific bo	10
21	49015	6196	1980XXXX	1980XXXX	N	U-Unknow	Presumed	Specific bo	20
523	49108	49108	1994XXXX	1994XXXX	N	U-Unknow	Presumed	Non-specif	30
526	49116	49116	19910401	19910401	N	A-Excellent	Presumed	Circular fea	60
532	49153	49153	19910328	19910328	N	B-Good	Presumed	Circular fea	40
533	49169	49169	19910401	19910401	N	A-Excellent	Presumed	Circular fea	50
534	49174	49174	19910401	19910401	N	A-Excellent	Presumed	Circular fea	50
535	49175	49175	19910419	19910419	N	A-Excellent	Presumed	Circular fea	40
87	49915	49915	20020608	20020608	N	A-Excellent	Presumed	Non-specif	30
88	49919	49919	20020610	20020610	N	A-Excellent	Presumed	Non-specif	30
89	49935	49935	20020529	20020529	N	A-Excellent	Presumed	Circular fea	40
38	50339	50339	1987XXXX	1987XXXX	N	U-Unknow	Presumed	Circular fea	60
568	51255	51255	19090405	19090405	N	U-Unknow	Presumed	Circular fea	50
576	51268	51268	19340530	19340530	N	U-Unknow	Presumed	Circular fea	90
578	51270	51270	19340418	19340418	N	U-Unknow	Presumed	Circular fea	90
583	51277	51277	19910419	19910419	N	A-Excellent	Presumed	Circular fea	40
595	51578	51578	20030602	20030602	N	A-Excellent	Presumed	Specific bo	20
596	51584	51584	20030602	20030602	N	A-Excellent	Presumed	Specific bo	10
597	51609	51609	20070627	20070627	N	A-Excellent	Presumed	Specific bo	20
598	51610	51610	20030603	20030603	N	A-Excellent	Presumed	Specific bo	10
599	51611	51611	20070627	20070627	N	A-Excellent	Presumed	Specific bo	20
600	51612	51612	20030603	20030603	N	A-Excellent	Presumed	Specific bo	20
601	51615	51615	20030603	20030603	N	A-Excellent	Presumed	Specific bo	20
602	51617	51617	20030603	20030603	N	A-Excellent	Presumed	Specific bo	10
180	52940	52940	20021214	20021214	N	U-Unknow	Presumed	Specific bo	10
1	52941	52941	20021208	20021208	N	U-Unknow	Presumed	Specific bo	10
2	52942	52942	20031022	20031022	N	U-Unknow	Presumed	Specific bo	10
3	52943	52943	20030124	20030124	N	U-Unknow	Presumed	Specific bo	10
7	52944	52944	20030122	20030122	N	U-Unknow	Presumed	Specific bo	10
8	52945	52945	20030122	20030122	N	U-Unknow	Presumed	Specific bo	10
21	54020	54020	20010121	20010121	N	B-Good	Presumed	Non-specif	30
4	54053	54053	1987XXXX	1987XXXX	N	U-Unknow	Presumed	Circular fea	90
36	54343	54343	20110102	20110102	N	U-Unknow	Presumed	Non-specif	30
241	54437	54437	20030530	20030530	N	C-Fair	Presumed	Non-specif	30
12	55248	6436	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Non-specif	30
14	55314	6388	19251222	19251222	N	U-Unknow	Presumed	Circular fea	90
16	55943	55927	20100620	20100620	N	C-Fair	Presumed	Specific bo	20
17	55944	55928	20030506	20030506	N	C-Fair	Presumed	Circular fea	60
18	55945	55929	19950516	19950516	N	C-Fair	Presumed	Circular fea	40
5	56582	56566	19340103	19340103	N	U-Unknow	Presumed	Circular fea	90
139	56817	56801	19110405	19110405	N	U-Unknow	Presumed	Circular fea	90

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140	56820	6708	19310201	19310201	N	U-Unknow	Presumed	Circular fea	90
141	56826	6273	19370510	19370510	N	U-Unknow	Presumed	Circular fea	90
142	56827	56811	19400108	19400108	N	U-Unknow	Presumed	Circular fea	100
206	56978	56962	19141216	19141216	N	U-Unknow	Presumed	Circular fea	90
1	57060	84356	19360303	19360303	N	U-Unknow	Presumed	Non-specif	30
253	57309	57293	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	100
254	57310	57294	19150116	19150116	N	U-Unknow	Presumed	Circular fea	100
258	57376	6328	19220814	19220814	N	U-Unknow	Presumed	Circular fea	90
267	57420	57404	19690505	19690505	N	U-Unknow	Presumed	Circular fea	90
276	57472	6674	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
277	57473	57457	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
278	57475	57459	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
17	58315	58279	19700423	19700423	N	U-Unknow	Presumed	Circular fea	50
18	58319	58279	19720916	19720916	N	U-Unknow	Presumed	Circular fea	50
19	58320	58284	19720227	19720227	N	U-Unknow	Presumed	Circular fea	50
20	58321	58285	19720409	19720409	N	U-Unknow	Presumed	Circular fea	90
21	58322	58286	19730504	19730504	N	U-Unknow	Presumed	Circular fea	50
22	58323	58287	19720310	19720310	N	U-Unknow	Presumed	Circular fea	50
23	58324	58288	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
6	58341	58305	19830501	19830501	N	U-Unknow	Presumed	Specific bo	20
23	58512	36817	19740117	19740117	N	U-Unknow	Presumed	Circular fea	90
1	58539	58503	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
2	58540	58504	19870412	19870412	N	U-Unknow	Presumed	Circular fea	50
5	58545	58509	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Non-specif	30
1	58840	6299	19990907	19990907	N	U-Unknow	Presumed	Circular fea	90
2	58841	6328	19770812	19770812	N	U-Unknow	Presumed	Circular fea	90
3	58844	58808	19990825	19990825	N	U-Unknow	Presumed	Circular fea	90
4	58845	45965	19850617	19850617	N	U-Unknow	Presumed	Circular fea	70
5	58848	58812	19770425	19770425	N	U-Unknow	Presumed	Circular fea	90
6	58854	6374	19931018	19931018	N	U-Unknow	Presumed	Circular fea	90
7	58855	58819	19920723	19920723	N	U-Unknow	Presumed	Circular fea	90
8	58856	6262	19940725	19940725	N	U-Unknow	Presumed	Circular fea	90
2	59191	57293	19091115	19091115	N	U-Unknow	Presumed	Circular fea	100
2	59560	58808	19870331	19870331	N	U-Unknow	Presumed	Circular fea	90
3	59769	59733	19100504	19100504	N	U-Unknow	Presumed	Non-specif	30
12	60409	36817	20020102	20020102	N	U-Unknow	Presumed	Circular fea	90
13	60410	35229	19381218	19381218	N	U-Unknow	Presumed	Circular fea	90
36	60484	60448	19571027	19571027	N	U-Unknow	Presumed	Circular fea	90
2	61682	16014	19100412	19100412	N	U-Unknow	Presumed	Circular fea	90
2	61718	6262	19490406	19490406	N	U-Unknow	Presumed	Circular fea	90
3	61721	58279	19720304	19720304	N	U-Unknow	Presumed	Circular fea	50
10	61842	61806	20100424	20100424	N	U-Unknow	Presumed	Non-specif	30
90	61988	61952	20060817	20060817	N	B-Good	Presumed	Specific bo	20
91	61992	61956	20060821	20060821	N	B-Good	Presumed	Specific bo	20
13	62054	62018	19910410	19910410	N	U-Unknow	Presumed	Circular fea	90
14	62056	62020	20010326	20010326	N	C-Fair	Presumed	Specific bo	10
15	62057	62021	20010326	20010326	N	B-Good	Presumed	Specific bo	20

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16	62059	62023	20130310	20130310	N	B-Good	Presumed	Specific bo	20
17	62060	62024	20010326	20010326	N	C-Fair	Presumed	Specific bo	10
18	62061	62025	20010326	20010326	N	C-Fair	Presumed	Specific bo	10
19	62064	62028	20010326	20010326	N	B-Good	Presumed	Specific bo	20
20	62066	62030	20010326	20010326	N	C-Fair	Presumed	Specific bo	10
21	62068	62032	20010326	20010326	N	A-Excellent	Presumed	Specific bo	20
22	62075	62039	20010326	20010326	N	B-Good	Presumed	Specific bo	20
23	62081	62045	19780411	19780411	N	U-Unknow	Presumed	Non-specif	30
24	62082	62046	20010326	20010326	N	C-Fair	Presumed	Specific bo	20
25	62084	62048	20010326	20010326	N	B-Good	Presumed	Specific bo	20
92	62089	62053	20020624	20020624	N	B-Good	Presumed	Specific bo	10
93	62091	62055	20020619	20020619	N	B-Good	Presumed	Specific bo	10
94	62093	62057	20020625	20020625	N	B-Good	Presumed	Specific bo	10
26	62099	62063	20010326	20010326	N	C-Fair	Presumed	Specific bo	20
95	62100	62064	20060901	20060901	N	B-Good	Presumed	Specific bo	20
27	62101	62065	20010326	20010326	N	B-Good	Presumed	Specific bo	20
28	62104	62068	20010326	20010326	N	B-Good	Presumed	Specific bo	20
29	62105	62069	20010326	20010326	N	D-Poor	Presumed	Specific bo	10
96	62108	62072	20080519	20080519	N	B-Good	Presumed	Specific bo	20
97	62110	62074	20020910	20020910	N	B-Good	Presumed	Specific bo	10
98	62113	62077	20020910	20020910	N	B-Good	Presumed	Specific bo	10
30	62127	62091	20010326	20010326	N	C-Fair	Presumed	Specific bo	20
99	62128	62092	20020612	20020612	N	B-Good	Presumed	Specific bo	10
100	62129	62093	20020702	20020702	N	B-Good	Presumed	Specific bo	10
101	62130	62094	20021122	20021122	N	B-Good	Presumed	Specific bo	10
31	62134	62098	19780430	20130310	N	U-Unknow	Presumed	Non-specif	30
32	62135	84074	20130504	20130504	N	A-Excellent	Presumed	Specific bo	10
34	62137	78220	19990409	19990409	N	U-Unknow	Presumed	Non-specif	30
103	62141	62105	20020705	20020705	N	B-Good	Presumed	Specific bo	10
104	62142	62106	20020821	20020821	N	B-Good	Presumed	Specific bo	10
105	62144	62108	20040623	20040623	N	B-Good	Presumed	Specific bo	10
106	62145	62109	20050812	20050812	N	B-Good	Presumed	Specific bo	20
107	62148	62112	20030825	20050825	N	B-Good	Presumed	Specific bo	10
108	62150	62114	20060913	20060913	N	B-Good	Presumed	Specific bo	20
109	62437	62400	20080516	20080516	N	B-Good	Presumed	Specific bo	10
110	62445	62408	20040608	20040608	N	B-Good	Presumed	Specific bo	10
111	62446	62409	20040608	20040608	N	B-Good	Presumed	Specific bo	10
112	62449	62412	20070808	20070808	N	B-Good	Presumed	Specific bo	20
113	62494	62457	20030512	20030512	N	B-Good	Presumed	Specific bo	20
114	62501	62464	20020403	20020403	N	B-Good	Presumed	Specific bo	10
115	62504	62467	20040121	20040121	N	B-Good	Presumed	Specific bo	10
116	62505	62468	20050701	20050701	N	B-Good	Presumed	Specific bo	20
118	62508	62471	20040511	20040511	N	B-Good	Presumed	Specific bo	10
119	62509	62472	20140506	20140506	N	B-Good	Presumed	Specific bo	10
120	62510	62473	20030404	20030404	N	B-Good	Presumed	Specific bo	10
121	62515	62478	20050805	20050805	N	B-Good	Presumed	Specific bo	20
122	62516	62479	20030827	20030827	N	B-Good	Presumed	Specific bo	10

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123	62522	62485	20080516	20080516	N	B-Good	Presumed	Specific bo	20
124	62527	62490	20031014	20031014	N	B-Good	Presumed	Specific bo	10
125	62528	62491	20060822	20060822	N	B-Good	Presumed	Specific bo	20
126	62529	62492	20020613	20020613	N	B-Good	Presumed	Specific bo	20
127	62538	62501	20020823	20020823	N	B-Good	Presumed	Specific bo	10
128	62540	62503	20060815	20060815	N	B-Good	Presumed	Specific bo	20
129	62545	62508	20050722	20050722	N	B-Good	Presumed	Specific bo	20
130	62546	62509	20060608	20060608	N	B-Good	Presumed	Specific bo	20
131	62547	62510	20141002	20141002	N	A-Excellent	Presumed	Specific bo	20
132	62549	62512	20020513	20020513	N	B-Good	Presumed	Specific bo	10
133	62552	62515	20040526	20040526	N	A-Excellent	Presumed	Specific bo	10
134	62553	62516	20040716	20040716	N	A-Excellent	Presumed	Specific bo	10
135	62566	62529	20040312	20040312	N	A-Excellent	Presumed	Specific bo	10
136	62571	62534	20050714	20050714	N	B-Good	Presumed	Specific bo	20
45	62597	62560	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Non-specif	30
79	62628	62591	20081016	20081016	N	D-Poor	Presumed	Non-specif	30
80	62629	62592	20090109	20090109	N	D-Poor	Presumed	Non-specif	30
81	62630	62593	20090419	20090419	N	D-Poor	Presumed	Non-specif	30
82	62631	62594	2012XXXX	2012XXXX	N	D-Poor	Presumed	Non-specif	30
2	62825	6583	19100410	19100410	N	U-Unknow	Presumed	Circular fea	90
31	62979	62925	20110712	20110712	N	C-Fair	Presumed	Specific bo	20
29	63374	63282	20010121	20010121	N	D-Poor	Presumed	Specific bo	10
30	63376	63284	20020309	20020309	N	C-Fair	Presumed	Specific bo	10
31	63377	63285	20020309	20020309	N	A-Excellent	Presumed	Circular fea	40
32	63378	63286	20020309	20020309	N	A-Excellent	Presumed	Circular fea	40
33	63379	63287	20020309	20020309	N	B-Good	Presumed	Circular fea	40
34	63380	63288	20010330	20010330	N	B-Good	Presumed	Circular fea	40
35	63381	63289	20031206	20031206	N	U-Unknow	Presumed	Circular fea	40
3	63614	63522	20020701	20020701	N	D-Poor	Presumed	Specific bo	10
1	64290	6072	19390524	19390524	N	X-None	Extirpated	Circular fea	50
2	64292	64197	19381227	19381227	N	X-None	Extirpated	Non-specif	30
3	64293	64198	19490712	19490712	N	X-None	Extirpated	Circular fea	60
4	64294	64199	19400118	19400118	N	X-None	Extirpated	Circular fea	60
5	64296	6231	19090506	19090506	N	X-None	Extirpated	Circular fea	90
7	64300	64205	19291218	19291218	N	X-None	Extirpated	Circular fea	90
1	64374	64295	19860723	19860723	N	U-Unknow	Presumed	Circular fea	50
49	66318	66236	19960629	19960629	N	U-Unknow	Presumed	Non-specif	30
50	66319	66237	20040615	20040615	N	U-Unknow	Presumed	Non-specif	30
51	66320	66238	20100602	20100602	N	U-Unknow	Presumed	Non-specif	30
49	66376	6328	19961007	19961007	N	U-Unknow	Presumed	Circular fea	90
50	66377	66293	19291216	19291216	N	U-Unknow	Presumed	Non-specif	30
153	66612	58285	19770501	19770501	N	U-Unknow	Presumed	Circular fea	90
154	66613	66497	19461121	19461121	N	U-Unknow	Presumed	Circular fea	60
155	66614	6571	19191021	19191021	N	U-Unknow	Presumed	Circular fea	90
156	66615	66499	19670512	19670512	N	U-Unknow	Presumed	Circular fea	90
317	66798	66655	20060605	20060605	N	U-Unknow	Presumed	Non-specif	30
31	68474	66655	20060125	20060125	N	U-Unknow	Presumed	Non-specif	30

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32	68475	68316	20060116	20060116	N	U-Unknow	Presumed	Circular fea	50
10	68553	68363	20060605	20060605	N	U-Unknow	Presumed	Non-specif	30
8	68700	25147	19990615	19990615	N	U-Unknow	Presumed	Circular fea	50
12	68713	68460	19890422	19890422	N	U-Unknow	Presumed	Specific bo	10
13	68714	6328	19951003	19951003	N	U-Unknow	Presumed	Circular fea	90
30	68787	68460	19890422	19890422	N	U-Unknow	Presumed	Specific bo	10
31	68788	6571	19360322	19360322	N	U-Unknow	Presumed	Circular fea	90
199	69217	68739	19970611	19970611	N	U-Unknow	Presumed	Non-specif	30
38	69218	68739	19970611	19970611	N	U-Unknow	Presumed	Non-specif	30
124	69223	33091	19980105	19980105	N	U-Unknow	Presumed	Specific bo	10
40	69287	68784	19990117	19990117	N	U-Unknow	Presumed	Circular fea	40
212	69290	30609	19940911	19940911	N	U-Unknow	Presumed	Specific bo	10
213	69292	68787	19940910	19940910	N	U-Unknow	Presumed	Circular fea	40
353	69293	68787	19940910	19940910	N	U-Unknow	Presumed	Circular fea	40
354	69294	68788	19940705	19940705	N	U-Unknow	Presumed	Specific bo	10
41	69295	68788	19941216	19941216	N	U-Unknow	Presumed	Specific bo	10
214	69296	68788	19941216	19941216	N	U-Unknow	Presumed	Specific bo	10
45	69297	68788	19941216	19941216	N	U-Unknow	Presumed	Specific bo	10
42	69298	68789	19940912	19940912	N	U-Unknow	Presumed	Circular fea	40
355	69299	68790	19940704	19940704	N	U-Unknow	Presumed	Circular fea	40
46	69300	68791	19940705	19940705	N	U-Unknow	Presumed	Circular fea	40
215	69301	68791	19940910	19940910	N	U-Unknow	Presumed	Circular fea	40
1	69816	69048	19630605	19630605	N	U-Unknow	Presumed	Circular fea	90
922	70041	69261	20070104	20070104	N	D-Poor	Presumed	Specific bo	10
925	70043	69263	20061121	20061121	N	B-Good	Presumed	Specific bo	20
4	71425	70521	20071010	20071010	N	U-Unknow	Presumed	Specific bo	10
2	71426	70522	20071010	20071010	N	U-Unknow	Presumed	Specific bo	10
6	71427	70523	20071012	20071012	N	U-Unknow	Presumed	Specific bo	10
7	71428	70524	20090424	20090424	N	U-Unknow	Presumed	Specific bo	20
10	71429	70525	20070921	20070921	N	U-Unknow	Presumed	Specific bo	10
8	71628	81822	20071015	20071015	N	U-Unknow	Presumed	Specific bo	10
33	71631	56801	19090406	19090406	N	U-Unknow	Presumed	Circular fea	90
2	71632	6674	19160513	19160513	N	U-Unknow	Presumed	Circular fea	90
35	71633	6568	19170406	19170406	N	U-Unknow	Presumed	Circular fea	90
1004	71840	70858	20060620	20060620	N	A-Excellent	Presumed	Specific bo	20
1005	71842	70860	20051102	20051102	N	A-Excellent	Presumed	Specific bo	20
1006	71843	70863	20051102	20051102	N	A-Excellent	Presumed	Specific bo	10
1007	71846	70865	20051102	20051102	N	A-Excellent	Presumed	Specific bo	10
1008	71847	70867	20070123	20070123	N	D-Poor	Presumed	Specific bo	10
1009	71854	70876	19941123	19941123	N	U-Unknow	Presumed	Non-specif	30
23	72743	71873	20070120	20070120	N	B-Good	Presumed	Circular fea	40
24	72746	71874	20070115	20070115	N	A-Excellent	Presumed	Circular fea	40
25	72749	71875	20070701	20070701	N	A-Excellent	Presumed	Circular fea	40
5	73102	72140	196406XX	196406XX	N	U-Unknow	Presumed	Circular fea	50
35	73122	72157	19700406	19700406	N	U-Unknow	Presumed	Circular fea	90
36	73124	72158	19890324	19890324	N	U-Unknow	Presumed	Non-specif	30
37	73125	37037	19700301	19700301	N	U-Unknow	Presumed	Circular fea	100

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38	73127	72161	20130304	20130304	N	U-Unknow	Presumed	Specific bo	10
1211	73170	72228	200702XX	200702XX	N	A-Excellent	Presumed	Circular fea	40
1212	73171	72229	200702XX	200702XX	N	A-Excellent	Presumed	Circular fea	40
1213	73172	72230	20070510	20070510	N	A-Excellent	Presumed	Specific bo	20
1214	73173	72231	200702XX	200702XX	N	A-Excellent	Presumed	Circular fea	40
1215	73174	72232	200702XX	200702XX	N	A-Excellent	Presumed	Circular fea	40
1216	73175	72233	20070120	20070120	N	A-Excellent	Presumed	Non-specif	30
1217	73177	72235	20070120	20070120	N	A-Excellent	Presumed	Non-specif	30
1218	73179	72237	20070120	20070120	N	A-Excellent	Presumed	Circular fea	40
1219	73180	72238	20070120	20070120	N	A-Excellent	Presumed	Circular fea	40
1220	73182	72240	20070120	20070120	N	A-Excellent	Presumed	Circular fea	40
1	73260	17008	XXXXXXXX	20131018	N	U-Unknow	Presumed	Non-specif	30
2	73262	72302	19860308	20131018	N	U-Unknow	Presumed	Non-specif	30
43	73348	72386	19490317	19490317	N	U-Unknow	Presumed	Circular fea	90
1	73551	72721	19320406	19320406	N	U-Unknow	Presumed	Circular fea	90
2	73555	36286	19761110	19761110	N	U-Unknow	Presumed	Circular fea	90
3	73558	84102	20110307	20110307	N	A-Excellent	Presumed	Specific bo	10
4	73566	72736	19580218	19580218	N	U-Unknow	Presumed	Circular fea	90
5	73567	72737	19580301	19580301	N	U-Unknow	Presumed	Non-specif	30
6	73568	6388	19410321	19410321	N	U-Unknow	Presumed	Circular fea	90
150	73765	72878	20050427	20050427	N	B-Good	Presumed	Specific bo	20
151	73777	72879	20050508	20050508	N	B-Good	Presumed	Specific bo	20
152	73779	72883	20010405	20010405	N	A-Excellent	Presumed	Specific bo	20
153	73782	72884	20050427	20050427	N	B-Good	Presumed	Specific bo	20
154	73783	72885	20010405	20010405	N	A-Excellent	Presumed	Specific bo	20
157	73790	72888	20050427	20050427	N	B-Good	Presumed	Specific bo	10
158	73796	72889	20020621	20020621	N	B-Good	Presumed	Circular fea	40
159	73812	72894	20050703	20050703	N	B-Good	Presumed	Specific bo	20
161	73826	72907	20020525	20020525	N	B-Good	Presumed	Circular fea	40
162	73829	72911	20020523	20020523	N	B-Good	Presumed	Circular fea	40
164	73845	72931	20100324	20100324	N	A-Excellent	Presumed	Specific bo	20
165	73860	72948	20010330	20010330	N	A-Excellent	Presumed	Specific bo	20
166	73880	72967	20050427	20050427	N	A-Excellent	Presumed	Specific bo	20
167	73893	72979	20050106	20050106	N	C-Fair	Presumed	Circular fea	40
168	73903	72990	20050123	20050123	N	U-Unknow	Presumed	Specific bo	10
1	74003	73074	19280422	19280422	N	U-Unknow	Presumed	Circular fea	90
2	74006	6571	19410528	19410528	N	U-Unknow	Presumed	Circular fea	90
193	74016	73085	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
194	74017	73086	20070503	20070503	N	U-Unknow	Presumed	Specific bo	20
219	74060	73129	20050427	20050427	N	A-Excellent	Presumed	Specific bo	20
220	74061	73130	20010406	20010406	N	A-Excellent	Presumed	Specific bo	20
221	74062	73131	20010406	20010406	N	A-Excellent	Presumed	Specific bo	20
223	74085	73153	20010331	20010331	N	A-Excellent	Presumed	Specific bo	20
224	74089	73156	20010330	20010330	N	A-Excellent	Presumed	Specific bo	20
225	74096	73166	20010407	20010407	N	B-Good	Presumed	Specific bo	20
226	74097	73167	20010329	20010329	N	B-Good	Presumed	Specific bo	20
227	74099	73168	20010407	20010407	N	A-Excellent	Presumed	Specific bo	20

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5	74526	73558	20070201	20070201	N	B-Good	Presumed	Specific bo	10
8	74659	58808	19290415	19290415	N	U-Unknow	Presumed	Circular fea	90
4	76607	75585	20040806	20040806	N	U-Unknow	Presumed	Specific bo	20
5	76623	75601	20030929	20030929	N	U-Unknow	Presumed	Specific bo	20
6	76624	75603	20030623	20030623	N	U-Unknow	Presumed	Specific bo	20
7	76625	75604	20030930	20030930	N	U-Unknow	Presumed	Specific bo	20
8	76627	75606	20030930	20030930	N	U-Unknow	Presumed	Specific bo	20
9	76631	75608	20030930	20030930	N	U-Unknow	Presumed	Specific bo	20
19	76957	75952	19960716	2004XXXX	N	U-Unknow	Presumed	Circular fea	60
20	76966	6266	199612XX	2006XXXX	N	U-Unknow	Presumed	Specific bo	20
21	76968	75962	199703XX	2006XXXX	N	U-Unknow	Presumed	Circular fea	50
138	76974	75969	20050630	20050630	N	U-Unknow	Presumed	Specific bo	20
198	77014	76014	20090521	20090521	N	B-Good	Presumed	Non-specif	30
203	77033	76032	20080716	20080716	N	U-Unknow	Presumed	Specific bo	10
204	77034	76033	20040505	20040505	N	C-Fair	Presumed	Specific bo	10
207	77049	76048	20090521	20090701	N	B-Good	Presumed	Circular fea	40
208	77050	76049	20060505	20060505	N	B-Good	Presumed	Specific bo	20
209	77051	76050	20060417	20060417	N	B-Good	Presumed	Specific bo	10
37	77067	76079	19790419	19790419	N	U-Unknow	Presumed	Circular fea	70
38	77074	76081	20020715	20020715	N	U-Unknow	Presumed	Non-specif	30
39	77075	76082	197706XX	197706XX	N	U-Unknow	Presumed	Circular fea	60
40	77076	76083	19860308	19860308	N	U-Unknow	Presumed	Non-specif	30
222	77142	76151	20000703	20000703	N	U-Unknow	Presumed	Non-specif	30
224	77149	76156	20050413	20090617	N	U-Unknow	Presumed	Circular fea	40
225	77150	76157	20050423	20090617	N	U-Unknow	Presumed	Circular fea	40
226	77152	76159	20050515	20090617	N	U-Unknow	Presumed	Non-specif	30
227	77154	76161	20010415	20010415	N	U-Unknow	Presumed	Non-specif	30
228	77155	76163	20080508	20080508	N	U-Unknow	Presumed	Non-specif	30
229	77159	76170	20090429	20090622	N	U-Unknow	Presumed	Non-specif	30
230	77160	76171	20090602	20090630	N	U-Unknow	Presumed	Non-specif	30
231	77169	76180	20090513	20090701	N	U-Unknow	Presumed	Non-specif	30
232	77170	76181	20000424	20000424	N	U-Unknow	Presumed	Circular fea	40
233	77172	76182	20090409	20090701	N	U-Unknow	Presumed	Non-specif	30
141	77263	76300	20060808	20060808	N	U-Unknow	Presumed	Specific bo	10
143	77290	76312	20050929	20050929	N	B-Good	Presumed	Specific bo	10
144	77306	76327	20060823	20060823	N	U-Unknow	Presumed	Specific bo	20
145	77310	76332	20060814	20060814	N	U-Unknow	Presumed	Specific bo	20
146	77312	76334	20060907	20060907	N	B-Good	Presumed	Specific bo	20
147	77322	76337	20060621	20060621	N	U-Unknow	Presumed	Specific bo	10
148	77323	76338	20060621	20060621	N	U-Unknow	Presumed	Specific bo	10
149	77337	76369	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
150	77338	76370	20060821	20060821	N	U-Unknow	Presumed	Specific bo	10
151	77340	76371	20060825	20060825	N	U-Unknow	Presumed	Specific bo	10
152	77341	76378	20060626	20060626	N	U-Unknow	Presumed	Specific bo	10
153	77342	76379	20060817	20060817	N	U-Unknow	Presumed	Specific bo	10
154	77370	76412	20060622	20060622	N	U-Unknow	Presumed	Specific bo	10
155	77372	76415	20060619	20060619	N	U-Unknow	Presumed	Specific bo	10

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156	77373	76416	20060620	20060620	N	U-Unknow	Presumed	Specific bo	20
157	77374	76417	20060718	20060718	N	B-Good	Presumed	Specific bo	10
158	77376	76421	20070502	20070502	N	B-Good	Presumed	Specific bo	20
159	77379	76423	20060718	20060718	N	B-Good	Presumed	Specific bo	10
160	77382	76426	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
161	77386	76429	20060831	20060831	N	U-Unknow	Presumed	Specific bo	10
163	77394	76445	20060613	20060613	N	B-Good	Presumed	Specific bo	20
164	77398	76447	20070516	20070516	N	U-Unknow	Presumed	Specific bo	20
165	77405	76458	20060622	20060622	N	B-Good	Presumed	Specific bo	20
166	77413	76463	20080514	20080514	N	B-Good	Presumed	Specific bo	20
171	77445	76497	20140919	20140919	N	U-Unknow	Presumed	Specific bo	20
173	77451	76504	20060605	20060605	N	U-Unknow	Presumed	Specific bo	10
174	77453	76505	20060606	20060606	N	U-Unknow	Presumed	Specific bo	10
175	77466	76520	20060828	20060828	N	U-Unknow	Presumed	Specific bo	10
176	77473	76528	20060906	20060906	N	U-Unknow	Presumed	Specific bo	10
177	77476	76531	20060830	20060830	N	U-Unknow	Presumed	Specific bo	10
178	77479	76534	20060912	20060912	N	U-Unknow	Presumed	Specific bo	10
179	77485	76538	20060629	20060629	N	B-Good	Presumed	Specific bo	10
180	77490	76544	20060906	20060906	N	U-Unknow	Presumed	Specific bo	20
181	77635	76689	20060804	20060804	N	U-Unknow	Presumed	Specific bo	10
182	77643	76696	20050825	20050825	N	U-Unknow	Presumed	Specific bo	10
10	77657	76711	20080516	20080516	N	U-Unknow	Presumed	Specific bo	20
273	77671	76720	20090720	20090720	N	U-Unknow	Presumed	Specific bo	10
183	77727	76784	20080520	20080520	N	U-Unknow	Presumed	Specific bo	20
185	77733	76790	20070803	20070803	N	U-Unknow	Presumed	Specific bo	10
187	77778	76837	20070514	20070514	N	U-Unknow	Presumed	Specific bo	10
188	77780	76840	20071003	20071003	N	U-Unknow	Presumed	Specific bo	10
39	77868	76909	20070315	20070522	N	B-Good	Presumed	Specific bo	10
5	77918	76977	20060420	20060420	N	B-Good	Presumed	Specific bo	20
7	77921	76979	20060505	20060505	N	B-Good	Presumed	Specific bo	20
8	77922	76980	20090417	20090417	N	B-Good	Presumed	Specific bo	10
9	77923	76982	20060417	20060417	N	B-Good	Presumed	Specific bo	10
40	77999	77057	20060525	20090701	N	D-Poor	Presumed	Specific bo	20
41	78014	77071	20050407	20050407	N	U-Unknow	Presumed	Specific bo	20
42	78028	77086	20090603	20090603	N	B-Good	Presumed	Specific bo	20
43	78043	77099	20090604	20090604	N	B-Good	Presumed	Specific bo	20
44	78046	77101	20090604	20090604	N	B-Good	Presumed	Specific bo	20
45	78050	77103	20090605	20090605	N	B-Good	Presumed	Specific bo	20
46	78054	77106	20090608	20090608	N	B-Good	Presumed	Specific bo	20
47	78160	77241	20060513	20060513	N	U-Unknow	Presumed	Specific bo	20
189	78561	77640	20110627	20110627	N	B-Good	Presumed	Specific bo	20
191	78588	6262	19290512	19290512	N	U-Unknow	Presumed	Circular fea	90
194	78595	77695	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Circular fea	90
195	78596	77696	19300427	19300427	N	U-Unknow	Presumed	Circular fea	90
199	78616	77718	19820521	19820521	N	U-Unknow	Presumed	Circular fea	70
22	78618	77731	19400126	19400126	N	U-Unknow	Presumed	Circular fea	70
25	78622	37043	19140406	19140406	N	U-Unknow	Presumed	Circular fea	90

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26	78624	77734	20050310	20050310	N	U-Unknow	Presumed	Non-specif	30
203	78643	77726	20010517	20010517	N	U-Unknow	Presumed	Circular fea	50
42	78644	35229	19310314	20120325	N	U-Unknow	Presumed	Circular fea	90
205	78648	77730	1941XXXX	1941XXXX	N	U-Unknow	Presumed	Circular fea	90
207	78650	77746	1982XXXX	1982XXXX	N	U-Unknow	Presumed	Circular fea	90
208	78651	77751	1982XXXX	1982XXXX	N	U-Unknow	Presumed	Circular fea	70
43	78652	77752	19850310	19850310	N	U-Unknow	Presumed	Circular fea	70
5	78716	77819	20050322	20050322	N	U-Unknow	Presumed	Non-specif	30
6	78720	77824	20080326	20080326	N	B-Good	Presumed	Specific bo	10
7	78721	77825	20050414	20050414	N	U-Unknow	Presumed	Circular fea	60
8	78722	77827	20080409	20080409	N	U-Unknow	Presumed	Non-specif	30
9	78724	77829	20080410	20080410	N	U-Unknow	Presumed	Non-specif	30
10	78731	77836	20080408	20080408	N	U-Unknow	Presumed	Non-specif	30
55	78800	77904	19380324	19380324	N	U-Unknow	Presumed	Non-specif	30
211	78921	78036	20010511	20010511	N	U-Unknow	Presumed	Non-specif	30
212	78924	78040	20010514	20010514	N	U-Unknow	Presumed	Specific bo	10
54	78958	78079	19370531	19370531	N	U-Unknow	Presumed	Non-specif	30
55	78959	78080	19810521	19810521	N	U-Unknow	Presumed	Circular fea	80
56	78960	78081	191605XX	191605XX	N	U-Unknow	Presumed	Non-specif	30
213	79026	78135	20060626	20060626	N	U-Unknow	Presumed	Non-specif	30
32	79071	78171	1980XXXX	1980XXXX	N	U-Unknow	Presumed	Circular fea	90
35	79083	78180	19900630	19900630	N	U-Unknow	Presumed	Circular fea	50
9	79112	78216	19771125	20130309	N	U-Unknow	Presumed	Non-specif	30
10	79114	78217	19780430	19780430	N	U-Unknow	Presumed	Circular fea	60
11	79116	78219	19891231	19891231	N	U-Unknow	Presumed	Non-specif	30
12	79119	78220	19990409	19990409	N	U-Unknow	Presumed	Non-specif	30
28	79348	78428	19770416	19770416	N	U-Unknow	Presumed	Circular fea	50
29	79349	78429	20060401	20060401	N	U-Unknow	Presumed	Circular fea	50
1	79384	62099	20110307	20110307	N	A-Excellent	Presumed	Specific bo	10
2	79385	78460	19910512	19910512	N	U-Unknow	Presumed	Non-specif	30
5	79404	78480	19760826	19760826	N	U-Unknow	Presumed	Non-specif	30
14	79407	93883	20130310	20130310	N	C-Fair	Presumed	Specific bo	10
15	79408	78487	19720330	19720330	N	U-Unknow	Presumed	Non-specif	30
215	79414	78488	20090521	20090521	N	U-Unknow	Presumed	Specific bo	20
216	79415	78494	20090519	20090519	N	U-Unknow	Presumed	Specific bo	20
217	79416	78495	20090520	20090520	N	U-Unknow	Presumed	Specific bo	10
47	79586	78679	18750818	18750818	N	U-Unknow	Presumed	Circular fea	60
83	79611	78661	20090419	20090419	N	D-Poor	Presumed	Non-specif	30
84	79619	78663	20090424	20090424	N	D-Poor	Presumed	Specific bo	10
15	79624	78664	20150327	20150327	N	U-Unknow	Presumed	Specific bo	20
85	79634	78666	20080714	20090421	N	D-Poor	Presumed	Non-specif	30
86	79635	78668	20090419	20090419	N	D-Poor	Presumed	Non-specif	30
87	79637	78670	20060410	20061016	N	D-Poor	Presumed	Non-specif	30
88	79639	78672	20070907	20070907	N	B-Good	Presumed	Non-specif	30
21	79703	5984	19970528	19970528	N	U-Unknow	Presumed	Circular fea	50
20	79731	26102	20100428	20100428	N	U-Unknow	Presumed	Circular fea	90
32	79785	78841	19830329	19830329	N	U-Unknow	Presumed	Circular fea	70

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37	79790	78844	19830212	19830212	N	U-Unknow	Presumed	Circular fea	60
38	79791	78845	19830220	19830220	N	U-Unknow	Presumed	Non-specif	30
39	79795	78906	20090311	20090311	N	U-Unknow	Presumed	Specific bo	10
40	79805	78907	20090311	20090311	N	U-Unknow	Presumed	Specific bo	10
41	79806	78910	20090312	20090312	N	U-Unknow	Presumed	Specific bo	10
42	79807	78911	20080410	20080410	N	U-Unknow	Presumed	Specific bo	20
43	79808	78913	20080409	20080409	N	U-Unknow	Presumed	Specific bo	10
44	79809	78915	20090327	20090327	N	U-Unknow	Presumed	Specific bo	10
46	79842	78917	20080408	20080408	N	U-Unknow	Presumed	Specific bo	10
47	79843	78919	20090326	20090326	N	U-Unknow	Presumed	Specific bo	10
48	79844	78920	20080425	20080425	N	U-Unknow	Presumed	Specific bo	10
49	79845	78922	20080326	20080326	N	C-Fair	Presumed	Specific bo	10
50	79846	78924	20090323	20090323	N	U-Unknow	Presumed	Specific bo	10
51	79851	78925	20110227	20110227	N	B-Good	Presumed	Specific bo	20
52	79852	78926	20090323	20090323	N	U-Unknow	Presumed	Specific bo	10
53	79853	78927	20090309	20090309	N	U-Unknow	Presumed	Specific bo	10
62	79911	78950	19850324	19850324	N	U-Unknow	Presumed	Non-specif	30
3	80022	6674	19391013	19391013	N	U-Unknow	Presumed	Circular fea	90
41	80034	35229	19270417	19270417	N	U-Unknow	Presumed	Circular fea	90
42	80052	79087	19830219	19830219	N	U-Unknow	Presumed	Circular fea	90
42	80349	79366	19980322	19980322	N	U-Unknow	Presumed	Circular fea	40
43	80350	79367	20090128	20090128	N	U-Unknow	Presumed	Specific bo	10
44	80351	79368	20021227	20021227	N	U-Unknow	Presumed	Circular fea	40
45	80352	79369	195903XX	195903XX	N	U-Unknow	Presumed	Circular fea	70
46	80356	79373	1987XXXX	1987XXXX	N	D-Poor	Presumed	Non-specif	30
41	80410	79435	19780410	19780410	N	U-Unknow	Presumed	Circular fea	60
42	80414	79438	19860206	19860206	N	U-Unknow	Presumed	Circular fea	60
5	80548	87205	20120325	20120325	N	U-Unknow	Presumed	Specific bo	10
6	80549	79570	20080312	20080312	N	U-Unknow	Presumed	Circular fea	50
1285	80595	79608	20070626	20070626	N	U-Unknow	Presumed	Specific bo	20
1286	80598	79609	20070626	20070626	N	U-Unknow	Presumed	Specific bo	20
1287	80599	79610	20070626	20070626	N	U-Unknow	Presumed	Specific bo	20
1288	80601	79614	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1289	80602	79615	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1290	80604	79616	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1297	80703	79711	20060626	20060626	N	U-Unknow	Presumed	Specific bo	20
1298	80707	79712	20060626	20060626	N	U-Unknow	Presumed	Specific bo	10
1299	80708	79713	20060626	20060626	N	U-Unknow	Presumed	Specific bo	10
1300	80709	79714	20060626	20060626	N	U-Unknow	Presumed	Specific bo	10
1301	80725	79730	20060620	20060620	N	U-Unknow	Presumed	Specific bo	10
1302	80727	79732	20060620	20060620	N	U-Unknow	Presumed	Specific bo	20
1303	80728	79733	20060621	20060621	N	U-Unknow	Presumed	Specific bo	10
1304	80729	79734	20060621	20060621	N	U-Unknow	Presumed	Specific bo	20
1305	80730	79736	20060621	20060621	N	U-Unknow	Presumed	Specific bo	20
1306	80731	79740	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1307	80735	79741	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1308	80737	79742	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20

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1309	80739	79745	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1310	80741	79746	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1311	80742	79748	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1312	80746	79753	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1313	80747	79754	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1314	80749	79756	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1315	80750	79757	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1316	80751	79758	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1317	80752	79759	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1318	80754	79763	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1319	80758	79765	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1320	80759	79766	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1321	80777	79774	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1322	80778	79782	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1323	80780	79787	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1324	80781	79789	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1325	80782	79790	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1326	80785	79793	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1327	80786	79794	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1328	80787	79795	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1329	80789	79796	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1330	80790	79797	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
91	80892	79938	20100406	20100406	N	U-Unknow	Presumed	Specific bo	20
92	80893	79939	20100407	20100407	N	U-Unknow	Presumed	Specific bo	10
93	80894	79940	20100413	20100413	N	U-Unknow	Presumed	Specific bo	10
1421	81171	80185	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
1422	81173	80187	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
1423	81175	80189	20070508	20070508	N	U-Unknow	Presumed	Circular fea	40
1424	81179	80195	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1425	81182	80197	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1426	81183	80198	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1427	81184	80199	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1428	81185	80200	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1429	81187	80202	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1430	81189	80203	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1431	81191	80204	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1432	81193	80207	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1433	81195	80208	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1434	81198	80213	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1435	81200	80216	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1436	81207	80219	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1437	81208	80220	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1438	81209	80221	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1439	81210	80222	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1441	81240	80254	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1442	81241	80255	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1443	81243	80256	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10

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1444	81248	80258	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1445	81249	80259	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1446	81251	80261	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1447	81259	80269	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1448	81260	80271	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1449	81261	80272	20060702	20060702	N	U-Unknow	Presumed	Specific bo	20
1450	81262	80273	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1451	81263	80274	20060702	20060702	N	U-Unknow	Presumed	Specific bo	10
1452	81264	80275	20060706	20060706	N	U-Unknow	Presumed	Specific bo	20
1453	81266	80276	20060705	20060705	N	U-Unknow	Presumed	Specific bo	20
1454	81267	80277	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1455	81268	80278	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1456	81269	80279	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1457	81271	80281	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1459	81274	80284	20060706	20060706	N	U-Unknow	Presumed	Specific bo	10
1460	81276	80286	20060706	20060706	N	U-Unknow	Presumed	Specific bo	20
1461	81278	80287	20060706	20060706	N	U-Unknow	Presumed	Specific bo	20
1463	81284	80293	20060704	20060704	N	U-Unknow	Presumed	Specific bo	10
1464	81287	80295	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1465	81288	80296	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1466	81290	80297	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1467	81291	80298	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1468	81292	80299	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1469	81293	80300	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
1470	81295	80306	20060703	20060703	N	U-Unknow	Presumed	Specific bo	10
1471	81296	80307	20060703	20060703	N	U-Unknow	Presumed	Specific bo	20
1472	81299	80309	20060705	20060705	N	U-Unknow	Presumed	Specific bo	20
1473	81300	80311	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1474	81301	80312	20060705	20060705	N	U-Unknow	Presumed	Specific bo	20
1475	81313	80324	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
18	81316	80341	19030401	19030401	N	X-None	Possibly Ex	Circular fea	90
1476	81318	80327	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1477	81324	80330	20060705	20060705	N	U-Unknow	Presumed	Specific bo	20
1478	81326	80333	20060705	20060705	N	U-Unknow	Presumed	Specific bo	10
1479	81328	80335	20060707	20060707	N	U-Unknow	Presumed	Specific bo	10
1480	81329	80339	20070509	20070509	N	U-Unknow	Presumed	Specific bo	20
1481	81330	80340	20070509	20070509	N	U-Unknow	Presumed	Specific bo	10
1482	81331	80342	20070509	20070509	N	U-Unknow	Presumed	Specific bo	20
1483	81332	80344	20070510	20070510	N	U-Unknow	Presumed	Specific bo	20
1484	81333	80345	20070510	20070510	N	U-Unknow	Presumed	Specific bo	10
1485	81334	80346	20070510	20070510	N	U-Unknow	Presumed	Specific bo	10
22	81337	80350	19010327	19010327	N	X-None	Extirpated	Circular fea	90
1486	81350	80364	20060525	20060525	N	U-Unknow	Presumed	Specific bo	10
50	81567	80568	19370406	19370406	N	U-Unknow	Presumed	Circular fea	90
6	81651	80652	19970131	19970131	N	U-Unknow	Presumed	Circular fea	70
36	81717	80714	20110703	20110703	N	U-Unknow	Presumed	Non-specif	30
37	81721	6602	20100722	20100722	N	U-Unknow	Presumed	Circular fea	80

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28	81880	80901	20070512	20070512	N	B-Good	Presumed	Circular fea	40
29	81883	80903	20050523	20050523	N	D-Poor	Presumed	Specific bo	10
30	81895	80907	20050612	20050612	N	B-Good	Presumed	Specific bo	10
1592	81975	80984	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1593	81976	80985	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1594	81977	80986	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1595	81978	80987	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1596	81982	80993	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1597	81985	80995	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1598	81986	80997	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1599	81996	81010	20060629	20060629	N	U-Unknow	Presumed	Specific bo	10
9	82245	81266	20081007	20081007	N	U-Unknow	Presumed	Specific bo	10
10	82246	81267	20081008	20081008	N	U-Unknow	Presumed	Specific bo	10
11	82247	81268	20081008	20081008	N	U-Unknow	Presumed	Specific bo	10
12	82248	81269	20081008	20081008	N	U-Unknow	Presumed	Specific bo	10
13	82249	81270	20081013	20081013	N	U-Unknow	Presumed	Specific bo	10
14	82250	81271	20081014	20081014	N	U-Unknow	Presumed	Specific bo	10
15	82251	81272	20081014	20081014	N	U-Unknow	Presumed	Specific bo	10
16	82252	81273	20081013	20081013	N	U-Unknow	Presumed	Specific bo	10
17	82253	81274	20081006	20081006	N	U-Unknow	Presumed	Specific bo	10
18	82254	81275	20090424	20090424	N	U-Unknow	Presumed	Specific bo	10
20	82256	81262	20080405	20080405	N	U-Unknow	Presumed	Specific bo	20
21	82274	81290	20090423	20090423	N	U-Unknow	Presumed	Specific bo	10
46	82343	6550	19441123	19441123	N	U-Unknow	Presumed	Circular fea	90
15	82356	81377	1941XXXX	1941XXXX	N	U-Unknow	Presumed	Circular fea	90
10	82468	81490	20060505	20060505	N	U-Unknow	Presumed	Specific bo	20
1642	82532	81565	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1643	82533	81566	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1644	82534	81567	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1645	82535	81568	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1646	82537	81570	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1647	82538	81571	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1648	82539	81572	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1649	82540	81573	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1650	82541	81574	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1651	82542	81575	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1652	82543	81576	20090310	20090310	N	C-Fair	Presumed	Specific bo	10
1653	82544	81577	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1654	82545	81578	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1655	82546	81579	20090310	20090310	N	C-Fair	Presumed	Specific bo	20
1665	82582	81613	2008XXXX	20080508	N	B-Good	Presumed	Specific bo	10
1666	82583	81614	20070605	20070605	N	B-Good	Presumed	Specific bo	10
1667	82584	81615	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1668	82586	81616	2008XXXX	2008XXXX	N	U-Unknow	Presumed	Specific bo	20
1669	82587	81618	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1670	82588	81619	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1671	82589	81620	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10

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1672	82590	81621	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1673	82592	81622	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1674	82593	81624	2008XXXX	20080508	N	U-Unknow	Presumed	Specific bo	10
1675	82600	81630	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1676	82602	81632	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1677	82603	81633	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1678	82606	81636	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1679	82611	81640	20070627	20070627	N	U-Unknow	Presumed	Specific bo	10
1680	82612	81641	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1681	82613	81643	20070627	20070627	N	U-Unknow	Presumed	Specific bo	20
1682	82614	81644	20060715	20060715	N	U-Unknow	Presumed	Circular fea	40
1683	82621	81650	20060715	20060715	N	U-Unknow	Presumed	Circular fea	40
1684	82629	81657	20060715	20060715	N	U-Unknow	Presumed	Circular fea	40
1685	82638	81666	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1686	82639	81668	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1687	82640	81670	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1688	82642	81671	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1689	82643	81672	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1690	82644	81674	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1691	82645	81675	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1692	82646	81676	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1693	82647	81677	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1694	82650	81679	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1695	82652	81680	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1696	82654	81682	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1697	82655	81683	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1698	82656	81686	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
89	82657	81687	19900511	19900511	N	U-Unknow	Presumed	Non-specif	30
1699	82664	81695	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1700	82666	81697	20060712	20060712	N	U-Unknow	Presumed	Specific bo	10
1701	82669	81701	20060712	20060712	N	U-Unknow	Presumed	Specific bo	20
1702	82672	81705	20060712	20060712	N	U-Unknow	Presumed	Specific bo	10
1703	82676	81707	20060712	20060712	N	U-Unknow	Presumed	Specific bo	10
1704	82677	81708	20060712	20060712	N	U-Unknow	Presumed	Specific bo	20
1705	82678	81709	20060712	20060712	N	U-Unknow	Presumed	Specific bo	10
1706	82679	81710	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1707	82681	81711	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1708	82682	81713	20060715	20060715	N	U-Unknow	Presumed	Specific bo	10
1709	82685	81715	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1710	82686	81716	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1711	82687	81718	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1712	82688	81719	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1713	82689	81720	20060712	20060712	N	U-Unknow	Presumed	Specific bo	20
1714	82692	81723	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1715	82693	81724	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1716	82694	81725	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1717	82695	81726	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20

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1718	82696	81727	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1719	82697	81728	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1720	82698	81729	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1721	82699	81731	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
22	82700	81730	19300131	19300131	N	U-Unknow	Presumed	Circular fea	90
1722	82701	81732	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1723	82702	81733	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1724	82703	81734	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1725	82704	81735	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1726	82705	81736	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
23	82706	81738	20080404	20080404	N	U-Unknow	Presumed	Specific bo	20
1727	82707	81737	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1728	82708	81739	20070609	20070609	N	U-Unknow	Presumed	Specific bo	10
1729	82709	81740	20070609	20070609	N	U-Unknow	Presumed	Specific bo	20
1730	82710	81741	20060713	20060713	N	U-Unknow	Presumed	Specific bo	20
1731	82711	81742	20060713	20060713	N	U-Unknow	Presumed	Specific bo	10
1732	82712	81743	20060715	20060715	N	U-Unknow	Presumed	Specific bo	20
1733	82713	81744	20070609	20070609	N	U-Unknow	Presumed	Specific bo	20
1734	82714	81745	20070609	20070609	N	U-Unknow	Presumed	Specific bo	20
1735	82715	81746	20070609	20070609	N	U-Unknow	Presumed	Specific bo	10
1736	82716	81747	20070609	20070609	N	U-Unknow	Presumed	Specific bo	10
1737	82717	81748	20070609	20070609	N	U-Unknow	Presumed	Specific bo	20
1738	82719	81749	20070609	20070609	N	U-Unknow	Presumed	Specific bo	10
1739	82722	81750	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
1740	82723	81751	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
1741	82724	81752	20070615	20070615	N	U-Unknow	Presumed	Specific bo	10
1742	82725	81756	20070615	20070615	N	U-Unknow	Presumed	Specific bo	10
1743	82726	81757	20070615	20070615	N	U-Unknow	Presumed	Specific bo	10
1744	82727	81758	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
1745	82734	81765	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
1746	82735	81767	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
1747	82739	81769	20070609	20070609	N	U-Unknow	Presumed	Specific bo	20
1748	82740	81771	20070615	20070615	N	U-Unknow	Presumed	Specific bo	10
1749	82741	81772	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
218	82788	6328	196905XX	196905XX	N	X-None	Possibly Ex	Circular fea	90
19	82798	81825	19310128	19310128	N	U-Unknow	Presumed	Circular fea	90
1840	83042	82054	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1841	83043	82055	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1842	83044	82056	20070602	20070602	N	U-Unknow	Presumed	Specific bo	20
1843	83045	82057	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1844	83046	82058	20070602	20070602	N	U-Unknow	Presumed	Specific bo	10
1845	83048	82060	20070615	20070615	N	U-Unknow	Presumed	Specific bo	20
294	83131	82148	19880319	19880319	N	U-Unknow	Presumed	Circular fea	60
12	83240	82233	20110410	20110410	N	B-Good	Presumed	Specific bo	20
1847	83337	82284	20060706	20060706	N	U-Unknow	Presumed	Specific bo	20
1848	83341	82328	20060310	20060310	N	U-Unknow	Presumed	Specific bo	20
1849	83344	82330	20060310	20060310	N	U-Unknow	Presumed	Specific bo	10

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1850	83345	82331	20060317	20060317	N	U-Unknow	Presumed	Specific bo	10
419	83532	82723	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
2	83548	82537	198003XX	198003XX	N	U-Unknow	Presumed	Non-specif	30
48	83677	82675	19980518	19980518	N	C-Fair	Presumed	Specific bo	20
50	83688	82686	19910507	19910507	N	U-Unknow	Presumed	Non-specif	30
420	83713	82725	20010423	20010423	N	U-Unknow	Presumed	Specific bo	10
421	83723	82726	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
422	83724	82727	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
423	83725	82764	20040507	20040507	N	U-Unknow	Presumed	Specific bo	20
424	83726	82728	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
425	83727	82765	20070501	20100330	N	U-Unknow	Presumed	Specific bo	20
426	83728	82729	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
427	83729	82730	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
428	83730	82731	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
429	83731	82766	20070501	20070501	N	U-Unknow	Presumed	Specific bo	20
430	83732	82767	20070501	20070501	N	U-Unknow	Presumed	Specific bo	20
431	83733	82769	20070501	20080510	N	U-Unknow	Presumed	Specific bo	20
432	83734	82733	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
433	83736	82734	20100323	20100323	N	U-Unknow	Presumed	Specific bo	10
434	83737	82770	20080510	20080510	N	U-Unknow	Presumed	Specific bo	20
435	83739	82735	20040506	20040506	N	U-Unknow	Presumed	Specific bo	10
436	83740	82736	20040506	20040506	N	U-Unknow	Presumed	Specific bo	10
437	83741	82737	20010423	20010423	N	U-Unknow	Presumed	Specific bo	10
438	83742	82738	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
439	83743	82739	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
440	83744	82740	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
441	83745	82743	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
443	83746	82744	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
444	83747	82745	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
442	83748	82771	20050424	20050324	N	U-Unknow	Presumed	Specific bo	20
445	83749	82746	20010423	20010423	N	U-Unknow	Presumed	Specific bo	10
446	83750	82772	20040504	20040504	N	U-Unknow	Presumed	Specific bo	20
447	83751	82747	20010330	20010330	N	A-Excellent	Presumed	Specific bo	10
448	83752	82748	20040506	20040506	N	U-Unknow	Presumed	Specific bo	10
450	83753	82750	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
452	83754	82751	20070429	20070429	N	U-Unknow	Presumed	Specific bo	10
453	83755	82752	20070430	20070430	N	U-Unknow	Presumed	Specific bo	10
454	83756	82753	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
455	83757	82755	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
456	83758	82756	20050423	20050423	N	U-Unknow	Presumed	Specific bo	10
457	83759	82757	20050423	20050423	N	U-Unknow	Presumed	Specific bo	10
459	83760	82759	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
460	83761	82773	20100323	20100323	N	U-Unknow	Presumed	Specific bo	20
461	83762	82774	20040410	20040410	N	U-Unknow	Presumed	Specific bo	20
462	83763	82775	20040410	20040410	N	U-Unknow	Presumed	Specific bo	20
463	83764	82760	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
464	83765	82761	20100323	20100323	N	U-Unknow	Presumed	Specific bo	10

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465	83766	82762	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
466	83767	82763	20070430	20070430	N	U-Unknow	Presumed	Specific bo	10
449	83768	82749	20010329	20010329	N	B-Good	Presumed	Specific bo	10
451	83769	84168	20070330	20070330	N	U-Unknow	Presumed	Specific bo	20
458	83770	82758	20010329	20010329	N	B-Good	Presumed	Specific bo	10
467	83784	82786	20010406	20010406	N	A-Excellent	Presumed	Specific bo	10
468	83785	82788	20010406	20010406	N	B-Good	Presumed	Specific bo	20
469	83786	82790	20010406	20010406	N	A-Excellent	Presumed	Specific bo	10
470	83787	82791	20010403	20010403	N	B-Good	Presumed	Specific bo	10
471	83788	82792	20100330	20100330	N	U-Unknow	Presumed	Specific bo	10
472	83789	82793	20080510	20080510	N	U-Unknow	Presumed	Specific bo	20
473	83790	82794	20070429	20070429	N	U-Unknow	Presumed	Specific bo	10
474	83791	82795	20100330	20100330	N	U-Unknow	Presumed	Specific bo	10
475	83792	82796	20070430	20070430	N	U-Unknow	Presumed	Specific bo	10
476	83793	82797	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
477	83794	82798	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
478	83795	82799	20010405	20010405	N	A-Excellent	Presumed	Specific bo	10
479	83796	82800	20010405	20010405	N	A-Excellent	Presumed	Specific bo	20
480	83797	82801	20030508	20030508	N	U-Unknow	Presumed	Specific bo	20
481	83798	82802	20030508	20030508	N	U-Unknow	Presumed	Specific bo	10
482	83799	82803	20020507	20020507	N	U-Unknow	Presumed	Specific bo	10
483	83800	82804	20050423	20050423	N	U-Unknow	Presumed	Specific bo	10
484	83801	82805	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
485	83802	82806	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
486	83803	82807	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
487	83804	82808	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
488	83805	82809	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
489	83806	82810	20100402	20100402	N	U-Unknow	Presumed	Specific bo	10
490	83807	82811	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
492	83815	82815	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
493	83816	82816	20010423	20010423	N	U-Unknow	Presumed	Specific bo	10
494	83817	82817	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
495	83818	82818	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
496	83819	82819	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
497	83820	82821	20010331	20010331	N	A-Excellent	Presumed	Specific bo	10
498	83821	82822	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
499	83822	82823	20070430	20070430	N	U-Unknow	Presumed	Specific bo	20
500	83823	82824	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
501	83824	82825	20010331	20010331	N	A-Excellent	Presumed	Specific bo	10
502	83825	82826	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
503	83826	82827	20050423	20050423	N	U-Unknow	Presumed	Specific bo	20
504	83827	82828	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
505	83828	82829	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
506	83829	82830	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
507	83830	82831	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
508	83831	82832	20010330	20010330	N	A-Excellent	Presumed	Specific bo	10
509	83832	82833	20050424	20050424	N	U-Unknow	Presumed	Specific bo	20

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510	83833	82834	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
511	83834	82835	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
512	83835	82836	20050424	20050424	N	U-Unknow	Presumed	Specific bo	10
513	83836	82837	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
514	83837	82839	20040503	20040503	N	U-Unknow	Presumed	Specific bo	10
515	83838	82840	20040503	20040503	N	U-Unknow	Presumed	Specific bo	20
516	83839	82841	20010330	20010330	N	B-Good	Presumed	Specific bo	10
517	83840	82842	20010330	20010330	N	A-Excellent	Presumed	Specific bo	20
518	83875	82876	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
519	83876	82877	20040502	20040502	N	U-Unknow	Presumed	Specific bo	10
520	83877	82878	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
521	83878	82879	20070430	20070430	N	U-Unknow	Presumed	Specific bo	10
522	83879	82880	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
523	83880	82881	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
524	83881	82882	20030512	20030512	N	U-Unknow	Presumed	Specific bo	10
525	83882	82883	20100324	20100324	N	U-Unknow	Presumed	Specific bo	10
526	83883	82884	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
527	83884	82885	20030523	20030523	N	U-Unknow	Presumed	Specific bo	20
528	83885	82886	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
529	83886	82887	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
530	83887	82888	20070429	20070429	N	U-Unknow	Presumed	Specific bo	20
534	83891	82893	20070430	20070430	N	U-Unknow	Presumed	Specific bo	10
535	83892	82894	20040506	20040506	N	U-Unknow	Presumed	Specific bo	10
545	83933	82911	19821207	19821207	N	U-Unknow	Presumed	Non-specif	30
566	83958	82942	20070505	20070505	N	U-Unknow	Presumed	Specific bo	10
567	83959	82943	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
568	83960	82944	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
569	83961	82945	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
570	83962	82946	20070504	20070504	N	U-Unknow	Presumed	Specific bo	20
571	83963	82947	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
572	83964	82948	20010515	20010515	N	U-Unknow	Presumed	Specific bo	10
573	83965	82949	20010515	20010515	N	U-Unknow	Presumed	Specific bo	10
574	83966	82950	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
575	83967	82952	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
576	83968	82953	20050510	20050510	N	U-Unknow	Presumed	Specific bo	10
577	83969	82954	20040410	20040410	N	U-Unknow	Presumed	Specific bo	10
578	83970	82955	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
579	83971	82956	20100328	20100328	N	U-Unknow	Presumed	Specific bo	10
580	83972	82957	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
581	83973	82958	20040411	20040411	N	U-Unknow	Presumed	Specific bo	10
582	83974	82959	20010428	20010428	N	U-Unknow	Presumed	Specific bo	10
590	83982	82971	20050510	20050510	N	U-Unknow	Presumed	Specific bo	10
591	83983	82972	20100401	20100401	N	U-Unknow	Presumed	Specific bo	10
592	83984	82973	20100510	20100510	N	U-Unknow	Presumed	Specific bo	10
593	83985	82974	20050509	20050509	N	U-Unknow	Presumed	Specific bo	20
594	83986	82975	20020519	20020519	N	U-Unknow	Presumed	Specific bo	10
595	83987	82976	20050509	20050509	N	U-Unknow	Presumed	Specific bo	10

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596	83988	82977	20100403	20100403	N	U-Unknow	Presumed	Specific bo	10
597	83989	82978	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
598	83990	82979	20010505	20010505	N	U-Unknow	Presumed	Specific bo	10
636	84062	83071	20080319	20080319	N	U-Unknow	Presumed	Specific bo	20
55	84082	83086	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Non-specif	30
56	84096	83103	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Specific bo	20
637	84107	83111	20010424	20010424	N	U-Unknow	Presumed	Specific bo	10
638	84108	83112	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
639	84109	83113	20010423	20010423	N	U-Unknow	Presumed	Specific bo	10
640	84110	83114	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
641	84111	83115	20020519	20020519	N	U-Unknow	Presumed	Specific bo	20
642	84112	83116	20050528	20050528	N	U-Unknow	Presumed	Specific bo	10
643	84113	83117	20010424	20010424	N	U-Unknow	Presumed	Specific bo	10
644	84114	83118	20020519	20020519	N	U-Unknow	Presumed	Specific bo	20
645	84115	83119	20020519	20020519	N	U-Unknow	Presumed	Specific bo	10
646	84116	83120	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
647	84117	83121	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
648	84118	83122	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
649	84119	83123	20030509	20030509	N	U-Unknow	Presumed	Specific bo	20
650	84120	83124	20030509	20030509	N	U-Unknow	Presumed	Specific bo	20
651	84121	83125	20090602	20090602	N	U-Unknow	Presumed	Specific bo	20
652	84122	83126	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
653	84123	83127	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
654	84124	83128	20100329	20100329	N	U-Unknow	Presumed	Specific bo	10
655	84125	83129	20050528	20050528	N	U-Unknow	Presumed	Specific bo	10
656	84126	83130	20020519	20020519	N	U-Unknow	Presumed	Specific bo	10
657	84127	83131	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
658	84128	83132	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
659	84129	83133	20070502	20070502	N	U-Unknow	Presumed	Specific bo	20
660	84133	83145	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
661	84134	83146	20100324	20100324	N	U-Unknow	Presumed	Specific bo	10
662	84135	83147	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
663	84136	83148	20010424	20010424	N	U-Unknow	Presumed	Specific bo	10
664	84137	83150	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
665	84138	83151	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
666	84139	83152	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
667	84140	83153	20070502	20070502	N	U-Unknow	Presumed	Specific bo	20
668	84141	83154	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
669	84142	83155	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
670	84143	83156	20070501	20070501	N	U-Unknow	Presumed	Specific bo	10
671	84144	83157	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
672	84145	83158	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
673	84146	83159	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
674	84147	83160	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
675	84149	83161	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
676	84150	83162	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
677	84151	83163	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10

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678	84152	83165	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
679	84153	83166	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
680	84154	83167	20040507	20040507	N	U-Unknow	Presumed	Specific bo	20
681	84155	83168	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
682	84156	83169	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
683	84157	83170	20050508	20050508	N	U-Unknow	Presumed	Specific bo	10
684	84158	83171	20040507	20040507	N	U-Unknow	Presumed	Specific bo	20
57	84168	83177	2005XXXX	2005XXXX	N	U-Unknow	Presumed	Circular fea	70
58	84183	83183	20070518	20070518	N	U-Unknow	Presumed	Specific bo	20
59	84186	6374	1987XXXX	1990XXXX	N	U-Unknow	Presumed	Circular fea	90
60	84189	83193	20070707	20070707	N	U-Unknow	Presumed	Specific bo	20
685	84200	83199	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
686	84201	83200	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
687	84202	83201	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
688	84203	83202	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
689	84204	83203	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
690	84205	83204	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
691	84206	83205	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
692	84207	83206	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
693	84208	83207	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
694	84209	83208	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
695	84210	83209	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
696	84211	83210	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
697	84212	83211	20100330	20100330	N	U-Unknow	Presumed	Specific bo	10
698	84213	83214	20090603	20090603	N	U-Unknow	Presumed	Specific bo	10
699	84214	83216	20100326	20100326	N	U-Unknow	Presumed	Specific bo	20
700	84215	83217	20100326	20100326	N	U-Unknow	Presumed	Specific bo	10
701	84216	83218	20090603	20090603	N	U-Unknow	Presumed	Specific bo	10
702	84217	83219	20020516	20030510	N	U-Unknow	Presumed	Specific bo	20
703	84218	83220	20100326	20100326	N	U-Unknow	Presumed	Specific bo	10
704	84219	83221	20100326	20100326	N	U-Unknow	Presumed	Specific bo	10
705	84220	83222	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
706	84221	83223	20030509	20030509	N	U-Unknow	Presumed	Specific bo	20
707	84222	83224	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
708	84223	83225	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
709	84224	83226	20100326	20100326	N	U-Unknow	Presumed	Specific bo	20
710	84225	83227	20100326	20100326	N	U-Unknow	Presumed	Specific bo	10
711	84226	83228	20100326	20100326	N	U-Unknow	Presumed	Specific bo	10
712	84227	83236	20020516	20070502	N	U-Unknow	Presumed	Specific bo	20
713	84241	83235	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
714	84242	83237	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10
715	84243	83238	20030509	20030509	N	U-Unknow	Presumed	Specific bo	20
716	84244	83239	20070502	20070502	N	U-Unknow	Presumed	Specific bo	10
717	84245	83240	20010426	20010426	N	U-Unknow	Presumed	Specific bo	20
718	84246	83241	20050528	20050528	N	U-Unknow	Presumed	Specific bo	10
719	84247	83242	20030510	20030510	N	U-Unknow	Presumed	Specific bo	10
720	84248	83243	20030509	20030509	N	U-Unknow	Presumed	Specific bo	10

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721	84249	83244	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
722	84250	83246	20070503	20070503	N	U-Unknow	Presumed	Specific bo	20
723	84251	83247	20070503	20070503	N	U-Unknow	Presumed	Specific bo	10
724	84252	83249	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
725	84253	83250	20020517	20030509	N	U-Unknow	Presumed	Specific bo	20
726	84254	83251	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
727	84255	83264	20090603	20090603	N	U-Unknow	Presumed	Specific bo	10
728	84256	83266	20090603	20090603	N	U-Unknow	Presumed	Specific bo	20
729	84257	83267	20100325	20100325	N	U-Unknow	Presumed	Specific bo	10
730	84258	83268	20020518	20020518	N	U-Unknow	Presumed	Specific bo	10
731	84259	83269	20080511	20080511	N	U-Unknow	Presumed	Specific bo	10
732	84260	83270	20020516	20020516	N	U-Unknow	Presumed	Specific bo	10
733	84269	83271	20020516	20030510	N	U-Unknow	Presumed	Specific bo	20
734	84270	83273	20030510	20030510	N	U-Unknow	Presumed	Specific bo	10
735	84271	83274	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
736	84272	83275	20030510	20030510	N	U-Unknow	Presumed	Specific bo	20
737	84273	83276	20010425	20010425	N	U-Unknow	Presumed	Specific bo	10
738	84274	83278	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
739	84275	83279	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
740	84276	83280	20100325	20100325	N	U-Unknow	Presumed	Specific bo	10
741	84277	83281	20030510	20030510	N	U-Unknow	Presumed	Specific bo	10
742	84278	83282	20010426	20010426	N	U-Unknow	Presumed	Specific bo	10
743	84281	83283	20100325	20100325	N	U-Unknow	Presumed	Specific bo	10
744	84282	83284	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
745	84283	83285	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
746	84284	83286	20030511	20040508	N	U-Unknow	Presumed	Specific bo	20
747	84285	83287	20070502	20070502	N	U-Unknow	Presumed	Specific bo	20
748	84286	83288	20020516	20020516	N	U-Unknow	Presumed	Specific bo	10
749	84287	83289	20020516	20020516	N	U-Unknow	Presumed	Specific bo	10
750	84288	83290	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
751	84289	83291	20030511	20030511	N	U-Unknow	Presumed	Specific bo	20
752	84290	83292	20030511	20030511	N	U-Unknow	Presumed	Specific bo	20
753	84291	83294	20020518	20020518	N	U-Unknow	Presumed	Specific bo	10
754	84292	83295	20050529	20050529	N	U-Unknow	Presumed	Specific bo	20
755	84293	83296	20010426	20010426	N	U-Unknow	Presumed	Specific bo	20
756	84294	83297	20090604	20090604	N	U-Unknow	Presumed	Specific bo	20
757	84320	83984	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
758	84321	83315	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
759	84322	83316	20090604	20090604	N	U-Unknow	Presumed	Specific bo	20
760	84323	83317	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
761	84324	83318	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
762	84325	83319	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
763	84326	83320	20090602	20090602	N	U-Unknow	Presumed	Specific bo	10
764	84327	83322	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
765	84328	83323	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
766	84329	83324	20070503	20070503	N	U-Unknow	Presumed	Specific bo	10
767	84330	83325	20010426	20010426	N	U-Unknow	Presumed	Specific bo	10

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768	84331	83326	20080512	20080512	N	U-Unknow	Presumed	Specific bo	10
769	84332	83327	20070503	20070503	N	U-Unknow	Presumed	Specific bo	10
770	84333	83328	20080511	20080511	N	U-Unknow	Presumed	Specific bo	10
771	84334	83329	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
49	84436	6674	19210521	19210521	N	U-Unknow	Presumed	Circular fea	90
61	84487	83650	2000XXXX	2000XXXX	N	U-Unknow	Presumed	Circular fea	90
772	84897	83865	20070503	20070503	N	U-Unknow	Presumed	Specific bo	20
773	84898	83866	20010426	20010426	N	U-Unknow	Presumed	Specific bo	10
774	84899	83867	20030510	20030510	N	U-Unknow	Presumed	Specific bo	10
775	84900	83868	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
776	84901	83869	20040508	20040508	N	U-Unknow	Presumed	Specific bo	20
777	84902	83870	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
778	84903	83871	20010426	20010426	N	U-Unknow	Presumed	Specific bo	10
779	84904	83872	20070503	20070503	N	U-Unknow	Presumed	Specific bo	10
780	84905	83873	20100325	20100325	N	U-Unknow	Presumed	Specific bo	10
781	84906	83874	20100325	20100325	N	U-Unknow	Presumed	Specific bo	10
782	84907	83875	20030510	20030510	N	U-Unknow	Presumed	Specific bo	10
783	84908	83876	20050529	20050529	N	U-Unknow	Presumed	Specific bo	20
784	84909	83877	20070503	20070503	N	U-Unknow	Presumed	Specific bo	20
785	84910	83878	20020517	20020517	N	U-Unknow	Presumed	Specific bo	10
786	84911	83879	20070503	20070503	N	U-Unknow	Presumed	Specific bo	20
787	84912	83880	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
788	84913	83881	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
789	84914	83882	20090603	20090603	N	U-Unknow	Presumed	Specific bo	10
790	84915	83883	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
791	84916	83884	20080511	20080511	N	U-Unknow	Presumed	Specific bo	20
792	84917	83885	20080511	20080511	N	U-Unknow	Presumed	Specific bo	20
793	84918	83886	20080511	20080511	N	U-Unknow	Presumed	Specific bo	10
794	84919	83887	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
795	84920	83888	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
796	84921	83889	20040508	20040508	N	U-Unknow	Presumed	Specific bo	20
797	84922	83890	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
798	84933	83901	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
799	84934	83902	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
800	84935	83904	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
801	84936	83905	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
802	84937	83906	20030511	20030511	N	U-Unknow	Presumed	Specific bo	10
803	84938	83907	20020518	20020518	N	U-Unknow	Presumed	Specific bo	20
804	84940	83908	20030511	20030511	N	U-Unknow	Presumed	Specific bo	20
805	84941	83909	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
806	84942	83910	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
807	84943	83911	20090604	20090604	N	U-Unknow	Presumed	Specific bo	10
808	84944	83912	20080511	20080511	N	U-Unknow	Presumed	Specific bo	10
809	84945	83913	20030511	20030511	N	U-Unknow	Presumed	Specific bo	10
810	84946	83914	20030511	20030511	N	U-Unknow	Presumed	Specific bo	20
811	84947	83915	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
812	84948	83916	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10

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813	84949	83917	20050529	20050529	N	U-Unknow	Presumed	Specific bo	20
814	84950	83918	20030511	20030511	N	U-Unknow	Presumed	Specific bo	10
815	84951	83919	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
816	84952	83921	20100327	20100327	N	U-Unknow	Presumed	Specific bo	10
817	84953	83922	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
818	84954	83924	20100325	20100325	N	U-Unknow	Presumed	Specific bo	20
819	84955	83925	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
820	84956	83926	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
821	84957	83927	20010515	20010515	N	U-Unknow	Presumed	Specific bo	20
822	84958	83928	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
823	84959	83929	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
824	84978	83953	20070504	20070504	N	U-Unknow	Presumed	Specific bo	10
825	84979	83954	20040508	20040508	N	U-Unknow	Presumed	Specific bo	20
826	84980	83955	20040508	20070504	N	U-Unknow	Presumed	Specific bo	20
827	84981	83956	20090603	20090603	N	U-Unknow	Presumed	Specific bo	10
828	84982	83958	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
829	84983	83960	20050529	20050529	N	U-Unknow	Presumed	Specific bo	10
830	84984	83961	20040411	20040411	N	U-Unknow	Presumed	Specific bo	20
831	84985	83962	20100327	20100327	N	U-Unknow	Presumed	Specific bo	10
832	84986	83983	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
833	84987	83968	20050529	20050529	N	U-Unknow	Presumed	Specific bo	20
834	84988	83969	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
835	84989	83970	20100327	20100327	N	U-Unknow	Presumed	Specific bo	10
836	84990	83971	20100327	20100327	N	U-Unknow	Presumed	Specific bo	20
837	84992	83972	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
838	84993	83974	20010427	20010427	N	U-Unknow	Presumed	Specific bo	10
839	84994	83975	20080512	20080512	N	U-Unknow	Presumed	Specific bo	10
840	84995	83976	20010514	20010514	N	U-Unknow	Presumed	Specific bo	10
841	84996	83977	20010514	20010514	N	U-Unknow	Presumed	Specific bo	20
842	84997	83978	20010514	20010514	N	U-Unknow	Presumed	Specific bo	10
843	84998	83979	20010514	20010514	N	U-Unknow	Presumed	Specific bo	20
844	84999	83980	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
845	85000	83981	20040509	20040509	N	U-Unknow	Presumed	Specific bo	10
846	85001	83982	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
847	85003	83963	20040508	20040508	N	U-Unknow	Presumed	Specific bo	10
2	85004	83949	20110225	20110225	N	U-Unknow	Presumed	Non-specif	30
98	85034	83995	19620404	19620404	N	U-Unknow	Presumed	Circular fea	90
848	85035	83997	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
849	85036	83998	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
850	85037	83999	20040508	20040508	N	U-Unknow	Presumed	Specific bo	20
851	85039	84000	20040509	20040509	N	U-Unknow	Presumed	Specific bo	10
852	85040	84001	20040509	20040509	N	U-Unknow	Presumed	Specific bo	10
853	85041	84002	20010514	20010514	N	U-Unknow	Presumed	Specific bo	10
854	85042	84003	20040508	20040508	N	U-Unknow	Presumed	Specific bo	20
855	85043	84004	20040509	20040509	N	U-Unknow	Presumed	Specific bo	10
856	85044	84005	20010515	20010515	N	U-Unknow	Presumed	Specific bo	10
857	85045	84006	20010515	20010515	N	U-Unknow	Presumed	Specific bo	20

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858	85046	84007	20030511	20030511	N	U-Unknow	Presumed	Specific bo	10
859	85047	84008	20040507	20040507	N	U-Unknow	Presumed	Specific bo	10
860	85048	84009	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
861	85049	84010	20040411	20040411	N	U-Unknow	Presumed	Specific bo	20
862	85050	84011	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
863	85051	84012	20100327	20100327	N	U-Unknow	Presumed	Specific bo	20
864	85052	84013	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
865	85053	84014	20100327	20100327	N	U-Unknow	Presumed	Specific bo	20
866	85054	84015	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
867	85055	84016	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
868	85056	84017	20100403	20100403	N	U-Unknow	Presumed	Specific bo	20
869	85057	84018	20070508	20070508	N	U-Unknow	Presumed	Specific bo	20
870	85058	84019	20100403	20100403	N	U-Unknow	Presumed	Specific bo	20
871	85059	84020	20070508	20070508	N	U-Unknow	Presumed	Specific bo	10
872	85060	84021	20090606	20090606	N	U-Unknow	Presumed	Specific bo	20
873	85061	84022	20040509	20040509	N	U-Unknow	Presumed	Specific bo	10
874	85062	84023	20010505	20010505	N	U-Unknow	Presumed	Specific bo	10
875	85063	84024	20040509	20040509	N	U-Unknow	Presumed	Specific bo	20
876	85069	84033	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
877	85070	84034	20050427	20050427	N	B-Good	Presumed	Specific bo	10
878	85071	84035	20010404	20010404	N	B-Good	Presumed	Specific bo	10
879	85078	84045	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
890	85079	84047	20050427	20050427	N	U-Unknow	Presumed	Specific bo	20
880	85080	84046	20050427	20050427	N	U-Unknow	Presumed	Specific bo	20
881	85081	84048	20050427	20050427	N	U-Unknow	Presumed	Specific bo	20
882	85082	84049	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
884	85083	84052	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
885	85084	84053	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
886	85085	84054	20050427	20050427	N	U-Unknow	Presumed	Specific bo	20
888	85086	84056	20050427	20050427	N	U-Unknow	Presumed	Specific bo	20
883	85089	84051	20050423	20050423	N	U-Unknow	Presumed	Specific bo	10
887	85090	84055	20040306	20050427	N	U-Unknow	Presumed	Specific bo	10
889	85091	84057	20010328	20010328	N	C-Fair	Presumed	Specific bo	10
891	85092	84058	20010327	20010327	N	C-Fair	Presumed	Specific bo	10
892	85093	84059	20010327	20010327	N	C-Fair	Presumed	Specific bo	10
47	85105	84075	20110308	20110308	N	B-Good	Presumed	Specific bo	10
48	85106	84076	20110308	20110308	N	A-Excellent	Presumed	Specific bo	10
895	85107	84077	20010403	20010403	N	B-Good	Presumed	Specific bo	10
896	85109	84079	20050427	20050427	N	U-Unknow	Presumed	Specific bo	10
897	85111	84081	20050427	20050427	N	A-Excellent	Presumed	Specific bo	20
899	85135	84138	20111021	20111021	N	U-Unknow	Presumed	Specific bo	10
900	85159	84131	20020528	20020528	N	B-Good	Presumed	Specific bo	10
901	85160	84132	20050427	20050427	N	A-Excellent	Presumed	Specific bo	20
902	85161	84133	20050509	20050509	N	A-Excellent	Presumed	Specific bo	20
903	85162	84134	20050427	20050427	N	A-Excellent	Presumed	Specific bo	20
904	85163	84135	20100324	20100324	N	A-Excellent	Presumed	Specific bo	20
905	85164	84136	20050417	20050417	N	A-Excellent	Presumed	Specific bo	20

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906	85165	84137	20010404	20010404	N	U-Unknow	Presumed	Specific bo	10
907	85166	82233	2009XXXX	2009XXXX	N	B-Good	Presumed	Specific bo	20
43	85173	84148	20051012	20051012	N	U-Unknow	Presumed	Specific bo	20
44	85174	84149	20100413	20100413	N	C-Fair	Presumed	Circular fea	40
45	85228	84206	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Circular fea	60
11	85266	84241	20100429	20100429	N	C-Fair	Presumed	Specific bo	10
12	85271	84247	20100324	20100324	N	U-Unknow	Presumed	Circular fea	40
13	85272	84248	20100429	20100429	N	C-Fair	Presumed	Specific bo	10
14	85273	84249	20100429	20100429	N	C-Fair	Presumed	Specific bo	20
15	85274	84250	20100429	20100429	N	C-Fair	Presumed	Specific bo	20
16	85275	84251	20100510	20100510	N	D-Poor	Presumed	Specific bo	20
17	85276	84252	20100429	20100429	N	C-Fair	Presumed	Specific bo	10
18	85277	84253	20100325	20100325	N	U-Unknow	Presumed	Circular fea	40
19	85278	84254	19980308	19980308	N	U-Unknow	Presumed	Non-specif	30
20	85279	84255	20110225	20110225	N	A-Excellent	Presumed	Specific bo	10
21	85280	84256	20110224	20110224	N	B-Good	Presumed	Specific bo	10
10	85289	64295	19600413	19600413	N	U-Unknow	Presumed	Circular fea	50
1	85298	6328	19020113	19020113	N	U-Unknow	Presumed	Circular fea	90
2	85299	84274	19610305	19610305	N	U-Unknow	Presumed	Circular fea	90
5	85304	84276	19620311	19620311	N	U-Unknow	Presumed	Circular fea	70
6	85305	84277	19800410	19800410	N	U-Unknow	Presumed	Circular fea	90
11	85325	43419	19060426	19060426	N	U-Unknow	Presumed	Circular fea	90
57	85331	84304	20100423	20100423	N	U-Unknow	Presumed	Circular fea	50
6	85392	84361	19930319	19930319	N	U-Unknow	Presumed	Circular fea	90
7	85393	84362	20110225	20110225	N	B-Good	Presumed	Specific bo	10
35	85620	84623	20080619	20080619	N	U-Unknow	Presumed	Specific bo	10
36	85622	84624	20080527	20080527	N	U-Unknow	Presumed	Specific bo	10
46	85766	85885	20110226	20110226	N	U-Unknow	Presumed	Circular fea	90
69	85848	84816	20100116	20100116	N	U-Unknow	Presumed	Circular fea	70
70	85849	84817	20080218	20080218	N	U-Unknow	Presumed	Non-specif	30
71	85850	84818	20110109	20110109	N	U-Unknow	Presumed	Circular fea	50
73	85852	84819	20110123	20110123	N	U-Unknow	Presumed	Non-specif	30
74	85853	84820	20111126	20111126	N	U-Unknow	Presumed	Non-specif	30
76	85855	84822	20100206	20100206	N	U-Unknow	Presumed	Non-specif	30
77	85856	6262	20070120	20070120	N	U-Unknow	Presumed	Circular fea	90
78	85857	84823	20110306	20110306	N	U-Unknow	Presumed	Circular fea	70
79	85858	84824	20101118	20101118	N	U-Unknow	Presumed	Circular fea	50
13	85995	35229	19280415	19280415	N	U-Unknow	Presumed	Circular fea	90
6	85999	84963	20100511	20100511	N	C-Fair	Presumed	Specific bo	20
7	86000	84964	20100511	20100511	N	D-Poor	Presumed	Specific bo	20
8	86001	84965	20101118	20101118	N	D-Poor	Presumed	Specific bo	20
9	86002	84966	20101116	20101116	N	D-Poor	Presumed	Specific bo	20
10	86003	84967	20100510	20100510	N	D-Poor	Presumed	Specific bo	20
11	86004	84968	20101116	20101116	N	D-Poor	Presumed	Specific bo	20
12	86005	84969	20101116	20101116	N	D-Poor	Presumed	Specific bo	20
13	86006	84970	20100510	20100510	N	D-Poor	Presumed	Specific bo	20
14	86007	84971	20100402	20100402	N	D-Poor	Presumed	Specific bo	20

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15	86008	84972	19660319	19660319	N	U-Unknow	Presumed	Non-specif	30
80	86036	85110	20061123	20061123	N	U-Unknow	Presumed	Circular fea	60
81	86038	85111	20100308	20100308	N	U-Unknow	Presumed	Non-specif	30
82	86039	85130	20070120	20070120	N	U-Unknow	Presumed	Circular fea	90
83	86040	85112	20110209	20110209	N	U-Unknow	Presumed	Circular fea	60
84	86041	85113	20070120	20070120	N	U-Unknow	Presumed	Circular fea	90
85	86042	85114	20110226	20110226	N	U-Unknow	Presumed	Non-specif	30
1	86045	85009	20120412	20120412	N	C-Fair	Presumed	Specific bo	20
86	86135	85115	20110130	20110130	N	U-Unknow	Presumed	Non-specif	30
87	86137	85878	20041214	20041214	N	U-Unknow	Presumed	Circular fea	90
90	86143	85120	20091222	20091222	N	U-Unknow	Presumed	Non-specif	30
88	86161	85132	20090215	20090215	N	U-Unknow	Presumed	Circular fea	90
89	86164	85139	20081230	20081230	N	U-Unknow	Presumed	Circular fea	90
119	86265	85250	20110917	20110917	N	B-Good	Presumed	Specific bo	20
113	86281	85261	20100720	20100720	N	A-Excellent	Presumed	Specific bo	20
39	86532	85512	2009XXXX	2009XXXX	N	U-Unknow	Presumed	Non-specif	30
40	86533	6696	2009XXXX	2009XXXX	N	U-Unknow	Presumed	Circular fea	90
42	86586	6262	19460411	19460411	N	U-Unknow	Presumed	Circular fea	90
43	86587	6299	19551221	19551221	N	U-Unknow	Presumed	Circular fea	90
44	86600	6647	19100503	19100503	N	U-Unknow	Presumed	Circular fea	90
46	86602	28885	2009XXXX	2009XXXX	N	U-Unknow	Presumed	Circular fea	90
45	86603	85578	2009XXXX	2009XXXX	N	U-Unknow	Presumed	Circular fea	50
47	86608	6571	19400417	19400417	N	U-Unknow	Presumed	Circular fea	90
48	86612	85582	19160123	19160123	N	U-Unknow	Presumed	Circular fea	90
49	86615	85584	19430614	19430614	N	U-Unknow	Presumed	Circular fea	90
54	86644	85611	19770804	19770804	N	U-Unknow	Presumed	Circular fea	90
38	86656	85584	19100512	19100512	N	U-Unknow	Presumed	Circular fea	90
55	86657	85626	19360111	19360111	N	U-Unknow	Presumed	Circular fea	90
56	86677	85651	19390203	19390203	N	U-Unknow	Presumed	Circular fea	90
59	86726	85697	19100331	19100331	N	U-Unknow	Presumed	Circular fea	90
60	86727	85698	19100406	19100406	N	U-Unknow	Presumed	Circular fea	90
179	86778	85751	19770805	19770805	N	U-Unknow	Presumed	Non-specif	30
275	86822	85789	2007XXXX	20120309	N	D-Poor	Presumed	Circular fea	40
279	86830	84821	198904XX	20000623	N	D-Poor	Presumed	Circular fea	70
280	86835	85801	198904XX	198904XX	N	U-Unknow	Presumed	Circular fea	50
2	86839	6674	19300619	19300619	N	U-Unknow	Presumed	Circular fea	90
10	86840	57457	19311231	19311231	N	U-Unknow	Presumed	Circular fea	90
11	86841	81730	19130127	19130127	N	U-Unknow	Presumed	Circular fea	90
1	86843	6717	19210601	19210601	N	U-Unknow	Presumed	Circular fea	90
13	86850	6717	19100423	19980516	N	X-None	Possibly Ex	Circular fea	90
1	86859	6674	191905XX	191905XX	N	U-Unknow	Presumed	Circular fea	90
2	86861	85831	19850308	19850308	N	U-Unknow	Presumed	Circular fea	100
3	86869	85835	19850311	19850311	N	U-Unknow	Presumed	Circular fea	80
15	86907	6674	19160505	19780520	N	X-None	Possibly Ex	Circular fea	90
9	86910	85808	20080722	20080722	N	U-Unknow	Presumed	Specific bo	10
12	86911	86142	20080619	20080619	N	U-Unknow	Presumed	Specific bo	10
17	86920	55928	20000715	200905XX	N	U-Unknow	Presumed	Circular fea	60

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18	86921	85884	19970619	20010715	N	U-Unknow	Presumed	Circular fea	60
62	86970	85938	19500202	19500202	N	U-Unknow	Presumed	Circular fea	90
63	86974	85941	19491008	19491008	N	U-Unknow	Presumed	Circular fea	90
221	87036	86004	20020531	20020531	N	U-Unknow	Presumed	Specific bo	10
223	87041	86008	20020518	20020518	N	U-Unknow	Presumed	Specific bo	20
224	87045	86012	20020516	20020516	N	U-Unknow	Presumed	Specific bo	20
226	87048	86016	20020514	20020514	N	U-Unknow	Presumed	Specific bo	10
227	87049	86017	20020514	20020514	N	U-Unknow	Presumed	Specific bo	10
228	87051	86018	20010626	20010626	N	U-Unknow	Presumed	Specific bo	10
229	87057	86025	20020511	20020511	N	U-Unknow	Presumed	Specific bo	10
40	87063	6696	19100419	19100419	N	U-Unknow	Presumed	Circular fea	90
230	87074	86041	20050928	20050928	N	U-Unknow	Presumed	Specific bo	10
231	87075	86042	20020904	20020904	N	B-Good	Presumed	Specific bo	10
41	87077	85651	19100424	19100424	N	U-Unknow	Presumed	Circular fea	90
232	87078	86044	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
67	87089	86064	20070624	20070624	N	U-Unknow	Presumed	Specific bo	20
238	87092	86057	19800523	19800523	N	U-Unknow	Presumed	Circular fea	60
69	87094	6602	20100602	20100602	N	U-Unknow	Presumed	Circular fea	80
70	87095	86066	20100604	20100604	N	U-Unknow	Presumed	Circular fea	40
247	87111	86074	20110630	20110630	N	C-Fair	Presumed	Specific bo	10
248	87112	86075	20110801	20110801	N	U-Unknow	Presumed	Specific bo	20
249	87113	86077	20110617	20110617	N	B-Good	Presumed	Specific bo	10
250	87117	86078	20110819	20110819	N	B-Good	Presumed	Specific bo	10
251	87118	86082	20180712	20180712	N	C-Fair	Presumed	Non-specif	30
252	87119	86083	20150608	20150608	N	B-Good	Presumed	Specific bo	20
253	87120	86084	20171007	20171007	N	D-Poor	Presumed	Specific bo	20
255	87122	86086	20150505	20150505	N	U-Unknow	Presumed	Specific bo	20
259	87126	86090	19940517	19940517	N	U-Unknow	Presumed	Circular fea	70
75	87223	80714	20100608	20100608	N	U-Unknow	Presumed	Non-specif	30
262	87284	86241	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Non-specif	30
263	87286	86243	2010XXXX	2010XXXX	N	U-Unknow	Presumed	Non-specif	30
265	87288	86245	20070605	20070605	N	B-Good	Presumed	Specific bo	10
266	87289	86246	2007XXXX	2007XXXX	N	B-Good	Presumed	Specific bo	10
272	87295	86252	20100505	20100505	N	U-Unknow	Presumed	Specific bo	10
274	87297	86254	20110725	20110725	N	C-Fair	Presumed	Specific bo	20
275	87298	86255	20110725	20110725	N	B-Good	Presumed	Non-specif	30
277	87300	86257	20110725	20110725	N	C-Fair	Presumed	Specific bo	20
278	87302	86258	20010724	20010724	N	B-Good	Presumed	Specific bo	10
279	87303	86259	20100617	20100617	N	U-Unknow	Presumed	Specific bo	20
280	87304	86260	20101110	20101110	N	U-Unknow	Presumed	Specific bo	10
281	87307	86263	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
281	87456	86419	20110421	20110513	N	U-Unknow	Presumed	Circular fea	50
22	87457	86421	19990816	2004XXXX	N	U-Unknow	Presumed	Non-specif	30
282	87458	86420	20110421	20110513	N	U-Unknow	Presumed	Non-specif	30
23	87459	86422	19990816	2004XXXX	N	U-Unknow	Presumed	Non-specif	30
24	87460	86423	19990816	2004XXXX	N	U-Unknow	Presumed	Non-specif	30
20	87471	6701	19160505	19980516	N	C-Fair	Presumed	Circular fea	90

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139	87523	86421	19990816	19991115	N	U-Unknow	Presumed	Non-specif	30
140	87524	86475	19990816	19991115	N	U-Unknow	Presumed	Non-specif	30
25	87581	86573	20120324	20120324	N	A-Excellent	Presumed	Specific bo	10
26	87582	86575	20120324	20120324	N	C-Fair	Presumed	Specific bo	10
28	87874	86909	20120911	20120911	N	B-Good	Presumed	Specific bo	10
29	87875	86910	20120912	20120912	N	B-Good	Presumed	Specific bo	10
49	87923	86962	19850309	19850309	N	U-Unknow	Presumed	Non-specif	30
50	87924	86971	188104XX	188104XX	N	U-Unknow	Presumed	Circular fea	90
51	87926	86972	20120330	20120330	N	B-Good	Presumed	Specific bo	10
28	88026	87066	20120425	20120425	N	U-Unknow	Presumed	Specific bo	10
66	88065	87066	20120425	20120425	N	U-Unknow	Presumed	Specific bo	10
16	88155	79087	19670513	19670513	N	U-Unknow	Presumed	Circular fea	90
51	88164	87200	20120324	20120324	N	D-Poor	Presumed	Specific bo	10
17	88165	87200	20120324	20120324	N	U-Unknow	Presumed	Specific bo	10
18	88166	87204	20120323	20120323	N	U-Unknow	Presumed	Specific bo	10
19	88169	87205	20120325	20120325	N	U-Unknow	Presumed	Specific bo	10
20	88170	87202	20120323	20120323	N	U-Unknow	Presumed	Specific bo	10
21	88171	87206	20120424	20120424	N	U-Unknow	Presumed	Specific bo	10
52	88172	87202	20120323	20120323	N	C-Fair	Presumed	Specific bo	10
22	88173	87214	20120424	20120424	N	U-Unknow	Presumed	Specific bo	10
53	88178	87206	20120424	20120424	N	C-Fair	Presumed	Specific bo	10
54	88179	87214	20120424	20120424	N	B-Good	Presumed	Specific bo	10
27	88190	87224	19920521	19920521	N	U-Unknow	Presumed	Non-specif	30
18	88192	87204	20120323	20120323	N	U-Unknow	Presumed	Specific bo	10
19	88193	87202	20120323	20120323	N	U-Unknow	Presumed	Specific bo	10
20	88194	87214	20120424	20120424	N	U-Unknow	Presumed	Specific bo	10
21	88267	87204	20120323	20120323	N	D-Poor	Presumed	Specific bo	10
35	88316	87329	20120903	20120903	N	C-Fair	Presumed	Specific bo	10
2	88329	87344	20120412	20120412	N	U-Unknow	Presumed	Specific bo	10
43	88330	87345	20120903	20120903	N	B-Good	Presumed	Specific bo	10
44	88331	87346	20120903	20120903	N	B-Good	Presumed	Specific bo	10
45	88332	87347	20120905	20120905	N	D-Poor	Presumed	Circular fea	40
49	88337	87351	20120905	20120905	N	D-Poor	Presumed	Specific bo	10
50	88338	87352	20120905	20120905	N	C-Fair	Presumed	Specific bo	10
213	88389	87399	20110221	20110221	N	U-Unknow	Presumed	Specific bo	10
19	88401	87206	20120424	20120424	N	U-Unknow	Presumed	Specific bo	10
20	88402	87214	20120424	20120424	N	U-Unknow	Presumed	Specific bo	10
37	88441	87204	20120323	20120323	N	U-Unknow	Presumed	Specific bo	10
264	88534	87560	XXXXXXXX	XXXXXXXX	N	U-Unknow	Presumed	Specific bo	10
48	88728	85831	20090302	20090302	N	U-Unknow	Presumed	Circular fea	100
351	89089	88071	19861211	19861211	N	C-Fair	Presumed	Circular fea	50
2	89171	88149	2004XXXX	2004XXXX	N	B-Good	Presumed	Specific bo	20
3	89394	88383	19100405	19100405	N	X-None	Possibly Ex	Non-specif	30
29	89443	88149	2004XXXX	2004XXXX	N	U-Unknow	Presumed	Specific bo	20
30	89461	88452	19941201	19941201	N	U-Unknow	Presumed	Specific bo	20
31	89489	88478	19580430	19580430	N	U-Unknow	Presumed	Specific bo	20
32	89490	88479	19561231	19561231	N	U-Unknow	Presumed	Circular fea	90

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34	89492	88481	19491216	19491216	N	U-Unknow	Presumed	Non-specif	30
35	89493	88483	19500405	19500405	N	U-Unknow	Presumed	Circular fea	70
37	89508	88498	19510103	19510103	N	U-Unknow	Presumed	Circular fea	90
33	89515	88504	19450514	19450514	N	U-Unknow	Presumed	Non-specif	30
66	89534	88525	20120820	20120820	N	U-Unknow	Presumed	Specific bo	10
232	89633	88618	20120503	20120503	N	U-Unknow	Presumed	Circular fea	40
88	89758	88744	20121111	20121111	N	C-Fair	Presumed	Specific bo	10
925	89881	88871	20010327	20010327	N	C-Fair	Presumed	Specific bo	10
926	89884	88875	20110525	20110525	N	U-Unknow	Presumed	Specific bo	10
245	89931	88924	20020309	20020309	N	B-Good	Presumed	Non-specif	30
498	89935	88926	19770605	19770605	Y	U-Unknow	Presumed	Circular fea	60
28	90130	89126	20121117	20121117	N	C-Fair	Presumed	Specific bo	10
1	91951	27990	19121021	19121021	N	U-Unknow	Presumed	Circular fea	90
2	91952	90910	19990815	19990815	N	U-Unknow	Presumed	Circular fea	90
3	91953	90911	20121111	20121111	N	U-Unknow	Presumed	Non-specif	30
58	92467	91358	20130324	20130324	N	U-Unknow	Presumed	Specific bo	20
1	92514	6674	19410518	19410518	N	X-None	Extirpated	Circular fea	90
2	92518	91456	19411130	19411130	N	X-None	Extirpated	Circular fea	90
3	92520	6571	19170407	19170407	N	X-None	Extirpated	Circular fea	90
12	92731	86971	18810325	18810325	N	U-Unknow	Presumed	Circular fea	90
29	92759	91684	20130317	20130317	N	B-Good	Presumed	Specific bo	10
4	92796	27990	191204XX	191204XX	N	X-None	Possibly Ex	Circular fea	90
5	92800	28885	19760415	19760415	N	X-None	Possibly Ex	Circular fea	90
58	93049	91975	20100526	20100526	N	U-Unknow	Presumed	Specific bo	10
251	93050	91977	19180514	19180514	N	U-Unknow	Presumed	Circular fea	90
252	93061	91986	19470528	19470528	N	U-Unknow	Presumed	Circular fea	40
253	93064	81730	19281113	19281113	N	U-Unknow	Presumed	Circular fea	90
56	93647	92503	20020302	20020302	N	U-Unknow	Presumed	Specific bo	10
52	94710	93577	20130310	20130310	N	B-Good	Presumed	Specific bo	10
53	94711	93578	20130310	20130310	N	B-Good	Presumed	Specific bo	10
54	94712	93579	19280601	19280601	N	U-Unknow	Presumed	Non-specif	30
53	94753	93622	20121115	20121115	N	D-Poor	Presumed	Specific bo	10
90	94813	93668	20131018	20131018	N	B-Good	Presumed	Specific bo	10
91	94815	93671	20131018	20131018	N	A-Excellent	Presumed	Specific bo	10
20	95016	93889	20130310	20130310	N	C-Fair	Presumed	Specific bo	10
21	95020	93894	20130309	20130309	N	C-Fair	Presumed	Specific bo	10
16	95058	93945	20131018	20131018	N	B-Good	Presumed	Specific bo	10
17	95059	87200	20130324	20130324	N	U-Unknow	Presumed	Specific bo	10
20	95064	93959	19850306	19850306	N	U-Unknow	Presumed	Non-specif	30
29	95175	94053	20130317	20130317	N	B-Good	Presumed	Specific bo	10
13	95739	93671	20131018	20131018	N	A-Excellent	Presumed	Specific bo	10
18	96849	95715	20110412	20110412	N	U-Unknow	Presumed	Specific bo	10
59	97267	96112	20150322	20150322	N	A-Excellent	Presumed	Specific bo	20
216	97491	96328	1998XXXX	1998XXXX	N	U-Unknow	Presumed	Non-specif	30
282	97605	96438	20140531	20140531	N	D-Poor	Presumed	Specific bo	10
283	97606	96439	20081003	20081003	N	U-Unknow	Presumed	Specific bo	10
284	97608	96440	20110127	20110127	N	U-Unknow	Presumed	Specific bo	10

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285	97609	96442	20100529	20100529	N	U-Unknow	Presumed	Specific bo	10
286	97627	96449	19840627	19840627	N	U-Unknow	Presumed	Circular fea	50
287	97628	96450	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Non-specif	30
288	97629	96451	20120911	20120911	N	U-Unknow	Presumed	Specific bo	10
289	97635	96453	1985XXXX	1985XXXX	N	U-Unknow	Presumed	Non-specif	30
290	97647	96471	20000716	20000716	N	U-Unknow	Presumed	Non-specif	30
291	97671	96501	20000712	20000712	N	U-Unknow	Presumed	Circular fea	40
292	97672	96502	20000715	20000715	N	U-Unknow	Presumed	Non-specif	30
293	97673	96503	20140813	20140813	N	C-Fair	Presumed	Specific bo	10
294	97676	96506	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	40
295	97681	96511	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
296	97683	96513	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
297	97685	96516	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
298	97688	96519	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Non-specif	30
299	97699	96526	19330604	19330604	N	U-Unknow	Presumed	Circular fea	90
300	97704	96529	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
301	97715	96541	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Non-specif	30
302	97717	96542	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
303	97720	96544	20130314	20130314	N	U-Unknow	Presumed	Specific bo	10
304	97722	96546	20130318	20130318	N	U-Unknow	Presumed	Specific bo	10
305	97723	96547	20140428	20140428	N	U-Unknow	Presumed	Circular fea	50
306	97724	96548	20100819	20100819	N	U-Unknow	Presumed	Specific bo	10
307	97729	96551	19360410	19360410	N	U-Unknow	Presumed	Circular fea	90
308	97730	96553	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Circular fea	50
309	97732	96555	2001XXXX	2001XXXX	N	U-Unknow	Presumed	Non-specif	30
310	97734	96556	19790429	19790429	N	U-Unknow	Presumed	Non-specif	30
311	97736	96558	20140428	20140428	N	U-Unknow	Presumed	Specific bo	10
312	97752	96576	20030720	20030720	N	U-Unknow	Presumed	Specific bo	20
313	97763	96585	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
314	97765	96587	19930805	19930805	N	U-Unknow	Presumed	Non-specif	30
315	97767	96589	19930806	19930806	N	U-Unknow	Presumed	Non-specif	30
316	97770	96593	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
317	97778	96601	20020823	20020823	N	U-Unknow	Presumed	Non-specif	30
318	97779	96602	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
319	97781	96603	20030627	20030627	N	U-Unknow	Presumed	Non-specif	30
320	97782	96605	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
321	97784	96607	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
322	97785	96608	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
323	97786	96609	20020823	20020823	N	U-Unknow	Presumed	Circular fea	40
324	97787	96611	20120910	20120910	N	U-Unknow	Presumed	Specific bo	10
326	97795	96618	20120615	20120615	N	B-Good	Presumed	Specific bo	10
327	97815	96626	20000706	20000706	N	U-Unknow	Presumed	Circular fea	40
328	97818	96630	20000706	20000706	N	U-Unknow	Presumed	Circular fea	40
329	97820	96633	19870624	19870624	N	U-Unknow	Presumed	Non-specif	30
330	97827	96638	20030828	20030828	N	U-Unknow	Presumed	Specific bo	20
331	97829	96645	20030820	20030820	N	U-Unknow	Presumed	Specific bo	10
332	97830	96648	19870624	19870624	N	U-Unknow	Presumed	Non-specif	30

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333	97834	96653	2010XXXX	2010XXXX	N	U-Unknow	Presumed	Circular fea	60
334	97835	96654	19870624	19870624	N	U-Unknow	Presumed	Non-specif	30
335	97844	96661	20000710	20000710	N	U-Unknow	Presumed	Non-specif	30
336	97849	96668	20000709	20000709	N	U-Unknow	Presumed	Non-specif	30
337	97851	96670	20090715	20090715	N	U-Unknow	Presumed	Non-specif	30
338	97852	96671	19790423	19790423	N	U-Unknow	Presumed	Non-specif	30
339	97854	96672	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
340	97857	96676	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
341	97861	96680	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
342	97863	96681	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
343	97874	96691	19960809	19960809	N	U-Unknow	Presumed	Circular fea	50
344	97905	96715	199407XX	199407XX	N	U-Unknow	Presumed	Specific bo	10
345	97906	96716	199407XX	199407XX	N	U-Unknow	Presumed	Specific bo	10
348	97953	96748	199407XX	199407XX	N	U-Unknow	Presumed	Specific bo	10
350	97956	96751	199407XX	199407XX	N	U-Unknow	Presumed	Specific bo	10
354	97967	96757	199107XX	199107XX	N	U-Unknow	Presumed	Specific bo	10
355	97969	96759	199407XX	199407XX	N	U-Unknow	Presumed	Specific bo	10
356	98012	96796	19850625	19850625	N	U-Unknow	Presumed	Non-specif	30
358	98103	96878	20150601	20150601	N	U-Unknow	Presumed	Specific bo	20
360	98110	96882	20150601	20150601	N	U-Unknow	Presumed	Specific bo	10
361	98113	96883	20150609	20150609	N	U-Unknow	Presumed	Specific bo	10
382	98193	96954	20150707	20150707	N	D-Poor	Presumed	Specific bo	10
383	98196	96958	20150707	20150707	N	U-Unknow	Presumed	Specific bo	10
387	98265	97026	19590327	19590327	N	U-Unknow	Presumed	Circular fea	90
390	98449	97189	20150723	20150723	N	U-Unknow	Presumed	Specific bo	10
391	98451	97190	20150811	20150811	N	U-Unknow	Presumed	Specific bo	20
392	98452	97192	20150723	20150723	N	U-Unknow	Presumed	Specific bo	10
393	98453	97193	20150805	20150805	N	U-Unknow	Presumed	Specific bo	10
394	98455	97194	20150811	20150811	N	U-Unknow	Presumed	Specific bo	10
346	98599	97330	1993XXXX	1993XXXX	N	U-Unknow	Presumed	Non-specif	30
217	99133	6299	19481029	19481029	N	U-Unknow	Presumed	Circular fea	90
282	100407	58285	19930404	19930404	N	U-Unknow	Presumed	Circular fea	90
1934	100672	99150	20070104	200805XX	N	U-Unknow	Presumed	Specific bo	10
14	101634	A0079	19261223	19261223	N	U-Unknow	Presumed	Circular fea	90
16	101635	6054	19090328	19090328	N	U-Unknow	Presumed	Circular fea	90
18	101651	A0095	19090429	19090429	N	U-Unknow	Presumed	Circular fea	90
19	101656	6571	19140404	19140404	N	U-Unknow	Presumed	Circular fea	90
20	101662	56801	19090410	19090410	N	U-Unknow	Presumed	Circular fea	90
21	101663	6647	19100503	19100503	N	U-Unknow	Presumed	Circular fea	90
18	101736	A0175	20150312	20150312	N	U-Unknow	Presumed	Specific bo	10
19	101738	A0176	20150312	20150312	N	U-Unknow	Presumed	Specific bo	10
379	101848	A0285	20121217	20121217	N	U-Unknow	Presumed	Specific bo	10
91	103387	A1793	20090427	20090427	N	X-None	Extirpated	Non-specif	30
92	103390	A1797	20090108	20090108	N	D-Poor	Presumed	Specific bo	10
93	103391	A1798	20090108	20090108	N	D-Poor	Presumed	Circular fea	40
94	103415	A1820	20080710	20080710	N	D-Poor	Presumed	Specific bo	10
12	103702	A2098	19650412	19650412	Y	U-Unknow	Presumed	Circular fea	70

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254	104240	A2649	20090330	20090330	N	U-Unknow	Presumed	Specific bo	10
13	104597	A2976	198XXXXX	198XXXXX	Y	U-Unknow	Presumed	Circular fea	70
192	105275	A3640	20150411	20150411	N	U-Unknow	Presumed	Circular fea	90
163	105485	A3830	19790623	19790623	N	U-Unknow	Presumed	Circular fea	60
338	105641	A3977	19760627	19760627	N	U-Unknow	Presumed	Circular fea	60
9	105725	81730	186XXXXX	186XXXXX	N	U-Unknow	Presumed	Circular fea	90
23	105741	A5571	19470601	19470601	N	U-Unknow	Presumed	Non-specif	30
21	105826	A4149	19740430	19740430	N	U-Unknow	Presumed	Circular fea	90
1	106610	A4917	19580506	19580506	N	U-Unknow	Presumed	Non-specif	30
2	106616	28885	19350416	19350416	N	U-Unknow	Presumed	Circular fea	90
3	106625	A4929	19831111	19831111	N	U-Unknow	Presumed	Non-specif	30
4	106627	78478	19860309	19860309	N	U-Unknow	Presumed	Non-specif	30
5	106628	A4931	19490406	19490406	N	U-Unknow	Presumed	Circular fea	80
11	106648	A4953	20161206	20161206	N	U-Unknow	Presumed	Specific bo	10
290	107309	A5572	20150725	20150725	N	U-Unknow	Presumed	Specific bo	10
2020	108566	A6795	20160630	20160630	N	A-Excellent	Presumed	Specific bo	20
42	110013	A8232	20150506	20150506	N	B-Good	Presumed	Specific bo	10
22	110231	A8441	19740327	19740327	N	U-Unknow	Presumed	Non-specif	30
23	110232	A8442	20150505	20150505	N	A-Excellent	Presumed	Specific bo	10
24	110234	A8444	2010XXXX	2010XXXX	N	U-Unknow	Presumed	Specific bo	20
25	110235	A8445	2010XXXX	2010XXXX	N	U-Unknow	Presumed	Specific bo	10
26	110236	A8446	2011XXXX	2011XXXX	N	U-Unknow	Presumed	Specific bo	20
27	110237	A8447	2011XXXX	2011XXXX	N	U-Unknow	Presumed	Specific bo	10
31	110242	A8452	20170321	20170321	N	U-Unknow	Presumed	Specific bo	10
20	110335	A8232	20150505	20150505	N	C-Fair	Presumed	Specific bo	10
82	111516	A9658	20170321	20170321	N	U-Unknow	Presumed	Specific bo	10
6	111608	A9753	20180504	20180504	N	C-Fair	Presumed	Specific bo	10
7	111609	A9754	20180504	20180504	N	C-Fair	Presumed	Specific bo	10
8	111610	A9755	20170907	20170907	N	A-Excellent	Presumed	Specific bo	20
9	111702	A9838	20170301	20170301	N	U-Unknow	Presumed	Circular fea	50
395	113155	B1260	20170531	20170531	N	U-Unknow	Presumed	Specific bo	20
396	113156	B1261	20170531	20170531	N	U-Unknow	Presumed	Specific bo	10
5	114073	6717	19550716	19550716	N	U-Unknow	Presumed	Circular fea	90
999	114445	B2516	20100124	20100124	N	U-Unknow	Presumed	Circular fea	40
397	114709	B2775	20170831	20170831	N	C-Fair	Presumed	Specific bo	10
13	114712	B2778	20180702	20180702	N	B-Good	Presumed	Non-specif	30
14	114713	B2779	20180616	20180616	N	A-Excellent	Presumed	Non-specif	30
580	114715	B2781	20170721	20170721	N	A-Excellent	Presumed	Specific bo	10
15	114736	B2802	20180601	20180601	N	A-Excellent	Presumed	Non-specif	30
16	114738	B2803	20180725	20180725	N	B-Good	Presumed	Non-specif	30
398	114743	B2809	20170725	20170725	N	B-Good	Presumed	Specific bo	10
46	115014	B3091	19921025	19921025	N	U-Unknow	Presumed	Non-specif	30
399	116586	B3673	20150504	20150504	N	U-Unknow	Presumed	Specific bo	10
400	116588	B3676	20150630	20150630	N	U-Unknow	Presumed	Specific bo	10
20	117170	B4243	20190602	20190602	N	B-Good	Presumed	Specific bo	20
401	117253	B4325	20170314	20170314	N	B-Good	Presumed	Specific bo	10
1	118236	76077	19930701	19930701	N	U-Unknow	Presumed	Specific bo	20

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1	118239	B5349	197209XX	197209XX	N	U-Unknow	Presumed	Non-specif	30
1	118240	B5349	19820915	19820915	N	U-Unknow	Presumed	Non-specif	30
1	118258	B5349	19880912	19880912	N	U-Unknow	Presumed	Non-specif	30
1	118271	B5349	20080603	20080603	N	U-Unknow	Presumed	Non-specif	30
1	118339	B5349	19881010	19881010	N	U-Unknow	Presumed	Non-specif	30
1	118355	B5349	19720409	19720409	N	U-Unknow	Presumed	Non-specif	30

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Trend	OccType	County	Quad	Elevation	Latitude	Longitude	UTM	PLSS	Location
Unknown	Natural/Na	Imperial	Borrego M	10	33.10192	-116.048	Zone-11 N	T12S, R09E	BAILEYS WI
Stable	Natural/Na	Imperial	Bard (3211	275	32.8462	-114.506	Zone-11 N	T15S, R23E	"THREE C D
Unknown	Natural/Na	Imperial	Ogilby (321	560	32.83105	-114.779	Zone-11 N	T15S, R21E	"SOUTH OF
Unknown	Natural/Na	Imperial	Ogilby (321	720	32.83464	-114.78	Zone-11 N	T15S, R21E	"CARGO M
Unknown	Natural/Na	Imperial	Ogilby (321	880	32.8375	-114.775	Zone-11 N	T15S, R21E	"NE OF CAF
Unknown	Natural/Na	Imperial	Ogilby (321	600	32.84153	-114.792	Zone-11 N	T15S, R21E	"PADRE MA
Unknown	Natural/Na	Imperial	Ogilby (321	880	32.8553	-114.765	Zone-11 N	T15S, R21E	"GUADALU
Unknown	Natural/Na	Imperial	Ogilby (321	740	32.85575	-114.786	Zone-11 N	T15S, R21E	"TYBO MIN
Unknown	Natural/Na	Imperial	Coyote We	375	32.7133	-115.965	Zone-11 N	T16.5S, R1(	0.6 MILE SC
Unknown	Natural/Na	Imperial	Coyote We	300	32.71895	-115.959	Zone-11 N	T16.5S, R1(	JUST SOUT
Unknown	Natural/Na	Imperial	Ogilby (321	720	32.83483	-114.779	Zone-11 N	T15S, R21E	CARGO MI
Unknown	Natural/Na	Imperial	Ogilby (321	680	32.87532	-114.816	Zone-11 N	T15S, R20E	CROWN MI
Unknown	Natural/Na	Imperial	Hedges (32	720	32.8846	-114.82	Zone-11 N	T15S, R20E	QUEEN MI
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.12992	-115.06	Zone-11 N	T12S, R18E	"MARY LOI
Unknown	Natural/Na	Imperial	Obsidian B	-230	33.14022	-115.658	Zone-11 N	T12S, R13E	UNNAMED
Unknown	Natural/Na	Imperial	Obsidian B	-230	33.16208	-115.64	Zone-11 N	T12S, R13E	MOUTH OF
Unknown	Natural/Na	Imperial	Frink (3311	-226	33.35546	-115.705	Zone-11 N	T09S, R12E	INSHORE P
Unknown	Natural/Na	Imperial	Wister (331	-230	33.28507	-115.605	Zone-11 N	T10S, R13E	NILAND LA
Unknown	Natural/Na	Imperial	Wister (331	-230	33.29209	-115.611	Zone-11 N	T10S, R13E	INSHORE P
Unknown	Natural/Na	Imperial	Wister (331	-230	33.3018	-115.616	Zone-11 N	T10S, R13E	INSHORE P
Unknown	Natural/Na	Imperial	Wister (331	-230	33.30878	-115.623	Zone-11 N	T10S, R13E	INSHORE P
Unknown	Natural/Na	Imperial	Wister (331	-230	33.30642	-115.618	Zone-11 N	T10S, R13E	MOUTH OF
Unknown	Natural/Na	Imperial	Ogilby (321	550	32.83702	-114.819	Zone-11 N	T15S, R20E	ABOUT 1.5
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Obsidian B	-235	33.17313	-115.642	Zone-11 N	T11S, R13E	SALTON SE
Unknown	Natural/Na	Imperial	Niland (331	-235	33.22531	-115.609	Zone-11 N	T11S, R13E	MULLET ISI
Unknown	Natural/Na	Imperial	Coyote We	340	32.67256	-115.895	Zone-11 N	T17S, R11E	6 AIR MILE
Fluctuating	Natural/Na	Imperial | I	Grays Well	200	32.90611	-115.061	Zone-11 N	T14S, R18E	ALGODONE
Unknown	Natural/Na	Imperial | I	Grays Well	220	32.7278	-114.782	Zone-11 N	T16S, R21E	SE CORNER
Stable	Natural/Na	Imperial | I	Grays Well	300	32.92889	-115.075	Zone-11 N	T14S, R18E	ALGODONE
Increasing	Natural/Na	Imperial	Grays Well	300	32.91623	-115.089	Zone-11 N	T14S, R18E	ALGODONE
Unknown	Natural/Na	Imperial | I	Grays Well NE	(321146	32.92004	-115.064	Zone-11 N	T14S, R18E	ALGODONE
Unknown	Natural/Na	Imperial	Mt. Barrow	1120	33.18913	-114.912	Zone-11 N	T11S, R20E	3.5 MILES N
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.10356	-115.693	Zone-11 N	T12S, R12E	INSHORE P
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.11027	-115.683	Zone-11 N	T12S, R12E	INSHORE P
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.0954	-115.718	Zone-11 N	T12S, R12E	TRIFOLIUM
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.09727	-115.727	Zone-11 N	T12S, R12E	TRIFOLIUM
Unknown	Natural/Na	Imperial	El Centro (3	2	32.75997	-115.612	Zone-11 N	T16S, R13E	ALONG THI
Unknown	Natural/Na	Imperial | I	Mt. Barrow	1400	33.29899	-115.219	Zone-11 N	T10S, R17E	CHOCOLAT
Unknown	Natural/Na	Imperial	Kane Spring	150	33.00798	-115.825	Zone-11 N	T13S, R11E	E OF BORR
Unknown	Natural/Na	Imperial | I	Imperial Re	60	32.91126	-114.476	Zone-11 N	T14S, R24E	COLORADC
Unknown	Natural/Na	Imperial	Yuha Basin	110	32.67708	-115.764	Zone-11 N	T17S, R12E	PINTO WAS

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Unknown	Natural/Na	Imperial	Kane Spring	-230	33.13949	-115.792	Zone-11 NA	T12S, R11E SAN FELIPE
Unknown	Natural/Na	Imperial	East of Aco	650	33.10237	-115.057	Zone-11 NA	T12S, R18E S END CHO
Unknown	Natural/Na	Imperial	Shell Reef (	120	33.22203	-116.042	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial | A	Laguna Dar	160	32.85427	-114.486	Zone-11 NA	T15S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Iris (33115	20	33.16121	-115.387	Zone-11 NA	T12S, R15E W SIDE CO/
Unknown	Natural/Na	Imperial	Midway W	95	32.70512	-115.172	Zone-11 NA	T17S, R18E ALL AMERI
Unknown	Natural/Na	Imperial | A	Picacho NV	220	33.2618	-114.688	Zone-11 NA	T10S, R22E VICINITY O
Unknown	Natural/Na	Imperial	Little Chucl	1200				*SENSITIVE
Decreasing	Natural/Na	Imperial | A	Laguna Dar	180	32.88393	-114.471	Zone-11 NA	T15S, R24E IMPERIAL F
Decreasing	Natural/Na	Imperial	Bard (3211	160	32.83245	-114.544	Zone-11 NA	T15S, R23E SOUTH SID
Increasing	Natural/Na	Imperial	Picacho (33	200	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.12729	-115.781	Zone-11 NA	T12S, R11E TRIFOLIUM
Unknown	Natural/Na	Imperial | A	Yuma West	120	32.74698	-114.7	Zone-11 NA	T16S, R22E FORT YUMA
Unknown	Natural/Na	Imperial	Coyote We	340	32.67364	-115.896	Zone-11 NA	T17S, R11E BLM CRUCI
Unknown	Natural/Na	Imperial	Coyote We	850	32.63938	-115.952	Zone-11 NA	T17S, R10E SKULL CAN
Unknown	Natural/Na	Imperial	Ogilby (321	240	32.7542	-114.824	Zone-11 NA	T16S, R20E ABOUT 0.8
Unknown	Natural/Na	Imperial	Ogilby (321	220	32.7574	-114.84	Zone-11 NA	T16S, R20E INTERSECT
Unknown	Natural/Na	Imperial	Ogilby (321	240	32.77837	-114.853	Zone-11 NA	T16S, R20E PILOT KNO
Unknown	Natural/Na	Imperial	Coyote We	280	32.73672	-115.964	Zone-11 NA	T16S, R10E NEAR COYC
Unknown	Natural/Na	Imperial | S	In-ko-pah Gorge (3211		32.69118	-116.101	Zone-11 NA	T17S, R09E NORTH OF
Unknown	Natural/Na	Imperial	Picacho Pe	490	32.98063	-114.636	Zone-11 NA	T14S, R22E IN LITTLE P
Unknown	Natural/Na	Imperial	Laguna Dar	160	32.85548	-114.491	Zone-11 NA	T15S, R24E BETWEEN A
Unknown	Natural/Na	Imperial | A	Laguna Dar	160	32.85092	-114.484	Zone-11 NA	T15S, R24E ALONG THE
Unknown	Natural/Na	Imperial	Coyote We	280	32.73672	-115.964	Zone-11 NA	T16S, R10E COYOTE W
Unknown	Natural/Na	Imperial	Brawley NV	150	32.91593	-115.748	Zone-11 NA	T14S, R12E 1 MILE NOI
Unknown	Natural/Na	Imperial	Brawley NV	140	32.93046	-115.75	Zone-11 NA	T14S, R12E 10.5 MILES
Unknown	Natural/Na	Imperial	Kane Spring	150	33.00989	-115.79	Zone-11 NA	T13S, R11E E OF BORR
Unknown	Natural/Na	Imperial	Brawley NV	100	32.95168	-115.733	Zone-11 NA	T14S, R12E ALONG RO/
Unknown	Natural/Na	Imperial	Kane Spring	15	33.233	-115.991	Zone-11 NA	T11S, R09E ALONG JEE
Unknown	Natural/Na	Imperial	Ninemile Wash (33114		33.13277	-114.99	Zone-11 NA	T12S, R19E CHOCOLAT
Unknown	Natural/Na	Imperial	Picacho Peak (3211486		33.11536	-114.764	Zone-11 NA	T12S, R21E PICHACO P
Unknown	Natural/Na	Imperial | E	East of Acolita (331151		33.31808	-115.309	Zone-11 NA	T10S, R16E CHOCOLAT
Increasing	Natural/Na	Imperial | I	In-ko-pah G	2000	32.66183	-116.06	Zone-11 NA	T17S, R09E PINTO/INK
Stable	Natural/Na	Imperial | S	Coyote We	2300	32.6954	-116.093	Zone-11 NA	T17S, R09E TIERRA BLA
Decreasing	Natural/Na	Imperial	Picacho (33	195	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Unknown	Natural/Na	Imperial	Picacho (33	200	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Decreasing	Natural/Na	Imperial	Bard (3211	145	32.82968	-114.539	Zone-11 NA	T15S, R23E ALL AMERI
Decreasing	Natural/Na	Imperial	Bard (3211	145	32.82968	-114.539	Zone-11 NA	T15S, R23E ALL AMERI
Decreasing	Natural/Na	Imperial	Picacho (33	195	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Decreasing	Natural/Na	Imperial	Bard (3211	150	32.82968	-114.539	Zone-11 NA	T15S, R23E ALL AMERI
Decreasing	Natural/Na	Imperial	Picacho (33	195	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Decreasing	Natural/Na	Imperial	Bard (3211	145	32.83243	-114.539	Zone-11 NA	T15S, R23E NORTH & S
Unknown	Natural/Na	Imperial	Picacho (33	195	33.02259	-114.612	Zone-11 NA	T13S, R22E PICACHO ST
Decreasing	Natural/Na	Imperial	Bard (3211	150	32.82968	-114.539	Zone-11 NA	T15S, R23E ALL AMERI
Unknown	Natural/Na	Imperial	Picacho (33	195	33.02331	-114.613	Zone-11 NA	T13S, R22E VICINITY O
Stable	Natural/Na	Imperial	Niland (331	-215	33.27344	-115.584	Zone-11 NA	T10S, R13E WISTER UN
Stable	Natural/Na	Imperial	Calipatria S	-235	33.09439	-115.706	Zone-11 NA	T12S, R12E BRUCHARD

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Unknown	Natural/Na	Imperial | A	Picacho (33	190	33.02696	-114.606	Zone-11 NA	T99X, R99X	IMPERIAL N
Stable	Natural/Na	Imperial | A	Laguna Dar	150	32.85535	-114.484	Zone-11 NA	T15S, R24E	COLORADC
Decreasing	Natural/Na	Imperial | A	Yuma East	125	32.73544	-114.659	Zone-11 NA	T16S, R22E	COLORADC
Unknown	Natural/Na	Imperial | A	Picacho NV	200	33.17959	-114.679	Zone-11 NA	T11S, R22E	COLORADC
Fluctuating	Natural/Na	Imperial | A	Cibola (331	220	33.32083	-114.716	Zone-11 NA	T10S, R21E	NORTHERN
Unknown	Natural/Na	Imperial	Brawley NV	150	32.95448	-115.763	Zone-11 NA	T14S, R12E	ALONG HU
Unknown	Natural/Na	Imperial	Yuha Basin	100	32.73324	-115.817	Zone-11 NA	T16S, R11E	SHELL BEDS
Unknown	Natural/Na	Imperial	Glamis SW	100	32.79365	-115.216	Zone-11 NA	T16S, R17E	EAST MESA
Unknown	Natural/Na	Imperial	Mount Sigr	50	32.67531	-115.712	Zone-11 NA	T17S, R12E	FROM US /
Decreasing	Natural/Na	Imperial | I	Quartz Peak (3311417		33.39605	-115.152	Zone-11 NA	T09S, R17E	CHUCKWAI
Fluctuating	Natural/Na	Imperial	Kane Spring	-150	33.1027	-115.904	Zone-11 NA	T12S, R10E	SAN FELIPE
Decreasing	Natural/Na	Imperial | I	Cibola (331	230	33.42004	-114.726	Zone-11 NA	T09S, R21E	PALO VERD
Unknown	Natural/Na	Imperial | S	Shell Reef (	240	33.23291	-116.096	Zone-11 NA	T11S, R08E	BASIN WAS
Unknown	Natural/Na	Imperial	Shell Reef (	100	33.22885	-116.033	Zone-11 NA	T11S, R09E	BETWEEN A
Unknown	Natural/Na	Imperial | S	Carrizo Mtı	560	32.87009	-116.156	Zone-11 NA	T15S, R08E	CARRIZO VA
Unknown	Natural/Na	Imperial	Bard (3211	145	32.82968	-114.539	Zone-11 NA	T15S, R23E	SOUTH SID
Unknown	Natural/Na	Imperial	Imperial Reservoir (32		32.9915	-114.502	Zone-11 NA	T14S, R24E	NORTH END
Decreasing	Natural/Na	Imperial	Laguna Dar	140	32.8514	-114.491	Zone-11 NA	T15S, R24E	JUST EAST
Unknown	Natural/Na	Imperial	Cibola (331	215	33.26573	-114.677	Zone-11 NA	T10S, R22E	NE OF THR
Decreasing	Natural/Na	Imperial	Picacho SW	190	33.03948	-114.65	Zone-11 NA	T13S, R22E	BEND OF R
Unknown	Natural/Na	Imperial	Harpers W	-125	33.09571	-115.936	Zone-11 NA	T12S, R10E	SAN SEBAS
Unknown	Natural/Na	Imperial	Yuma West	230	32.74592	-114.736	Zone-11 NA	T16S, R21E	6 MILES WI
Unknown	Natural/Na	Imperial	Midway W	145	32.70782	-115.016	Zone-11 NA	T17S, R19E	25 MILES W
Unknown	Natural/Na	Imperial	Glamis NW	70	32.97026	-115.256	Zone-11 NA	T14S, R17E	16 MILES E
Unknown	Natural/Na	Imperial	Coyote We	400	32.73846	-115.995	Zone-11 NA	T16S, R09E	NEAR OCOT
Unknown	Natural/Na	Imperial	Carrizo Mtı	400	32.87931	-116.065	Zone-11 NA	T15S, R09E	2 MILES EA
Unknown	Natural/Na	Imperial	Carrizo Mtı	1000	32.94865	-116.056	Zone-11 NA	T14S, R09E	RED ROCK
Unknown	Natural/Na	Imperial	Carrizo Mtı	430	32.87899	-116.093	Zone-11 NA	T15S, R09E	CARRIZO IM
Unknown	Natural/Na	Imperial	Ogilby (321	240	32.76411	-114.837	Zone-11 NA	T16S, R20E	VICINITY O
Unknown	Natural/Na	Imperial	Kane Spring	-156	33.18648	-115.854	Zone-11 NA	T11S, R11E	1 MILE WES
Unknown	Natural/Na	Imperial	Yuha Basin	290	32.67335	-115.831	Zone-11 NA	T17S, R11E	YUHA CUT-
Unknown	Natural/Na	Imperial	Glamis NW	83	32.94116	-115.234	Zone-11 NA	T14S, R17E	N PORTION
Unknown	Natural/Na	Imperial	Coyote We	400	32.65658	-115.882	Zone-11 NA	T17S, R11E	APPROXIM
Unknown	Natural/Na	Imperial	In-ko-pah C	1950	32.67528	-116.075	Zone-11 NA	T17S, R09E	ALONG THI
Unknown	Natural/Na	Imperial	Ogilby (321	720	32.881	-114.823	Zone-11 NA	T15S, R20E	TUMCO WA
Unknown	Natural/Na	Imperial	In-ko-pah C	1840	32.67177	-116.058	Zone-11 NA	T17S, R09E	IN MYER VA
Unknown	Natural/Na	Imperial	In-ko-pah C	3640	32.63744	-116.098	Zone-11 NA	T18S, R09E	ALONG SM
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.12992	-115.06	Zone-11 NA	T12S, R18E	"MARY LOD
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.10046	-115.752	Zone-11 NA	T12S, R12E	POE LATER
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.15708	-115.805	Zone-11 NA	T12S, R11E	TRIFOLIUM
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.14731	-115.795	Zone-11 NA	T12S, R11E	TRIFOLIUM
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.15494	-115.796	Zone-11 NA	T12S, R11E	INSHORE P
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.10962	-115.758	Zone-11 NA	T12S, R12E	DRAINS BE
Unknown	Natural/Na	Imperial	Obsidian B	-225	33.17074	-115.632	Zone-11 NA	T11S, R13E	MOUTH OF
Unknown	Natural/Na	Imperial	Niland (331	-230	33.1764	-115.624	Zone-11 NA	T11S, R13E	VAIL LATER
Unknown	Natural/Na	Imperial | S	In-ko-pah C	2950	32.67397	-116.106	Zone-11 NA	T17S, R08E	MOUNTAIN
Unknown	Natural/Na	Imperial	Lion Head I	1200	33.26836	-115.264	Zone-11 NA	T10S, R16E	OLD RANCH

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Unknown	Natural/Na	Imperial	Pegleg Well (3311532)		33.34367	-115.206	Zone-11 N	T09S, R17E SALVATION
Unknown	Natural/Na	Imperial	Lion Head I	900	33.30732	-115.353	Zone-11 N	T10S, R16E LION HEAD
Unknown	Natural/Na	Imperial	Lion Head Mtn. (3311		33.35417	-115.324	Zone-11 N	T09S, R16E BEAL WELL
Unknown	Natural/Na	Imperial	Blue Mountain (33115		33.17089	-115.07	Zone-11 N	T11S, R18E AERIAL GU
Unknown	Natural/Na	Imperial | /	Cibola (331	225	33.37676	-114.722	Zone-11 N	T09S, R21E ABOUT 4 M
Unknown	Natural/Na	Imperial	Harpers W	100	33.09739	-115.935	Zone-11 N	T12S, R10E VICINITY O
Unknown	Natural/Na	Imperial	Kane Sprin	150	33.19378	-115.885	Zone-11 N	T11S, R10E "BARCHAN
Unknown	Natural/Na	Imperial	Kane Sprin	150	33.19378	-115.885	Zone-11 N	T11S, R10E "BARCHAN
Unknown	Natural/Na	Imperial	Superstitio	160	32.92615	-115.794	Zone-11 N	T14S, R11E 2.5 AIR MIL
Unknown	Natural/Na	Imperial	Brawley NV	150	32.90439	-115.746	Zone-11 N	T14S, R12E NORTH OF
Unknown	Natural/Na	Imperial	Brawley NV	50	32.91893	-115.715	Zone-11 N	T14S, R12E 3.5 MILES S
Unknown	Natural/Na	Imperial	Kane Sprin	22	33.17725	-115.891	Zone-11 N	T11S, R10E 6 MILES NV
Unknown	Natural/Na	Imperial	Kane Sprin	-148	33.08966	-115.787	Zone-11 N	T12S, R11E APPROX 1.:
Unknown	Natural/Na	Imperial	Kane Sprin	-150	33.09365	-115.824	Zone-11 N	T12S, R11E APPROXIM
Unknown	Natural/Na	Imperial	Kane Sprin	-155	33.10814	-115.854	Zone-11 N	T12S, R11E APPROXIM
Unknown	Natural/Na	Imperial	Superstitio	220	32.97558	-115.842	Zone-11 N	T14S, R11E 0.25 MILE \
Unknown	Natural/Na	Imperial	Shell Reef (	110	33.15337	-116.032	Zone-11 N	T12S, R09E BETWEEN S
Unknown	Natural/Na	Imperial	Painted Go	165	32.78571	-115.888	Zone-11 N	T16S, R10E 2 MI W OF
Unknown	Natural/Na	Imperial	Carrizo Mtı	800	32.77076	-116.079	Zone-11 N	T16S, R09E ALONG CO
Unknown	Natural/Na	Imperial	Yuha Basin	110	32.67708	-115.764	Zone-11 N	T17S, R12E PINTO WAS
Unknown	Natural/Na	Imperial	Harpers W	-90	33.12699	-115.895	Zone-11 N	T12S, R10E APPROX 10
Unknown	Natural/Na	Imperial	Kane Sprin	-180	33.10606	-115.82	Zone-11 N	T12S, R11E 0.8 MI SE C
Unknown	Natural/Na	Imperial	Kane Sprin	-180	33.11651	-115.851	Zone-11 N	T12S, R11E 0.6-0.7 MIL
Unknown	Natural/Na	Imperial	Kane Sprin	-230	33.1427	-115.785	Zone-11 N	T12S, R11E JUST NORT
Unknown	Natural/Na	Imperial	Niland (331	-235	33.20074	-115.591	Zone-11 N	T11S, R13E JUST NORT
Unknown	Natural/Na	Imperial	Grays Well	253	32.75401	-114.802	Zone-11 N	T16S, R21E ALONG I-8,
Unknown	Natural/Na	Imperial | /	Yuma East (3211465) |		32.73269	-114.633	Zone-11 N	T16S, R22E YUMA, COL
Unknown	Natural/Na	Imperial	Clyde (321	390	32.92059	-114.989	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Clyde (321	390	32.92559	-114.997	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	400	32.9042	-115.014	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	400	32.89865	-115.02	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	300	32.94198	-115.058	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	300	32.88754	-115.011	Zone-11 N	T15S, R19E ALGODDON
Unknown	Natural/Na	Imperial	Acolita (33	200	33.05558	-115.232	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	400	32.87809	-115.004	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	350	32.88614	-115.029	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	400	32.91031	-115.03	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	360	32.92833	-115.043	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	200	32.79	-114.926	Zone-11 N	T16S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Ogilby (321	200	32.75699	-114.861	Zone-11 N	T16S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	225	33.09809	-115.292	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	280	32.81309	-114.9	Zone-11 N	T15S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	300	32.81531	-114.946	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	300	32.83238	-114.915	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Clyde (321	330	32.89587	-114.977	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	350	32.86697	-114.942	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	210	33.1178	-115.275	Zone-11 N	T12S, R16E ALGODONE

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Unknown	Natural/Na	Imperial	Acolita (33	250	33.07507	-115.212	Zone-11 N	T12S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	220	33.10752	-115.264	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	320	32.95182	-115.05	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	350	32.9324	-115.013	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	340	32.95121	-115.034	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	360	32.92253	-115.012	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	340	32.96364	-115.038	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	220	33.10752	-115.264	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	340	32.86697	-114.942	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	250	33.07507	-115.212	Zone-11 N	T12S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	175	33.00352	-115.192	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	200	33.05558	-115.232	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	240	33.09809	-115.292	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Glamis SE (	200	32.86225	-115.067	Zone-11 N	T15S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	280	32.91558	-115.119	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	400	32.9324	-115.013	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	360	32.92253	-115.012	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	300	32.81531	-114.946	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Ogilby (321	205	32.75699	-114.861	Zone-11 N	T16S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	280	32.81309	-114.9	Zone-11 N	T15S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	310	32.83238	-114.915	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Clyde (321	380	32.92059	-114.989	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	340	32.95121	-115.034	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	260	33.04141	-115.162	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	220	33.10752	-115.264	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	250	33.07507	-115.212	Zone-11 N	T12S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	180	33.00352	-115.192	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Acolita (33	200	33.05558	-115.232	Zone-11 N	T13S, R17E ALGODONE
Unknown	Natural/Na	Imperial	Amos (331	220	33.09809	-115.292	Zone-11 N	T12S, R16E ALGODONE
Unknown	Natural/Na	Imperial	Glamis SE (	115	32.83642	-115.114	Zone-11 N	T15S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	160	32.78837	-114.937	Zone-11 N	T16S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Glamis SE (	200	32.86225	-115.067	Zone-11 N	T15S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	280	32.91558	-115.119	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	390	32.9324	-115.013	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	360	32.92253	-115.012	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	300	32.81531	-114.946	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	280	32.81309	-114.9	Zone-11 N	T15S, R20E ALGODONE
Unknown	Natural/Na	Imperial	Cactus (32	300	32.83238	-114.915	Zone-11 N	T15S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Clyde (321	380	32.92059	-114.989	Zone-11 N	T14S, R19E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32	340	32.95121	-115.034	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Obsidian B	-230	33.16224	-115.649	Zone-11 N	T11S, R13E VAIL LATER
Unknown	Natural/Na	Imperial |	Imperial Re	190	33.00531	-114.502	Zone-11 N	T13S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Yuma West	180	32.73188	-114.743	Zone-11 N	T16S, R21E PILOT KNO
Unknown	Natural/Na	Imperial	Seeley (321	-49	32.84726	-115.67	Zone-11 N	T15S, R13E 6 MI W IMI
Unknown	Natural/Na	Imperial	Harpers W	-120	33.09648	-115.906	Zone-11 N	T12S, R10E VICINITY O
Unknown	Natural/Na	Imperial |	Bard (3211	150	32.81121	-114.538	Zone-11 N	T15S, R23E 2 TO 3 MI N
Unknown	Natural/Na	Imperial |	Carrizo Mt	440	32.87588	-116.101	Zone-11 N	T15S, R09E OLD CARRI

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial | A	Yuma East	140	32.77133	-114.531	Zone-11 NA	T16S, R23E ABOUT 5 M
Unknown	Natural/Na	Imperial	Pegleg Wel	1320	33.29255	-115.191	Zone-11 NA	T10S, R17E SALVATION
Unknown	Natural/Na	Imperial | I	Palo Verde	230	33.43201	-114.736	Zone-11 NA	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial	Picacho Pe	680	32.96216	-114.644	Zone-11 NA	T14S, R22E PICACHO M
Unknown	Natural/Na	Imperial	Bard (3211	140	32.82248	-114.552	Zone-11 NA	T15S, R23E 2 MILES NC
Unknown	Natural/Na	Imperial	Imperial Re	400	32.89031	-114.482	Zone-11 NA	T15S, R24E SENATOR M
Decreasing	Natural/Na	Imperial | A	Picacho SW	200	33.04766	-114.672	Zone-11 NA	T13S, R22E JUST S OF H
Unknown	Natural/Na	Imperial | A	Laguna Dar	200	32.82892	-114.506	Zone-11 NA	T15S, R23E POTHOLES.
Unknown	Natural/Na	Imperial	Hedges (32	620	32.93336	-114.852	Zone-11 NA	T14S, R20E INDIAN WA
Unknown	Natural/Na	Imperial	Palo Verde	506	33.28753	-114.812	Zone-11 NA	T10S, R21E MILPITAS W
Unknown	Natural/Na	Imperial | A	Picacho NW	220	33.23939	-114.687	Zone-11 NA	T11S, R22E WALTERS C
Unknown	Natural/Na	Imperial	Cibola (331	225	33.33242	-114.71	Zone-11 NA	T10S, R21E BETWEEN I
Unknown	Natural/Na	Imperial | A	Imperial Re	195	32.98307	-114.499	Zone-11 NA	T14S, R24E FERGUSON
Unknown	Natural/Na	Imperial	Brawley (3	-120	32.98392	-115.525	Zone-11 NA	T13S, R14E BRAWLEY.
Unknown	Natural/Na	Imperial	Niland (331	-230	33.19475	-115.592	Zone-11 NA	T11S, R13E WEST PONI
Unknown	Natural/Na	Imperial | A	Laguna Dar	300	32.82892	-114.506	Zone-11 NA	T15S, R23E POTHOLES,
Unknown	Natural/Na	Imperial	Calipatria S	-160	33.04142	-115.705	Zone-11 NA	T13S, R12E 5 MI W OF
Unknown	Natural/Na	Imperial	Bard (3211	135	32.77059	-114.587	Zone-11 NA	T16S, R23E 3 MILES EN
Unknown	Natural/Na	Imperial | A	Laguna Dar	-153	32.82561	-114.497	Zone-11 NA	T15S, R24E LAGUNA DA
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 NA	T13S, R13E WESTMORI
Unknown	Natural/Na	Imperial	Hedges (32	620	32.93336	-114.852	Zone-11 NA	T14S, R20E INDIAN WA
Unknown	Natural/Na	Imperial	Palo Verde	506	33.28753	-114.812	Zone-11 NA	T10S, R21E MILPITAS W
Unknown	Natural/Na	Imperial	Glamis (32	335	32.95226	-115.074	Zone-11 NA	T14S, R18E THREE MI S
Unknown	Natural/Na	Imperial	Plaster City	100	32.79227	-115.86	Zone-11 NA	T16S, R11E PLASTER CI
Unknown	Natural/Na	Imperial	Obsidian B	-235	33.14364	-115.739	Zone-11 NA	T12S, R12E 10 MI NW V
Unknown	Natural/Na	Imperial	Coyote We	420	32.69005	-115.908	Zone-11 NA	T17S, R10E 5 MILE SE C
Unknown	Natural/Na	Imperial	Kane Spring NW (3311		33.18003	-115.922	Zone-11 NA	T11S, R10E 7 MILES NE
Unknown	Natural/Na	Imperial	Ogilby (321	360	32.81754	-114.841	Zone-11 NA	T15S, R20E OGILBY.
Unknown	Natural/Na	Imperial	Kane Spring	-25	33.15782	-115.895	Zone-11 NA	T12S, R10E 5 MI NE KA
Unknown	Natural/Na	Imperial	Seventeen	280	33.2992	-116.045	Zone-11 NA	T10S, R09E CORAL REE
Unknown	Natural/Na	Imperial	Westmorla	-160	33.0317	-115.625	Zone-11 NA	T13S, R13E WESTMORI
Unknown	Natural/Na	Imperial | A	Laguna Dar	200	32.82892	-114.506	Zone-11 NA	T15S, R23E POTHOLES,
Increasing	Natural/Na	Imperial	Picacho SW	190	33.06197	-114.684	Zone-11 NA	T13S, R22E MOUTH OF
Increasing	Natural/Na	Imperial | A	Picacho SW	190	33.08296	-114.691	Zone-11 NA	T12S, R22E UNNAMED
Increasing	Natural/Na	Imperial	Picacho SW	200	33.03059	-114.638	Zone-11 NA	T13S, R22E TAYLOR LA
Increasing	Natural/Na	Imperial | A	Picacho SW	240	33.08448	-114.712	Zone-11 NA	T12S, R21E MOUTH OF
Unknown	Natural/Na	Imperial | A	Imperial Re	195	32.98307	-114.499	Zone-11 NA	T14S, R24E FERGUSON
Unknown	Natural/Na	Imperial	Cibola (331	225	33.33242	-114.71	Zone-11 NA	T10S, R21E BETWEEN I
Decreasing	Natural/Na	Imperial | A	Cibola (331	230	33.35789	-114.7	Zone-11 NA	T09S, R21E CIBOLA REV
Unknown	Natural/Na	Imperial	Frink (3311	-220	33.35145	-115.73	Zone-11 NA	T09S, R12E BOMBAY B
Unknown	Natural/Na	Imperial	Wister (331	-199	33.31892	-115.612	Zone-11 NA	T10S, R13E 7 MI NW N
Unknown	Natural/Na	Imperial | A	Laguna Dar	300	32.82892	-114.506	Zone-11 NA	T15S, R23E POTHOLES.
Unknown	Natural/Na	Imperial | I	Calexico (3	10	32.66977	-115.496	Zone-11 NA	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial	Niland (331	-220	33.23864	-115.572	Zone-11 NA	T11S, R13E 3 MI W OF
Unknown	Natural/Na	Imperial | A	Cibola (331	230	33.34733	-114.714	Zone-11 NA	T09S, R21E COLORADC
Unknown	Natural/Na	Imperial	Laguna Dar	160	32.85932	-114.49	Zone-11 NA	T15S, R24E JUST E OF I
Unknown	Natural/Na	Imperial | A	Yuma East	140	32.77133	-114.531	Zone-11 NA	T16S, R23E 4 MILES DC

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial | /	Laguna Dar	300	32.82892	-114.506	Zone-11 N	T15S, R23E POTHOLES.
Unknown	Natural/Na	Imperial	Hedges (32	620	32.93336	-114.852	Zone-11 N	T14S, R20E INDIAN WA
Unknown	Natural/Na	Imperial	Palo Verde	506	33.28753	-114.812	Zone-11 N	T10S, R21E MILPITAS V
Unknown	Natural/Na	Imperial	Niland (331	-200	33.19475	-115.592	Zone-11 N	T11S, R13E WEST PONI
Unknown	Natural/Na	Imperial	Wiest (331	-180	33.12947	-115.513	Zone-11 N	T12S, R14E CALIPATRIA
Unknown	Natural/Na	Imperial	Palo Verde	235	33.41585	-114.75	Zone-11 N	T09S, R21E 1.5 MI SW (
Unknown	Natural/Na	Imperial | /	Laguna Dar	300	32.82892	-114.506	Zone-11 N	T15S, R23E POTHOLES.
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMORI
Unknown	Natural/Na	Imperial | I	Palo Verde	230	33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial | /	Imperial Re	195	32.98307	-114.499	Zone-11 N	T14S, R24E FERGUSON
Unknown	Natural/Na	Imperial	Cibola (331	225	33.33242	-114.71	Zone-11 N	T10S, R21E BETWEEN I
Unknown	Natural/Na	Imperial | /	Cibola (331	230	33.35789	-114.7	Zone-11 N	T09S, R21E CIBOLA REV
Unknown	Natural/Na	Imperial | /	Laguna Dar	200	32.88393	-114.471	Zone-11 N	T15S, R24E IMPERIAL D
Unknown	Natural/Na	Imperial | /	Laguna Dar	300	32.82892	-114.506	Zone-11 N	T15S, R23E POTHOLES.
Unknown	Natural/Na	Imperial | /	Cibola (331	230	33.34733	-114.714	Zone-11 N	T09S, R21E COLORADC
Unknown	Natural/Na	Imperial | /	Yuma East	140	32.77133	-114.531	Zone-11 N	T16S, R23E 4 MILES BE
Unknown	Natural/Na	Imperial | /	Laguna Dar	300	32.82892	-114.506	Zone-11 N	T15S, R23E IN THE VICI
Unknown	Natural/Na	Imperial	Cibola (331	230	33.35643	-114.716	Zone-11 N	T09S, R21E ASU REVEG
Unknown	Natural/Na	Imperial	Bard (3211	140	32.80754	-114.592	Zone-11 N	T15S, R23E ALONG THE
Unknown	Natural/Na	Imperial	Imperial Re	195	32.98003	-114.502	Zone-11 N	T14S, R24E FERGUSON
Decreasing	Natural/Na	Imperial | /	Cibola (331	230	33.35789	-114.7	Zone-11 N	T09S, R21E CIBOLA REV
Unknown	Natural/Na	Imperial	Cibola (331	225	33.33242	-114.71	Zone-11 N	T10S, R21E BETWEEN I
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.06609	-115.704	Zone-11 N	T13S, R12E ALONG VEI
Unknown	Natural/Na	Imperial	Westmorla	185	33.08919	-115.614	Zone-11 N	T12S, R13E ALONG GEI
Unknown	Natural/Na	Imperial | /	Picacho NV	220	33.23939	-114.687	Zone-11 N	T11S, R22E WALTERS C
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMORI
Unknown	Natural/Na	Imperial	Cibola (331	225	33.33242	-114.71	Zone-11 N	T10S, R21E BETWEEN I
Unknown	Natural/Na	Imperial | /	Yuma West	120	32.74698	-114.7	Zone-11 N	T16S, R22E LOWER RES
Unknown	Natural/Na	Imperial	Cibola (331	230	33.35921	-114.702	Zone-11 N	T09S, R21E "EUCALYPT
Unknown	Natural/Na	Imperial | /	Picacho NV	215	33.2549	-114.69	Zone-11 N	T11S, R22E VICINITY O
Unknown	Natural/Na	Imperial | /	Palo Verde	245	33.42538	-114.634	Zone-11 N	T09S, R22E 0.6 MILE SC
Unknown	Natural/Na	Imperial | /	Picacho NV	210	33.1706	-114.682	Zone-11 N	T11S, R22E ALONG CO
Unknown	Natural/Na	Imperial | /	Picacho SW	(3311416)	33.04708	-114.645	Zone-11 N	T13S, R22E ALONG CO
Unknown	Natural/Na	Imperial	Picacho NV	210	33.21586	-114.679	Zone-11 N	T11S, R22E NEAR GILM
Decreasing	Natural/Na	Imperial | /	Imperial Re	200	32.97114	-114.494	Zone-11 N	T14S, R24E SOUTHERN
Unknown	Natural/Na	Imperial | /	Yuma West	125	32.73559	-114.662	Zone-11 N	T16S, R22E 1.7 MILES V
Unknown	Natural/Na	Imperial	Calipatria S	-220	33.12364	-115.693	Zone-11 N	T12S, R12E EIGHT MI N
Unknown	Natural/Na	Imperial	Niland (331	-190	33.22531	-115.609	Zone-11 N	T11S, R13E MULLET ISL
Unknown	Natural/Na	Imperial	Yuma West	120	32.74698	-114.647	Zone-11 N	T16S, R22E WEST PONI
Unknown	Natural/Na	Imperial	Iris (33115	90	33.2193	-115.417	Zone-11 N	T11S, R15E W SIDE OF
Unknown	Natural/Na	Imperial	Iris (33115	80	33.20224	-115.413	Zone-11 N	T11S, R15E W SIDE OF
Unknown	Natural/Na	Imperial	Amos (331	100	33.0889	-115.296	Zone-11 N	T12S, R16E W SIDE CO.
Unknown	Natural/Na	Imperial	Tortuga (33	50	33.13364	-115.359	Zone-11 N	T12S, R15E MAMMOTI
Unknown	Natural/Na	Imperial	Tortuga (33	60	33.14737	-115.365	Zone-11 N	T12S, R15E ABOUT 1.5
Unknown	Natural/Na	Imperial	Tortuga (33	60	33.1603	-115.373	Zone-11 N	T12S, R15E E SIDE OF H
Unknown	Natural/Na	Imperial	Amos (331	60	33.11928	-115.338	Zone-11 N	T12S, R16E AREA BETW
Unknown	Natural/Na	Imperial	Alamorio (3	100	32.92932	-115.421	Zone-11 N	T14S, R15E HOLTVILLE

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Niland (331	235	33.18329	-115.623	Zone-11 NA	T11S, R13E	ROCK HILL,
Unknown	Natural/Na	Imperial	Wiest (331	170	33.07481	-115.509	Zone-11 NA	T13S, R14E	RAMER & F
Unknown	Natural/Na	Imperial | A	Picacho SW	190	33.09642	-114.71	Zone-11 NA	T12S, R21E	COLORADC
Unknown	Natural/Na	Imperial	Bonds Corr	40	32.69837	-115.271	Zone-11 NA	T17S, R17E	ALL AMERI(
Unknown	Natural/Na	Imperial	Seeley (321	80	32.82064	-115.703	Zone-11 NA	T15S, R12E	NEW RIVEF
Unknown	Natural/Na	Imperial | A	Palo Verde	230	33.40328	-114.727	Zone-11 NA	T09S, R21E	PALO VERD
Unknown	Natural/Na	Imperial	Palo Verde	240	33.42541	-114.685	Zone-11 NA	T09S, R22E	2.5 MI E OF
Unknown	Natural/Na	Imperial	Palo Verde	240	33.42541	-114.685	Zone-11 NA	T09S, R22E	2.5 MI E OF
Unknown	Natural/Na	Imperial	Bard (3211	160	32.83281	-114.544	Zone-11 NA	T15S, R23E	ALL AMERI(
Unknown	Natural/Na	Imperial	Bard (3211	150	32.82642	-114.551	Zone-11 NA	T15S, R23E	ALL AMERI(
Unknown	Natural/Na	Imperial	In-ko-pah (	3900					*SENSITIVE
Unknown	Natural/Na	Imperial	Borrego M(	700					*SENSITIVE
Unknown	Natural/Na	Imperial	In-ko-pah (	3200					*SENSITIVE
Unknown	Natural/Na	Imperial	Picacho Pe	1100					*SENSITIVE
Unknown	Natural/Na	Imperial	Carrizo Mtı	1800					*SENSITIVE
Unknown	Natural/Na	Imperial	Imperial Re	195	32.98264	-114.499	Zone-11 NA	T14S, R24E	VICINITY O
Unknown	Natural/Na	Imperial | A	Laguna Dar	300	32.82892	-114.506	Zone-11 NA	T15S, R23E	ENCOMPAS
Unknown	Natural/Na	Imperial	Bard (3211	135	32.79004	-114.566	Zone-11 NA	T16S, R23E	5 MI NE OF
Unknown	Natural/Na	Imperial	Superstitio	200	32.97705	-115.827	Zone-11 NA	T14S, R11E	ABOUT 1.5
Unknown	Natural/Na	Imperial	Coyote We	400	32.66492	-115.895	Zone-11 NA	T17S, R11E	N AND S OI
Unknown	Natural/Na	Imperial	Glamis (32:	360	33.00507	-115.07	Zone-11 NA	T13S, R18E	GLAMIS, AI
Unknown	Natural/Na	Imperial	Shell Reef (	77	33.14048	-116.07	Zone-11 NA	T12S, R09E	0.6 MILE W
Unknown	Natural/Na	Imperial	Glamis SE (	115	32.77392	-115.132	Zone-11 NA	T16S, R18E	EAST MESA
Unknown	Natural/Na	Imperial	Brawley (3:	-110	32.97893	-115.54	Zone-11 NA	T13S, R14E	100 YARDS
Unknown	Natural/Na	Imperial	Holtville Ea	-15	32.81449	-115.382	Zone-11 NA	T15S, R15E	HOLTVILLE.
Unknown	Natural/Na	Imperial	Harpers W(	-120	33.09648	-115.906	Zone-11 NA	T12S, R10E	HARPERS V
Unknown	Natural/Na	Imperial	Painted Go	180	32.79176	-115.919	Zone-11 NA	T16S, R10E	COYOTE W
Unknown	Natural/Na	Imperial	Seeley (321	60	32.86643	-115.649	Zone-11 NA	T15S, R13E	WIENERT R
Unknown	Natural/Na	Imperial	Heber (321	-15	32.6781	-115.642	Zone-11 NA	T17S, R13E	MOUNT SI(
Unknown	Natural/Na	Imperial	Grays Well	155	32.74448	-114.964	Zone-11 NA	T16S, R19E	EAST MESA
Unknown	Natural/Na	Imperial	Glamis NW	100	32.96883	-115.221	Zone-11 NA	T14S, R17E	ALONG HIG
Unknown	Natural/Na	Imperial	Harpers W(	-70	33.09275	-115.974	Zone-11 NA	T12S, R10E	ALONG SAI
Unknown	Natural/Na	Imperial	Holtville NE	30	32.90665	-115.286	Zone-11 NA	T14S, R16E	NEAR HIGH
Unknown	Natural/Na	Imperial	Durmid (33	-30	33.39221	-115.763	Zone-11 NA	T09S, R12E	RANGE RO/
Unknown	Natural/Na	Imperial	Kane Spring	-90	33.1349	-115.891	Zone-11 NA	T12S, R10E	ABOUT 2 M
Unknown	Natural/Na	Imperial	Kane Spring	-110	33.15495	-115.866	Zone-11 NA	T12S, R11E	HWY 86, AI
Unknown	Natural/Na	Imperial	Kane Spring	50	33.14484	-115.973	Zone-11 NA	T12S, R10E	1.3 MILES N
Unknown	Natural/Na	Imperial	Kane Spring	40	33.12859	-115.977	Zone-11 NA	T12S, R10E	ALONG PO
Unknown	Natural/Na	Imperial	Cactus (32:	300	32.81865	-115.015	Zone-11 NA	T15S, R19E	EAST OF CC
Unknown	Natural/Na	Imperial	Painted Go	200	32.86359	-115.925	Zone-11 NA	T15S, R10E	WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	70	32.97174	-115.943	Zone-11 NA	T14S, R10E	CARRIZO W
Unknown	Natural/Na	Imperial	Carrizo Mtı	600	32.91115	-116.025	Zone-11 NA	T14S, R09E	SW OF FISH
Unknown	Natural/Na	Imperial	In-ko-pah (	1900					*SENSITIVE
Unknown	Natural/Na	Imperial	In-ko-pah (	1500					*SENSITIVE
Unknown	Natural/Na	Imperial	In-ko-pah (	1400					*SENSITIVE
Unknown	Natural/Na	Imperial	Painted Go	1600					*SENSITIVE
Unknown	Natural/Na	Imperial	In-ko-pah (	1500					*SENSITIVE

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial | /	Laguna Dar	160	32.85092	-114.484	Zone-11 N	T15S, R24E	ALONG THE
Unknown	Natural/Na	Imperial | /	Laguna Dar	160	32.85092	-114.484	Zone-11 N	T15S, R24E	ALONG THE
Unknown	Refugium;	Imperial	Buzzards P	600	33.19105	-114.758	Zone-11 N	T11S, R21E	ARROWEEI
Decreasing	Natural/Na	Imperial | /	Picacho NV	200	33.23939	-114.687	Zone-11 N	T11S, R22E	WALTERS C
Decreasing	Natural/Na	Imperial	Iris (33115	60	33.2453	-115.486	Zone-11 N	T11S, R14E	EAST HIGH
Unknown	Natural/Na	Imperial	Imperial Re	300	32.90869	-114.482	Zone-11 N	T14S, R24E	SENATOR V
Unknown	Natural/Na	Imperial	Laguna Dar	120	32.82587	-114.499	Zone-11 N	T15S, R24E	IMMEDIATI
Unknown	Natural/Na	Imperial	In-ko-pah C	2680	32.65535	-116.085	Zone-11 N	T17S, R09E	JUNIPER SP
Unknown	Natural/Na	Imperial	In-ko-pah C	3100	32.64255	-116.079	Zone-11 N	T17S, R09E	MESQUITE
Unknown	Natural/Na	Imperial | I	In-ko-pah C	2740	32.63503	-116.056	Zone-11 N	T18S, R09E	BOUNDARY
Unknown	Natural/Na	Imperial	In-ko-pah C	1880	32.66572	-116.075	Zone-11 N	T17S, R09E	MORTERO
Unknown	Natural/Na	Imperial | S	Oasis (3311	200	33.40696	-116.082	Zone-11 N	T09S, R09E	STEINS RES
Unknown	Natural/Na	Imperial | /	Picacho SW	190	33.03753	-114.673	Zone-11 N	T13S, R22E	CARRIZO W
Unknown	Natural/Na	Imperial | /	Yuma West	120	32.73559	-114.662	Zone-11 N	T16S, R22E	BETWEEN C
Decreasing	Natural/Na	Imperial | /	Picacho (33	190	33.02337	-114.596	Zone-11 N	T13S, R23E	SOUTH SID
Unknown	Natural/Na	Imperial | /	Red Hill SW	190	33.00947	-114.504	Zone-11 N	T13S, R23E	NORTH OF
Unknown	Natural/Na	Imperial	Imperial Re	180	32.98197	-114.501	Zone-11 N	T14S, R24E	FERGUSON
Unknown	Natural/Na	Imperial | /	Bard (3211	140	32.78916	-114.534	Zone-11 N	T16S, R23E	WEST SIDE
Unknown	Natural/Na	Imperial	Picacho NV	210	33.20412	-114.682	Zone-11 N	T11S, R22E	WALKER LA
Unknown	Natural/Na	Imperial | /	Picacho NV	200	33.17959	-114.679	Zone-11 N	T11S, R22E	COLORADC
Unknown	Natural/Na	Imperial | /	Picacho NV	200	33.17959	-114.679	Zone-11 N	T11S, R22E	ALONG THE
Unknown	Natural/Na	Imperial | /	Picacho NV	200	33.17959	-114.679	Zone-11 N	T11S, R22E	ALONG THE
Unknown	Natural/Na	Imperial | /	Picacho NV	200	33.17959	-114.679	Zone-11 N	T11S, R22E	COLORADC
Unknown	Natural/Na	Imperial | /	Laguna Dar	160	32.85092	-114.484	Zone-11 N	T15S, R24E	ALONG THE
Unknown	Natural/Na	Imperial	Ogilby (321	1000	32.8501	-114.789	Zone-11 N	T15S, R21E	VICINITY O
Unknown	Natural/Na	Imperial	Ogilby (321	499	32.8674	-114.839	Zone-11 N	T15S, R20E	3.5 MILES N
Unknown	Natural/Na	Imperial	Picacho Pe	720	32.9507	-114.786	Zone-11 N	T14S, R21E	IN WASHES
Unknown	Natural/Na	Imperial	Ogilby (321	390	32.84061	-114.87	Zone-11 N	T15S, R20E	ALONG RAI
Unknown	Natural/Na	Imperial	Ogilby (3211477) | He		32.8806	-114.816	Zone-11 N	T15S, R20E	NEAR TUM
Unknown	Natural/Na	Imperial	Cactus (321	400	32.86211	-114.889	Zone-11 N	T15S, R20E	4.2 MILES N
Unknown	Natural/Na	Imperial	Quartz Pea	1000	33.05875	-114.789	Zone-11 N	T13S, R21E	JULIAN WA
Unknown	Natural/Na	Imperial	Ninemile W	1000	33.12877	-114.882	Zone-11 N	T12S, R20E	EAST OF BU
Unknown	Natural/Na	Imperial	Ninemile W	600	33.04581	-115.006	Zone-11 N	T13S, R19E	5 MILES NC
Unknown	Natural/Na	Imperial	Quartz Pea	1000	33.00222	-114.781	Zone-11 N	T13S, R21E	INDIAN PAS
Unknown	Natural/Na	Imperial	Laguna Dar	180	32.86992	-114.489	Zone-11 N	T15S, R24E	APPROXIM
Unknown	Natural/Na	Imperial	Picacho NV	520	33.22867	-114.756	Zone-11 N	T11S, R21E	>2 MILES E
Unknown	Natural/Na	Imperial	Mt. Barrow	1070	33.15555	-114.899	Zone-11 N	T12S, R20E	WEST OF 4
Unknown	Natural/Na	Imperial	Palo Verde	1000	33.36363	-114.848	Zone-11 N	T09S, R20E	NEAR FLAT
Unknown	Natural/Na	Imperial	Palo Verde	1500	33.33232	-114.776	Zone-11 N	T10S, R21E	VICINITY O
Unknown	Natural/Na	Imperial	Coyote Wells (3211568		32.65694	-116.014	Zone-11 N	T17S, R09E	DAVIES VA
Unknown	Natural/Na	Imperial	Painted Gorge (32115		32.83169	-116.016	Zone-11 N	T15S, R09E	EASTERN S
Unknown	Natural/Na	Imperial	Carrizo Mtı	1000	32.79338	-116.026	Zone-11 N	T16S, R09E	FOSSIL CAN
Unknown	Natural/Na	Imperial	Painted Gorge (32115		32.80931	-115.984	Zone-11 N	T16S, R10E	PAINTED G
Unknown	Natural/Na	Imperial	In-ko-pah C	4250	32.62181	-116.094	Zone-11 N	T18S, R09E	AROUND T
Unknown	Natural/Na	Imperial | S	In-ko-pah C	2300	32.67397	-116.106	Zone-11 N	T17S, R08E	MOUNTAIN
Unknown	Natural/Na	Imperial | S	In-ko-pah Gorge (3211		32.65897	-116.101	Zone-11 N	T17S, R09E	DESERT TO
Unknown	Natural/Na	Imperial | S	In-ko-pah C	3600	32.64003	-116.099	Zone-11 N	T17S, R09E	ON THE GR

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Carrizo Mtı	1000	32.79475	-116.024	Zone-11 N	T16S, R09E FOSSIL CAN
Unknown	Natural/Na	Imperial	Heber (321	-20	32.70862	-115.64	Zone-11 N	T17S, R13E 2 MILES NC
Unknown	Natural/Na	Imperial | S	In-ko-pah (	2300	32.67397	-116.106	Zone-11 N	T17S, R08E MOUNTAIN
Unknown	Natural/Na	Imperial | I	Mount Sigr	200	32.65791	-115.77	Zone-11 N	T17S, R12E SOUTH OF
Unknown	Natural/Na	Imperial	Painted Go	1800	32.83169	-116.016	Zone-11 N	T15S, R09E EASTERN SI
Unknown	Natural/Na	Imperial	Carrizo Mtı	1000	32.79475	-116.024	Zone-11 N	T16S, R09E FOSSIL CAN
Unknown	Natural/Na	Imperial	Plaster City	1200	32.9724	-116.01	Zone-11 N	T14S, R09E FISH MOUN
Unknown	Natural/Na	Imperial	Niland (331	-226	33.18537	-115.597	Zone-11 N	T11S, R13E VAIL 3 DRA
Decreasing	Introduced	Imperial | A	Palo Verde	240	33.41279	-114.697	Zone-11 N	T09S, R22E OXBOW PC
Decreasing	Introduced	Imperial	Picacho NV	205	33.13788	-114.692	Zone-11 N	T12S, R22E COLORADC
Unknown	Introduced	Imperial | A	Picacho (33	190	33.02704	-114.587	Zone-11 N	T13S, R23E COLORADC
Unknown	Natural/Na	Imperial	Harpers W	-31	33.12564	-115.942	Zone-11 N	T12S, R10E HIGHWAY
Unknown	Natural/Na	Imperial	Coyote We	280	32.73672	-115.964	Zone-11 N	T16S, R10E COYOTE W
Unknown	Natural/Na	Imperial	Harpers W	60	33.11431	-115.943	Zone-11 N	T12S, R10E 5.1 AIR MIL
Unknown	Natural/Na	Imperial	Frink (3311	-170	33.36006	-115.73	Zone-11 N	T09S, R12E 1 MILE NOI
Unknown	Natural/Na	Imperial	Grays Well	155	32.70911	-114.948	Zone-11 N	T16S, R20E WHERE HIC
Unknown	Natural/Na	Imperial	Grays Well	200	32.74057	-114.847	Zone-11 N	T16S, R20E WHERE HIC
Unknown	Natural/Na	Imperial	Niland (331	-230	33.1818	-115.621	Zone-11 N	T11S, R13E JUST SE OF
Unknown	Natural/Na	Imperial	Niland (331	-230	33.1818	-115.621	Zone-11 N	T11S, R13E JUST SE OF
Unknown	Natural/Na	Imperial	Niland (331	-230	33.1818	-115.621	Zone-11 N	T11S, R13E JUST SE OF
Unknown	Natural/Na	Imperial	Hedges (32	700	32.88266	-114.827	Zone-11 N	T15S, R20E MESQUITE
Unknown	Natural/Na	Imperial	Hedges (32	720	32.8846	-114.82	Zone-11 N	T15S, R20E (GOLDEN) (
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.12992	-115.06	Zone-11 N	T12S, R18E "MARY LOI
Unknown	Natural/Na	Imperial | I	Palo Verde	230	33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial	Palo Verde	230	33.42237	-114.732	Zone-11 N	T09S, R21E 0.75 MILE N
Unknown	Natural/Na	Imperial	Niland (331	-125	33.24069	-115.518	Zone-11 N	T11S, R14E NILAND.
Unknown	Natural/Na	Imperial	Holtville Ea	-15	32.81449	-115.382	Zone-11 N	T15S, R15E HOLTVILLE.
Unknown	Natural/Na	Imperial	Holtville W	-45	32.80251	-115.447	Zone-11 N	T15S, R15E MELOLAND
Unknown	Natural/Na	Imperial	Bard (3211	140	32.77645	-114.637	Zone-11 N	T16S, R22E THREE MILI
Unknown	Natural/Na	Imperial | A	Picacho NV	220	33.23966	-114.687	Zone-11 N	T11S, R22E COLORADC
Unknown	Natural/Na	Imperial | I	Calexico (3	10	32.66977	-115.496	Zone-11 N	T17S, R14E SALTON BA
Unknown	Natural/Na	Imperial	Seventeen	500	33.28721	-116.069	Zone-11 N	T10S, R09E PALM WAS
Unknown	Natural/Na	Imperial | I	Calexico (3211564) | H		32.66977	-115.496	Zone-11 N	T17S, R14E NEAR CALE
Unknown	Natural/Na	Imperial	Heber (3211565)		32.73088	-115.53	Zone-11 N	T16S, R14E HEBER, IMI
Unknown	Natural/Na	Imperial	Brawley (3	-120	32.98392	-115.525	Zone-11 N	T13S, R14E BRAWLEY,
Unknown	Natural/Na	Imperial	Bonds Corr	-2	32.73302	-115.365	Zone-11 N	T16S, R16E OLD BEACH
Unknown	Natural/Na	Imperial	Grays Well	300	32.88668	-115.045	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Ogilby (321	400	32.81754	-114.841	Zone-11 N	T15S, R20E OGILBY, NE
Unknown	Natural/Na	Imperial	Holtville West (321157		32.80251	-115.447	Zone-11 N	T15S, R15E MELOLAND
Unknown	Natural/Na	Imperial	Glamis (32	300	32.99414	-115.101	Zone-11 N	T13S, R18E 1.7 MILES \
Unknown	Natural/Na	Imperial	Tortuga (33	220	33.16323	-115.325	Zone-11 N	T11S, R16E SOUTH OF
Unknown	Natural/Na	Imperial	Kane Spring	150	33.09668	-115.831	Zone-11 N	T12S, R11E SOUTH OF
Unknown	Natural/Na	Imperial	Midway W	140	32.70782	-115.016	Zone-11 N	T17S, R19E 25 MILES W
Unknown	Natural/Na	Imperial | S	In-ko-pah Gorge (3211		32.67397	-116.106	Zone-11 N	T17S, R08E MOUNTAIN
Unknown	Natural/Na	Imperial	Painted Go	200	32.77485	-115.941	Zone-11 N	T16S, R10E COYOTE W
Unknown	Natural/Na	Imperial	Grays Well	220	32.73514	-114.797	Zone-11 N	T16S, R21E PILOT KNO
Unknown	Natural/Na	Imperial	Kane Spring	-200	33.11131	-115.768	Zone-11 N	T12S, R12E TRIFOLIUM

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Unknown	Natural/Na	Imperial	Shell Reef (	180	33.19057	-116.057	Zone-11 N	T11S, R09E BETWEEN S
Unknown	Natural/Na	Imperial	Kane Sprin	42	33.18732	-115.987	Zone-11 N	T11S, R09E 2.25 MILES
Unknown	Natural/Na	Imperial | I	Durmid (33	-220	33.46954	-115.979	Zone-11 N	T08S, R10E NORTH ENI
Unknown	Natural/Na	Imperial | /	Palo Verde (3311446)		33.41324	-114.658	Zone-11 N	T09S, R22E CIBOLA BRI
Unknown	Natural/Na	Imperial	Grays Well	210	32.72007	-114.774	Zone-11 N	T16S, R21E PILOT KNO
Unknown	Natural/Na	Imperial	Glamis (32	265	32.9108	-115.112	Zone-11 N	T14S, R18E WEST SIDE
Unknown	Natural/Na	Imperial	Grays Well	200	32.72301	-114.779	Zone-11 N	T16S, R21E PILOT KNOI
Unknown	Natural/Na	Imperial	Calipatria S	-235	33.11146	-115.697	Zone-11 N	T12S, R12E SOUTHERN
Unknown	Natural/Na	Imperial	Calexico (3	20	32.69576	-115.414	Zone-11 N	T17S, R15E ALONG JAS
Unknown	Natural/Na	Imperial	Heber (321	-20	32.7408	-115.573	Zone-11 N	T16S, R13E 0.3 MILE W
Unknown	Natural/Na	Imperial	Brawley NV	-50	32.88524	-115.684	Zone-11 N	T15S, R12E 0.1 MILE EA
Unknown	Natural/Na	Imperial	Heber (321	-20	32.74509	-115.591	Zone-11 N	T16S, R13E 200 FEET E.
Unknown	Natural/Na	Imperial	Heber (321	-20	32.7379	-115.6	Zone-11 N	T16S, R13E 200' EAST C
Unknown	Natural/Na	Imperial	Calexico (3	-35	32.69949	-115.395	Zone-11 N	T17S, R15E 0.1 MILE SC
Unknown	Natural/Na	Imperial	Grays Well	200	32.72972	-114.791	Zone-11 N	T16S, R21E PILOT KNO
Unknown	Natural/Na	Imperial	Grays Well	200	32.74686	-114.815	Zone-11 N	T16S, R20E ABOUT 2.5
Unknown	Natural/Na	Imperial	Ogilby (321	220	32.75725	-114.828	Zone-11 N	T16S, R20E 0.5 MILE ES
Unknown	Natural/Na	Imperial	Wister (331	-130	33.31407	-115.579	Zone-11 N	T10S, R13E 1.4 MILES E
Unknown	Natural/Na	Imperial	El Centro (3	-29	32.79239	-115.606	Zone-11 N	T16S, R13E SILSBEE, AE
Unknown	Natural/Na	Imperial	Holtville W	-25	32.78034	-115.433	Zone-11 N	T16S, R15E 7 MILES EA
Unknown	Natural/Na	Imperial	Westmorla	-175	33.07037	-115.577	Zone-11 N	T13S, R13E 3.5 MILES N
Unknown	Natural/Na	Imperial	Heber (321	-15	32.72508	-115.543	Zone-11 N	T16S, R14E SOUTH OF
Unknown	Natural/Na	Imperial	Seeley (321	25	32.75155	-115.634	Zone-11 N	T16S, R13E JUST SOUT
Unknown	Natural/Na	Imperial	Mount Sigr	-20	32.70905	-115.64	Zone-11 N	T16S, R13E BROCKMAN
Unknown	Natural/Na	Imperial	Mount Sigr	-20	32.70973	-115.631	Zone-11 N	T16S, R13E NORTH SID
Unknown	Natural/Na	Imperial	Heber (321	-20	32.71789	-115.621	Zone-11 N	T16S, R13E WEST SIDE
Unknown	Natural/Na	Imperial	Heber (321	-10	32.71028	-115.62	Zone-11 N	T16S, R13E EAST SIDE (
Unknown	Natural/Na	Imperial	El Centro (3	-55	32.85481	-115.617	Zone-11 N	T15S, R13E NORTH SID
Unknown	Natural/Na	Imperial	El Centro (3	-60	32.85469	-115.609	Zone-11 N	T15S, R13E NORTH SID
Unknown	Natural/Na	Imperial	El Centro (3	-60	32.85885	-115.621	Zone-11 N	T15S, R13E EAST SIDE (
Unknown	Natural/Na	Imperial	Acolita (33	260	33.04784	-115.158	Zone-11 N	T13S, R17.5 EAST SIDE (
Unknown	Natural/Na	Imperial	Acolita (33	260	33.04841	-115.162	Zone-11 N	T13S, R17E EAST SIDE (
Unknown	Natural/Na	Imperial	Acolita (33	240	33.03168	-115.177	Zone-11 N	T13S, R17E EAST SIDE (
Unknown	Natural/Na	Imperial	Amos (331	235	33.09079	-115.253	Zone-11 N	T12S, R16E EAST SIDE (
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.94856	-115.406	Zone-11 N	T14S, R15E ALONG STA
Unknown	Natural/Na	Imperial	Holtville W	-40	32.79964	-115.474	Zone-11 N	T15S, R14E NEXT TO M
Unknown	Natural/Na	Imperial	Westmorla	-140	33.01865	-115.606	Zone-11 N	T13S, R13E NEAR INTE
Unknown	Natural/Na	Imperial	Superstitio	200	32.95758	-115.83	Zone-11 N	T14S, R11E SUPERSTITI
Unknown	Natural/Na	Imperial	Calipatria S	-225	33.15332	-115.637	Zone-11 N	T12S, R13E ALONG THI
Unknown	Natural/Na	Imperial | S	Carrizo Mtı	450	32.87613	-116.112	Zone-11 N	T15S, R08E THE GENER
Unknown	Natural/Na	Imperial	Cactus (3211478) | Cly		32.97808	-115.13	Zone-11 N	T13S, R17.5 ALGODONE
Unknown	Natural/Na	Imperial	Lion Head Mtn. (33115		33.33752	-115.331	Zone-11 N	T10S, R16E BEALS WEL
Unknown	Natural/Na	Imperial	Imperial Re	190	32.9784	-114.5	Zone-11 N	T14S, R24E EAST SIDE (
Unknown	Natural/Na	Imperial | /	Picacho (33	200	33.02351	-114.615	Zone-11 N	T13S, R22E CONFLUEN
Unknown	Natural/Na	Imperial	Picacho SW	200	33.02597	-114.634	Zone-11 N	T13S, R22E IMMEDIAT
Unknown	Natural/Na	Imperial	Laguna Dar	160	32.85034	-114.493	Zone-11 N	T15S, R24E 2 MILES AB
Unknown	Natural/Na	Imperial	Heber (321	-21	32.75942	-115.638	Zone-11 N	T16S, R13E SILSBEE.

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Unknown	Natural/Na	Imperial	Imperial Re	300	32.90809	-114.49	Zone-11 N	T14S, R24E 5 MILES NC
Unknown	Natural/Na	Imperial	Niland (331	-225	33.19475	-115.592	Zone-11 N	T11S, R13E ALAMO DU
Unknown	Natural/Na	Imperial | I	West of Palo Verde Pe		33.3821	-114.994	Zone-11 N	T09S, R19E 13 MI W PA
Unknown	Natural/Na	Imperial | I	Palo Verde	230	33.43647	-114.735	Zone-11 N	T08S, R21E PALO VERD
Unknown	Natural/Na	Imperial | S	In-ko-pah (	2800	32.65978	-116.099	Zone-11 N	T17S, R09E MOUNTAIN
Unknown	Natural/Na	Imperial | A	Picacho SW (3311416)		33.18	-114.7	Zone-11 N	T11S, R22E 20 MILES N
Unknown	Natural/Na	Imperial | I	Wiley Well (3311448)		33.492	-114.992	Zone-11 N	T08S, R19E 18 MILES W
Unknown	Natural/Na	Imperial | I	Calexico (3	0	32.66977	-115.496	Zone-11 N	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial	Coyote We	360	32.73718	-115.909	Zone-11 N	T16S, R10E OCOTILLO,
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	200	32.83176	-114.547	Zone-11 N	T15S, R23E 3 MILES NC
Unknown	Natural/Na	Imperial	Araz (3211	320	32.79131	-114.655	Zone-11 N	T16S, R22E 6 MILES WI
Unknown	Natural/Na	Imperial	East of Aco	100	33.02148	-115.117	Zone-11 N	T13S, R18E 3 MILES NV
Unknown	Natural/Na	Imperial	East of Aco	100	33.02148	-115.117	Zone-11 N	T13S, R18E 3 MILES NV
Unknown	Natural/Na	Imperial	East of Aco	300	33.01297	-115.104	Zone-11 N	T13S, R18E 2 MILES NV
Unknown	Natural/Na	Imperial	Glamis (321	300	32.99335	-115.08	Zone-11 N	T13S, R18E GLAMIS TO
Unknown	Natural/Na	Imperial	Glamis (321	250	32.99548	-115.108	Zone-11 N	T13S, R18E 2 MILES WI
Unknown	Natural/Na	Imperial	East of Aco	200	33.02662	-115.125	Zone-11 N	T13S, R17.5 3.5 MILES N
Unknown	Natural/Na	Imperial	Glamis NW	100	33.0006	-115.263	Zone-11 N	T13S, R17E 10.7 MILES
Unknown	Natural/Na	Imperial	Quartz Pea	1600	33.07914	-114.847	Zone-11 N	T12S, R20E BLACK MOU
Unknown	Natural/Na	Imperial | S	In-ko-pah (	3400	32.63483	-116.093	Zone-11 N	T18S, R09E VICINITY OI
Unknown	Natural/Na	Imperial	Little Picac	40	32.9758	-114.632	Zone-11 N	T14S, R22E LITTLE PICA
Unknown	Natural/Na	Imperial	Quartz Pea	900	33.02503	-114.767	Zone-11 N	T13S, R21E GAVILAN W
Unknown	Natural/Na	Imperial	Pegleg Wel	1600	33.39863	-115.165	Zone-11 N	T09S, R17E SOUTH OF
Unknown	Natural/Na	Imperial	Brawley (32	-120	32.98392	-115.525	Zone-11 N	T13S, R14E BRAWLEY.
Unknown	Natural/Na	Imperial | I	Calexico (3	10	32.66977	-115.496	Zone-11 N	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial	El Centro (3	-40	32.79162	-115.563	Zone-11 N	T16S, R14E EL CENTRO
Unknown	Natural/Na	Imperial	Heber (321	-10	32.73088	-115.53	Zone-11 N	T16S, R14E HEBER, IMI
Unknown	Natural/Na	Imperial	El Centro (3	-25	32.7651	-115.607	Zone-11 N	T16S, R13E LOCATED A
Unknown	Natural/Na	Imperial	Holtville Ea	-15	32.81449	-115.382	Zone-11 N	T15S, R15E HOLTVILLE.
Unknown	Natural/Na	Imperial	El Centro (3	-50	32.84768	-115.569	Zone-11 N	T15S, R14E CITY OF IM
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMOR
Unknown	Natural/Na	Imperial | A	Picacho SW (3311416)		33.18	-114.7	Zone-11 N	T11S, R22E 20 MILES N
Unknown	Natural/Na	Imperial	El Centro (3	-40	32.79162	-115.563	Zone-11 N	T16S, R14E EL CENTRO
Unknown	Natural/Na	Imperial | A	Yuma East	125	32.77133	-114.531	Zone-11 N	T16S, R23E ABOUT 4 M
Unknown	Natural/Na	Imperial | S	In-ko-pah (	3400	32.63483	-116.093	Zone-11 N	T18S, R09E VICINITY O
Unknown	Natural/Na	Imperial | S	In-ko-pah (	2700	32.67397	-116.106	Zone-11 N	T17S, R08E MOUNTAIN
Unknown	Natural/Na	Imperial | I	Thumb Pea	650	33.43519	-114.892	Zone-11 N	T08S, R20E IN THE MU
Unknown	Natural/Na	Imperial | A	Picacho NV	220	33.23939	-114.687	Zone-11 N	T11S, R22E VICINITY O
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMORI
Unknown	Natural/Na	Imperial	East of Aco	100	33.02148	-115.117	Zone-11 N	T13S, R18E 3 MILES NV
Unknown	Natural/Na	Imperial	Painted Go	500	32.81632	-115.973	Zone-11 N	T15S, R10E PAINTED G
Unknown	Natural/Na	Imperial	Kane Spring	-10	33.21186	-115.991	Zone-11 N	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Kane Spring	-30	33.21037	-115.98	Zone-11 N	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Hedges (32	800	32.9791	-114.781	Zone-11 N	T14S, R21E IN AND AD.
Unknown	Natural/Na	Imperial	Hedges (32	545	32.9017	-114.865	Zone-11 N	T14S, R20E 1.4 AIR MIL
Unknown	Natural/Na	Imperial	Hedges (32	540	32.89262	-114.855	Zone-11 N	T15S, R20E ABOUT 0.7

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Unknown	Natural/Na	Imperial	Hedges (32	560	32.88196	-114.841	Zone-11 N	T15S, R20E 0.7 AIR MIL
Unknown	Natural/Na	Imperial	Hedges (32	605	32.89612	-114.842	Zone-11 N	T14S, R20E 1.3 MILES N
Unknown	Natural/Na	Imperial	Hedges (32	615	32.90317	-114.844	Zone-11 N	T14S, R20E 1.8 AIR MIL
Unknown	Natural/Na	Imperial	Hedges (3211487)		32.92013	-114.85	Zone-11 N	T14S, R20E SOUTH OF
Unknown	Natural/Na	Imperial	Hedges (32	650	32.95455	-114.858	Zone-11 N	T14S, R20E NORTH OF
Unknown	Natural/Na	Imperial	Hedges (32	690	32.96358	-114.861	Zone-11 N	T14S, R20E 6.3 AIR MIL
Unknown	Natural/Na	Imperial	Quartz Pea	785	33.01246	-114.875	Zone-11 N	T13S, R20E 5.8 AIR MIL
Unknown	Natural/Na	Imperial	Ninemile W	1040	33.09684	-114.902	Zone-11 N	T12S, R20E 20 MILES N
Unknown	Natural/Na	Imperial	Ninemile W	725	33.00126	-114.902	Zone-11 N	T13S, R20E 9.8 AIR MIL
Unknown	Natural/Na	Imperial	Ninemile W	775	33.02064	-114.903	Zone-11 N	T13S, R20E 9.8 AIR MIL
Unknown	Natural/Na	Imperial	Kane Spring	-48	33.21351	-115.972	Zone-11 N	T11S, R10E ALONG TUI
Unknown	Natural/Na	Imperial	Kane Spring	-113	33.22905	-115.949	Zone-11 N	T11S, R10E ALONG TUI
Unknown	Natural/Na	Imperial	Kane Spring	-73	33.22209	-115.94	Zone-11 N	T11S, R10E 0.3 MI NOF
Unknown	Natural/Na	Imperial	Ninemile W	805	33.02894	-114.904	Zone-11 N	T13S, R20E 3.8 AIR MIL
Unknown	Natural/Na	Imperial	Kane Spring	83	33.17752	-115.945	Zone-11 N	T11S, R10E CAMPBELL
Unknown	Natural/Na	Imperial	Ninemile W	850	33.04496	-114.904	Zone-11 N	T13S, R20E 5.3 AIR MIL
Unknown	Natural/Na	Imperial	Ninemile W	900	33.05235	-114.902	Zone-11 N	T13S, R20E 3.5 AIR MIL
Unknown	Natural/Na	Imperial	Buzzards P	980	33.17467	-114.875	Zone-11 N	T11S, R20E 2.3 AIR MIL
Unknown	Natural/Na	Imperial	Kane Spring	100	33.18354	-115.914	Zone-11 N	T11S, R10E SE CAMPBE
Unknown	Natural/Na	Imperial	Kane Spring	48	33.1653	-115.903	Zone-11 N	T11S, R10E 2.7 MI N O
Unknown	Natural/Na	Imperial	Kane Spring	34	33.15601	-115.913	Zone-11 N	T12S, R10E 2 MI N OF S
Unknown	Natural/Na	Imperial	Hedges (32	710	32.97726	-114.865	Zone-11 N	T14S, R20E ALONG WE
Unknown	Natural/Na	Imperial	Kane Spring	138	33.14547	-115.948	Zone-11 N	T12S, R10E 1.3 MI N O
Unknown	Natural/Na	Imperial	Kane Spring	21	33.14546	-115.917	Zone-11 N	T12S, R10E 1.3 MI N O
Unknown	Natural/Na	Imperial	Kane Spring	-34	33.14213	-115.904	Zone-11 N	T12S, R10E 1.1 MI N O
Unknown	Natural/Na	Imperial	Ogilby (321	400	32.8326	-114.838	Zone-11 N	T15S, R20E IN WASH O
Unknown	Natural/Na	Imperial	Ninemile W	1200	33.12533	-114.909	Zone-11 N	T12S, R20E IMPERIAL C
Unknown	Natural/Na	Imperial	Chuckwalla	1650	33.42183	-115.18	Zone-11 N	T09S, R17E WASH NEA
Unknown	Natural/Na	Imperial	Kane Spring	-76	33.12585	-115.906	Zone-11 N	T12S, R10E ALONG STA
Unknown	Natural/Na	Imperial	Kane Spring	-57	33.12586	-115.925	Zone-11 N	T12S, R10E ALONG STA
Unknown	Natural/Na	Imperial	Kane Spring	-32	33.20614	-115.972	Zone-11 N	T11S, R10E ALONG TUI
Unknown	Natural/Na	Imperial	Kane Spring	130	33.16013	-115.954	Zone-11 N	T12S, R10E 6.1 MILES W
Unknown	Natural/Na	Imperial	Kane Spring	90	33.1805	-115.909	Zone-11 N	T11S, R10E 3.8 MI N O
Unknown	Natural/Na	Imperial	Kane Spring	0	33.13409	-115.921	Zone-11 N	T12S, R10E SAN FELIPE
Unknown	Natural/Na	Imperial	Kane Spring	-90	33.22332	-115.958	Zone-11 N	T11S, R10E ALONG TUI
Unknown	Natural/Na	Imperial	Kane Spring	74	33.15188	-115.966	Zone-11 N	T12S, R10E 2.5 MI EAS
Unknown	Natural/Na	Imperial	Kane Spring	74	33.15535	-115.953	Zone-11 N	T12S, R10E 3.2 MI EAS
Unknown	Natural/Na	Imperial	Kane Spring	-50	33.13947	-115.9	Zone-11 N	T12S, R10E SAN FELIPE
Unknown	Natural/Na	Imperial	Kane Spring	5	33.19602	-115.978	Zone-11 N	T11S, R10E ABOUT 0.5
Unknown	Natural/Na	Imperial	Kane Spring	59	33.18768	-115.98	Zone-11 N	T11S, R09E 4 MI SW OF
Unknown	Natural/Na	Imperial	Kane Spring	66	33.18358	-115.991	Zone-11 N	T11S, R09E 4.5 MI SW
Unknown	Natural/Na	Imperial	Kane Spring	177	33.16476	-115.991	Zone-11 N	T11S, R09E TARANTUL
Unknown	Natural/Na	Imperial	Kane Spring	21	33.13624	-115.991	Zone-11 N	T12S, R09E 0.2 MI EAS
Unknown	Natural/Na	Imperial	Kane Spring	44	33.13718	-115.985	Zone-11 N	T12S, R09E 1 MILE NOI
Unknown	Natural/Na	Imperial	Shell Reef (	179	33.22408	-116.069	Zone-11 N	T11S, R09E JUST SOUT
Unknown	Natural/Na	Imperial	Shell Reef (	150	33.22762	-116.057	Zone-11 N	T11S, R09E FROM TULI
Unknown	Natural/Na	Imperial	Shell Reef (	99	33.21993	-116.045	Zone-11 N	T11S, R09E SOUTH OF

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Unknown	Natural/Na	Imperial	Shell Reef (	75	33.22239	-116.033	Zone-11 N	T11S, R09E JUST NORT
Unknown	Natural/Na	Imperial	Shell Reef (	78	33.21781	-116.035	Zone-11 N	T11S, R09E SOUTH OF
Unknown	Natural/Na	Imperial	Shell Reef (	48	33.21985	-116.019	Zone-11 N	T11S, R09E ALONG/NC
Unknown	Natural/Na	Imperial	Shell Reef (	40	33.21707	-116.012	Zone-11 N	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Shell Reef (	68	33.19533	-116.01	Zone-11 N	T11S, R09E ABOUT MIL
Unknown	Natural/Na	Imperial	Shell Reef (	55	33.19836	-116.007	Zone-11 N	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Shell Reef (	120	33.18221	-116.035	Zone-11 N	T11S, R09E TARANTUL
Unknown	Natural/Na	Imperial	Shell Reef (	100	33.16242	-116.01	Zone-11 N	T11S, R09E 9.3 AIR MIL
Unknown	Natural/Na	Imperial	Shell Reef (	35	33.13148	-116.009	Zone-11 N	T12S, R09E 0.4 MILE N
Unknown	Natural/Na	Imperial	Shell Reef (	80	33.14914	-116.029	Zone-11 N	T12S, R09E 1.6 MILES N
Unknown	Natural/Na	Imperial	Shell Reef (	61	33.13202	-116.036	Zone-11 N	T12S, R09E ALONG JEE
Unknown	Natural/Na	Imperial	Borrego M	25	33.1257	-116.017	Zone-11 N	T12S, R09E ALONG HW
Unknown	Natural/Na	Imperial	Shell Reef (	91	33.15063	-116.075	Zone-11 N	T12S, R09E 1.4 MILES N
Unknown	Natural/Na	Imperial	Shell Reef (	120	33.14871	-116.05	Zone-11 N	T12S, R09E 1.6 MI N O
Unknown	Natural/Na	Imperial |	In-ko-pah Gorge (3211		32.64938	-116.11	Zone-11 N	T17S, R08E IN-KOH-PA
Unknown	Natural/Na	Imperial	Wister (33	-224	33.27814	-115.602	Zone-11 N	T10S, R13E Z LATERAL
Unknown	Natural/Na	Imperial	Calipatria S	-225	33.09863	-115.735	Zone-11 N	T12S, R12E TRIFOLIUM
Unknown	Natural/Na	Imperial	Calipatria S	-222	33.09583	-115.692	Zone-11 N	T12S, R12E TRIFOLIUM
Unknown	Natural/Na	Imperial	Niland (331	-222	33.20572	-115.588	Zone-11 N	T11S, R13E O LATERAL
Unknown	Natural/Na	Imperial |	Cibola (331	230	33.34733	-114.714	Zone-11 N	T09S, R21E COLORADC
Unknown	Natural/Na	Imperial	Kane Spring	-50	33.21664	-115.974	Zone-11 N	T11S, R10E TULE WASH
Unknown	Natural/Na	Imperial	Brawley (3	-104	32.98103	-115.554	Zone-11 N	T13S, R14E EAST OF TH
Unknown	Natural/Na	Imperial	Hedges (32	537	32.90071	-114.863	Zone-11 N	T14S, R20E UNNAMED
Unknown	Natural/Na	Imperial	Ninemile W	945	33.07672	-114.894	Zone-11 N	T12S, R20E WASH BETV
Unknown	Natural/Na	Imperial	Ninemile W	1045	33.10116	-114.888	Zone-11 N	T12S, R20E WASH EAST
Unknown	Natural/Na	Imperial	Thumb Pea	282	33.42841	-114.762	Zone-11 N	T09S, R21E SAND WAS
Unknown	Natural/Na	Imperial	Buzzards Peak (331142		33.20311	-114.867	Zone-11 N	T11S, R20E BRAIDED W
Unknown	Natural/Na	Imperial	Clyde (321	366	32.92479	-114.991	Zone-11 N	T14S, R19E EASTERN EI
Unknown	Natural/Na	Imperial	Palo Verde	238	33.39347	-114.748	Zone-11 N	T09S, R21E ALONG NO
Unknown	Natural/Na	Imperial	Harpers Well (3311518		33.09648	-115.906	Zone-11 N	T12S, R10E HARPERS V
Unknown	Natural/Na	Imperial	Harpers W	-115	33.09881	-115.929	Zone-11 N	T12S, R10E SAN FELIPE
Unknown	Natural/Na	Imperial |	Laguna Dar	180	32.87889	-114.472	Zone-11 N	T15S, R24E 0.6 MILE W
Unknown	Natural/Na	Imperial	Niland (331	-163	33.25451	-115.54	Zone-11 N	T10S, R14E VICINITY O
Unknown	Natural/Na	Imperial	Seeley (321	-49	32.84726	-115.67	Zone-11 N	T15S, R13E 6 MILES WI
Unknown	Natural/Na	Imperial	Picacho NV	525	33.14004	-114.721	Zone-11 N	T12S, R21E VICINITY O
Unknown	Natural/Na	Imperial	Glamis NW	110	32.97156	-115.187	Zone-11 N	T13S, R17E 7.2 MILES V
Unknown	Natural/Na	Imperial	Picacho NV	220	33.16163	-114.683	Zone-11 N	T12S, R22E COLORADC
Unknown	Natural/Na	Imperial	Picacho SW	200	33.02673	-114.635	Zone-11 N	T13S, R22E COLORADC
Unknown	Natural/Na	Imperial	Picacho NV	210	33.20277	-114.684	Zone-11 N	T11S, R22E IN THE VICI
Unknown	Natural/Na	Imperial |	Calexico (3	5	32.66977	-115.496	Zone-11 N	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial |	Picacho SW	200	33.12595	-114.699	Zone-11 N	T99X, R99X 24 MI S OF
Unknown	Natural/Na	Imperial	Glamis (32	300	32.99335	-115.08	Zone-11 N	T13S, R18E 1 MI W OF
Unknown	Natural/Na	Imperial	Kane Spring	-180	33.11182	-115.838	Zone-11 N	T12S, R11E KANE SPRI
Unknown	Natural/Na	Imperial |	Palo Verde	230	33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial |	Picacho NV	210	33.21003	-114.678	Zone-11 N	T11S, R22E 15 MI SOU
Unknown	Natural/Na	Imperial	Hedges (32	780	32.89976	-114.826	Zone-11 N	T14S, R20E MINES IN T
Unknown	Natural/Na	Imperial	Hedges (32	780	32.89976	-114.826	Zone-11 N	T14S, R20E CARGO MU

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Buzzards P	750	33.21128	-114.767	Zone-11 N	T11S, R21E BARREN M
Unknown	Natural/Na	Imperial	Hedges (32	820	32.90686	-114.826	Zone-11 N	T14S, R20E CARGO MU
Unknown	Natural/Na	Imperial	Obsidian B	-235	33.17506	-115.641	Zone-11 N	T11S, R13E SALTON SE
Unknown	Natural/Na	Imperial	Lion Head I	1360	33.33771	-115.33	Zone-11 N	T10S, R16E BEAL WELL
Unknown	Natural/Na	Imperial | I	Calexico (3	5	32.66977	-115.496	Zone-11 N	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial	Lion Head I	1360	33.33771	-115.33	Zone-11 N	T10S, R16E BEAL WELL
Unknown	Natural/Na	Imperial | I	Palo Verde (3311446)		33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial	Hedges (32	800	32.98877	-114.792	Zone-11 N	T13S, R21E ABOUT 6 M
Unknown	Natural/Na	Imperial	Hedges (32	800	32.98877	-114.792	Zone-11 N	T13S, R21E ABOUT 6 M
Unknown	Natural/Na	Imperial	Bard (3211	275	32.8462	-114.506	Zone-11 N	T15S, R23E PICACHO M
Unknown	Natural/Na	Imperial	Ogilby (321	740	32.86227	-114.77	Zone-11 N	T15S, R21E AMERICAN
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.12992	-115.06	Zone-11 N	T12S, R18E CHOCOLAT
Unknown	Natural/Na	Imperial	Iris Wash (3	790	33.36806	-115.453	Zone-11 N	T09S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Iris Wash (3	790	33.36806	-115.453	Zone-11 N	T09S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Lion Head I	950	33.30837	-115.358	Zone-11 N	T10S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Lion Head I	950	33.30837	-115.358	Zone-11 N	T10S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Lion Head I	950	33.30837	-115.358	Zone-11 N	T10S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Lion Head I	950	33.30837	-115.358	Zone-11 N	T10S, R15E CHOCOLAT
Unknown	Natural/Na	Imperial	Ninemile W	1170	33.0872	-114.935	Zone-11 N	T12S, R19E CHOCOLAT
Unknown	Natural/Na	Imperial	Lion Head I	1180	33.26578	-115.265	Zone-11 N	T10S, R16E CHOCOLAT
Unknown	Natural/Na	Imperial	Iris Wash (3	90	33.29305	-115.495	Zone-11 N	T10S, R14E CHOCOLAT
Unknown	Natural/Na	Imperial	Iris Wash (3	90	33.29305	-115.495	Zone-11 N	T10S, R14E CHOCOLAT
Unknown	Natural/Na	Imperial	Heber (321	10	32.68835	-115.597	Zone-11 N	T17S, R13E WISTARIA 2
Unknown	Natural/Na	Imperial	El Centro (3	-30	32.77256	-115.561	Zone-11 N	T16S, R14E EL CENTRO
Unknown	Natural/Na	Imperial	Holtville W	-20	32.75243	-115.502	Zone-11 N	T16S, R14E SE OF EL CE
Unknown	Natural/Na	Imperial	Midway W	90	32.70502	-115.211	Zone-11 N	T17S, R17E SOUTH SID
Unknown	Natural/Na	Imperial	Holtville Ea	26	32.81554	-115.283	Zone-11 N	T15S, R16E WEST SIDE
Unknown	Natural/Na	Imperial	Midway W	85	32.70124	-115.183	Zone-11 N	T17S, R17E 0.25 MILE S
Unknown	Natural/Na	Imperial	Holtville Ea	85	32.87464	-115.297	Zone-11 N	T15S, R16E ALONG HO
Unknown	Natural/Na	Imperial	Brawley NV	1920	32.96531	-115.675	Zone-11 N	T14S, R13E 0.35 MILE S
Unknown	Natural/Na	Imperial	Yuma West	130	32.7324	-114.716	Zone-11 N	T16S, R21E ALONG ALA
Unknown	Natural/Na	Imperial	Heber (321	-21	32.75942	-115.638	Zone-11 N	T16S, R13E SILSBEE.
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Palo Verde	250	33.41585	-114.75	Zone-11 N	T09S, R21E ABOUT 2 M
Unknown	Natural/Na	Imperial	El Centro (3	-20	32.75799	-115.556	Zone-11 N	T16S, R14E 0.8 MI NNE
Unknown	Natural/Na	Imperial	El Centro (3	30	32.7637	-115.554	Zone-11 N	T16S, R14E EL CENTRO
Unknown	Natural/Na	Imperial	El Centro (3	30	32.78036	-115.586	Zone-11 N	T16S, R13E EL CENTRO
Unknown	Natural/Na	Imperial	El Centro (3	30	32.78193	-115.594	Zone-11 N	T16S, R13E EL CENTRO
Unknown	Natural/Na	Imperial	Calexico (3	0	32.70918	-115.5	Zone-11 N	T16S, R14E NW CORNE
Unknown	Natural/Na	Imperial	El Centro (3	-40	32.80033	-115.54	Zone-11 N	T15S, R14E EL CENTRO
Unknown	Natural/Na	Imperial	Iris (331152	-95	33.23498	-115.493	Zone-11 N	T11S, R14E ALONG UN
Unknown	Natural/Na	Imperial	Wister (331	-190	33.28364	-115.577	Zone-11 N	T10S, R13E ALONG UN
Unknown	Natural/Na	Imperial	Wister (331	-190	33.29466	-115.586	Zone-11 N	T10S, R13E ALONG UN
Unknown	Natural/Na	Imperial	Imperial Re	200	32.88341	-114.469	Zone-11 N	T15S, R24E IMPERIAL D
Unknown	Natural/Na	Imperial	Ogilby (321	360	32.81682	-114.789	Zone-11 N	T15S, R21E 3 MILES EA
Unknown	Natural/Na	Imperial	In-ko-pah C	1300	32.63562	-116.016	Zone-11 N	T18S, R09E PINTO CAN
Unknown	Natural/Na	Imperial | I	Mount Sigr	984	32.65791	-115.77	Zone-11 N	T17S, R12E PINTO WAS

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Unknown	Natural/Na	Imperial	Hedges (32	640	32.91583	-114.837	Zone-11 N	T14S, R20E ON BLM RI
Unknown	Natural/Na	Imperial	Wister (331	-190	33.32789	-115.613	Zone-11 N	T10S, R13E 8.40 MI NW
Unknown	Natural/Na	Imperial	Wister (331	-190	33.27536	-115.57	Zone-11 N	T10S, R13E 4.20 MI NW
Unknown	Natural/Na	Imperial	Wister (331	-190	33.25633	-115.538	Zone-11 N	T10S, R14E AT BM 168
Unknown	Natural/Na	Imperial	Niland (331	-190	33.25137	-115.531	Zone-11 N	T10S, R14E 1.30 MI NW
Unknown	Natural/Na	Imperial	Niland (331	-190	33.24874	-115.525	Zone-11 N	T11S, R14E 0.90 MI NW
Unknown	Natural/Na	Imperial	Iris (33115	-100	33.2369	-115.497	Zone-11 N	T11S, R14E ABOUT 1.0
Unknown	Natural/Na	Imperial	Iris (33115	-100	33.22156	-115.464	Zone-11 N	T11S, R14E 3.1 MI SW (
Unknown	Natural/Na	Imperial	Iris (33115	-15	33.21425	-115.447	Zone-11 N	T11S, R15E 4.1 MI SW (
Unknown	Natural/Na	Imperial	Iris (33115	-15	33.21128	-115.441	Zone-11 N	T11S, R15E 4.5 MI SW (
Unknown	Natural/Na	Imperial	Acolita (33	280	33.04224	-115.139	Zone-11 N	T13S, R17.5 5.0 MI NW
Unknown	Natural/Na	Imperial	Coyote We	340	32.67364	-115.896	Zone-11 N	T17S, R11E BLM CRUCI
Unknown	Natural/Na	Imperial	Coyote We	830	32.64039	-115.95	Zone-11 N	T17S, R10E SKULL VALI
Unknown	Natural/Na	Imperial	Seeley (321	-41	32.79372	-115.691	Zone-11 N	T16S, R12E SEELEY.
Unknown	Natural/Na	Imperial	Picacho SW (3311416)		33.04594	-114.688	Zone-11 N	T13S, R22E SANDY WA
Unknown	Natural/Na	Imperial	Quartz Pea	1000	33.05875	-114.789	Zone-11 N	T13S, R21E JULIAN WA
Unknown	Natural/Na	Imperial	Mt. Barrow	1385	33.13107	-114.949	Zone-11 N	T12S, R19E AT THE WE
Unknown	Natural/Na	Imperial	Palo Verde	850	33.3242	-114.778	Zone-11 N	T10S, R21E 9.5 MILES S
Unknown	Natural/Na	Imperial	Cibola (3311436) | Pal		33.29252	-114.753	Zone-11 N	T10S, R21E 10.5 MILES
Unknown	Natural/Na	Imperial	Lion Head Mtn. (3311		33.33752	-115.331	Zone-11 N	T10S, R16E BEAL WELL
Unknown	Natural/Na	Imperial	Hedges (32	550	32.91613	-114.878	Zone-11 N	T14S, R20E ALONG PIP
Unknown	Natural/Na	Imperial	Ninemile W	1050	33.09941	-114.889	Zone-11 N	T12S, R20E 1.5 MI NE (
Unknown	Natural/Na	Imperial	Quartz Pea	820	33.02118	-114.878	Zone-11 N	T13S, R20E ABOUT 1.5
Unknown	Natural/Na	Imperial	Ninemile W	910	33.05999	-114.9	Zone-11 N	T13S, R20E 2 MI SE OF
Unknown	Natural/Na	Imperial	Ninemile W	860	33.04415	-114.885	Zone-11 N	T13S, R20E 3.17 MI SE
Unknown	Natural/Na	Imperial	Ninemile W	800	33.02731	-114.904	Zone-11 N	T13S, R20E EAST SIDE (
Unknown	Natural/Na	Imperial	Buzzards P	876	33.20611	-114.855	Zone-11 N	T11S, R20E EAST SIDE (
Unknown	Natural/Na	Imperial	Buzzards P	1010	33.14886	-114.871	Zone-11 N	T12S, R20E ABOUT 0.5
Unknown	Natural/Na	Imperial	Clyde (321	560	32.94062	-114.887	Zone-11 N	T14S, R20E ROAD BETV
Unknown	Natural/Na	Imperial	Clyde (321	635	32.97366	-114.896	Zone-11 N	T14S, R20E WEST SIDE
Unknown	Natural/Na	Imperial	Buzzards P	940	33.183	-114.871	Zone-11 N	T11S, R20E VICINITY O
Unknown	Natural/Na	Imperial	Buzzards P	840	33.2142	-114.861	Zone-11 N	T11S, R20E JUST SOUT
Unknown	Natural/Na	Imperial	Ninemile W	970	33.08061	-114.893	Zone-11 N	T12S, R20E 1 MI E OF H
Unknown	Natural/Na	Imperial	Pegleg Wel	1540	33.37444	-115.178	Zone-11 N	T09S, R17E SOUTH SID
Unknown	Natural/Na	Imperial	Hedges (32	685	32.9578	-114.838	Zone-11 N	T14S, R20E WEST SIDE
Unknown	Natural/Na	Imperial	Cibola (3311436)		33.3504	-114.708	Zone-11 N	T09S, R21E 6 MILES SO
Unknown	Natural/Na	Imperial | I	Palo Verde	350	33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial	Pegleg Wel	1860	33.25472	-115.188	Zone-11 N	T10S, R17E 2.6 MI EAS
Unknown	Natural/Na	Imperial	Pegleg Wel	1380	33.3053	-115.196	Zone-11 N	T10S, R17E 4.0 MI NE (
Unknown	Natural/Na	Imperial	Hedges (32	550	32.88189	-114.845	Zone-11 N	T15S, R20E ABOUT 0.7
Unknown	Natural/Na	Imperial	Hedges (32	615	32.92644	-114.851	Zone-11 N	T14S, R20E INDIAN WA
Unknown	Natural/Na	Imperial	Hedges (32	630	32.94817	-114.858	Zone-11 N	T14S, R20E 0.9 MILE N
Unknown	Natural/Na	Imperial	Buzzards P	960	33.17928	-114.874	Zone-11 N	T11S, R20E 2.50 MI S C
Unknown	Natural/Na	Imperial	Buzzards P	720	33.23708	-114.842	Zone-11 N	T11S, R20E 1.5 MI NNE
Unknown	Natural/Na	Imperial	Buzzards P	670	33.24861	-114.832	Zone-11 N	T11S, R20E 2.5 MI NE (
Unknown	Natural/Na	Imperial	Palo Verde	580	33.26036	-114.815	Zone-11 N	T10S, R20E 4 MI NE OF
Unknown	Natural/Na	Imperial	Palo Verde	490	33.27637	-114.8	Zone-11 N	T10S, R21E 4 MI SSW C

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Unknown	Natural/Na	Imperial	Wister (331	-180	33.26487	-115.56	Zone-11 NA	T10S, R14E ABOUT 3.0
Unknown	Transplant	Imperial	El Centro (3	-40	32.79162	-115.563	Zone-11 NA	T16S, R14E EL CENTRO
Unknown	Natural/Na	Imperial	Mount Sigr	70	32.68881	-115.742	Zone-11 NA	T17S, R12E PINTO WAS
Unknown	Natural/Na	Imperial	Yuha Basin	242	32.64654	-115.836	Zone-11 NA	T17S, R11E PINTO WAS
Unknown	Natural/Na	Imperial	Glamis SE (	143	32.79207	-115.063	Zone-11 NA	T16S, R18E GLAMIS SA
Unknown	Natural/Na	Imperial	Plaster City	75	32.94662	-115.881	Zone-11 NA	T14S, R11E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	87	32.95932	-115.918	Zone-11 NA	T14S, R10E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	78	32.94522	-115.89	Zone-11 NA	T14S, R10E WEST MES/
Unknown	Natural/Na	Imperial	Niland (331	-231	33.20812	-115.615	Zone-11 NA	T11S, R13E JUST NW O
Decreasing	Natural/Na	Imperial	Niland (331	-200	33.22531	-115.609	Zone-11 NA	T11S, R13E MULLET ISL
Decreasing	Natural/Na	Imperial	Obsidian Bu	-217	33.17313	-115.642	Zone-11 NA	T11S, R13E OBSIDIAN B
Unknown	Natural/Na	Imperial	Harpers W(	20	33.12566	-115.985	Zone-11 NA	T12S, R09E ALONG STA
Unknown	Natural/Na	Imperial | A	Imperial Re	190	32.89945	-114.471	Zone-11 NA	T15S, R24E WEST SIDE
Unknown	Natural/Na	Imperial	Picacho SW	220	33.11346	-114.705	Zone-11 NA	T12S, R21E POND/MAI
Unknown	Natural/Na	Imperial	Harpers W(	-115	33.09857	-115.928	Zone-11 NA	T12S, R10E SAN FELIPE
Unknown	Natural/Na	Imperial	Imperial Re	190	32.97182	-114.472	Zone-11 NA	T14S, R24E CALIFORNI/
Unknown	Natural/Na	Imperial	Imperial Re	190	32.96479	-114.471	Zone-11 NA	T14S, R24E CA SIDE OF
Unknown	Natural/Na	Imperial	Imperial Re	190	32.95556	-114.473	Zone-11 NA	T14S, R24E CA SIDE OF
Unknown	Natural/Na	Imperial | I	Grays Well	150	32.70949	-114.978	Zone-11 NA	T16S, R19E SOUTH POI
Unknown	Natural/Na	Imperial	Grays Well	200	32.75652	-114.836	Zone-11 NA	T16S, R20E SE END OF
Unknown	Natural/Na	Imperial	Clyde (321	400	32.9089	-114.965	Zone-11 NA	T14S, R19E EAST SIDE (
Unknown	Natural/Na	Imperial	Tortuga (33	89	33.15105	-115.359	Zone-11 NA	T12S, R15E EAST MESA
Unknown	Natural/Na	Imperial	Frink NW (3	-115	33.41701	-115.693	Zone-11 NA	T09S, R12E ABOUT 0.5
Unknown	Natural/Na	Imperial	Obsidian Bu	-230	33.16947	-115.631	Zone-11 NA	T11S, R13E ABOUT 0.4
Unknown	Natural/Na	Imperial	Calipatria S	-220	33.08433	-115.704	Zone-11 NA	T12S, R12E ABOUT 0.9
Unknown	Natural/Na	Imperial	Calipatria S	-220	33.10442	-115.684	Zone-11 NA	T12S, R12E MARSH WE
Unknown	Natural/Na	Imperial	Seeley (321	-100	32.81508	-115.714	Zone-11 NA	T15S, R12E VICINITY O
Unknown	Natural/Na	Imperial	Midway W(	95	32.70459	-115.173	Zone-11 NA	T17S, R17E VICINITY O
Unknown	Natural/Na	Imperial	Laguna Dar	170	32.85724	-114.493	Zone-11 NA	T15S, R24E EAST SHOR
Unknown	Natural/Na	Imperial	Laguna Dar	170	32.87652	-114.482	Zone-11 NA	T15S, R24E GENERAL A
Unknown	Natural/Na	Imperial	Imperial Re	240	32.90208	-114.485	Zone-11 NA	T15S, R24E WEST OF S(
Unknown	Natural/Na	Imperial | A	Imperial Re	180	32.9292	-114.48	Zone-11 NA	T14S, R24E COLORADC
Unknown	Natural/Na	Imperial | A	Imperial Re	180	32.94577	-114.479	Zone-11 NA	T14S, R24E COLORADC
Unknown	Natural/Na	Imperial	Seventeen	145	33.25336	-116.05	Zone-11 NA	T10S, R09E NORTH FOI
Unknown	Natural/Na	Imperial	Shell Reef (	130	33.18636	-116.044	Zone-11 NA	T11S, R09E TARANTUL/
Unknown	Natural/Na	Imperial	Shell Reef (	124	33.19985	-116.015	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Shell Reef (	45	33.2099	-116.008	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Shell Reef (	59	33.20888	-116.014	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Shell Reef (	140	33.18617	-116.01	Zone-11 NA	T11S, R09E VICINITY O
Unknown	Natural/Na	Imperial	Shell Reef (	143	33.18717	-116.05	Zone-11 NA	T11S, R09E TARANTUL/
Unknown	Natural/Na	Imperial	Kane Spring	-77	33.22932	-115.955	Zone-11 NA	T11S, R10E ABOUT 0.2
Unknown	Natural/Na	Imperial	Shell Reef (	23	33.22567	-116.003	Zone-11 NA	T11S, R09E NORTH OF
Unknown	Natural/Na	Imperial	Kane Spring	21	33.22104	-116.001	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Kane Spring	-30	33.21038	-115.975	Zone-11 NA	T11S, R10E TULE WASH
Unknown	Natural/Na	Imperial	Kane Spring	46	33.19257	-115.991	Zone-11 NA	T11S, R09E TULE WASH
Unknown	Natural/Na	Imperial	Kane Spring	23	33.19199	-115.976	Zone-11 NA	T11S, R10E TULE WASH
Unknown	Natural/Na	Imperial	Kane Spring	150	33.18309	-115.977	Zone-11 NA	T11S, R10E TULE WASH

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Unknown	Natural/Na	Imperial	Kane Sprin	150	33.17814	-115.983	Zone-11 N	T11S, R09E 8.1 MILES N
Unknown	Natural/Na	Imperial	Kane Sprin	55	33.18384	-115.96	Zone-11 N	T11S, R10E SOUTHERN
Unknown	Natural/Na	Imperial	Kane Sprin	70	33.18586	-115.967	Zone-11 N	T11S, R10E SOUTHERN
Unknown	Natural/Na	Imperial	Kane Sprin	12	33.19347	-115.956	Zone-11 N	T11S, R10E TULE/CAM
Unknown	Natural/Na	Imperial	Kane Sprin	4	33.19538	-115.951	Zone-11 N	T11S, R10E CAMPBELL
Unknown	Natural/Na	Imperial	Kane Sprin	169	33.16824	-115.964	Zone-11 N	T11S, R10E TULE/CAM
Unknown	Natural/Na	Imperial	Kane Sprin	175	33.17119	-115.976	Zone-11 N	T11S, R10E E SIDE OF F
Unknown	Natural/Na	Imperial	Kane Sprin	83	33.18123	-115.997	Zone-11 N	T11S, R09E SOUTHERN
Unknown	Natural/Na	Imperial	Shell Reef (	100	33.18264	-116.003	Zone-11 N	T11S, R09E SOUTHERN
Unknown	Natural/Na	Imperial	Shell Reef (	100	33.17565	-116.024	Zone-11 N	T11S, R09E 10 TO 11 M
Unknown	Natural/Na	Imperial	Shell Reef (	80	33.15166	-116.006	Zone-11 N	T12S, R09E 8.9 MILES \
Unknown	Natural/Na	Imperial	Shell Reef (	60	33.14526	-116.012	Zone-11 N	T12S, R09E TARANTUL
Unknown	Natural/Na	Imperial	Kane Sprin	20	33.13258	-115.992	Zone-11 N	T12S, R09E TARANTUL
Unknown	Natural/Na	Imperial	Kane Sprin	-8	33.14243	-115.909	Zone-11 N	T12S, R10E 2.7 MI NOF
Unknown	Natural/Na	Imperial	Kane Sprin	-42	33.13413	-115.9	Zone-11 N	T12S, R10E NORTH OF
Unknown	Natural/Na	Imperial	Kane Sprin	-144	33.13118	-115.872	Zone-11 N	T12S, R11E NORTH OF
Unknown	Natural/Na	Imperial	Kane Sprin	86	33.17462	-115.904	Zone-11 N	T11S, R10E SOUTHEAS
Unknown	Natural/Na	Imperial	Kane Sprin	15	33.17507	-115.89	Zone-11 N	T11S, R10E JUST SOUT
Unknown	Natural/Na	Imperial	Kane Sprin	10	33.16002	-115.897	Zone-11 N	T12S, R10E 3.3 MILES N
Unknown	Natural/Na	Imperial	Seventeen	78	33.26211	-116.024	Zone-11 N	T10S, R09E ARROYO SA
Unknown	Natural/Na	Imperial	Shell Reef (	121	33.17177	-116.044	Zone-11 N	T11S, R09E WEST TARA
Unknown	Natural/Na	Imperial	Kane Sprin	62	33.1854	-115.966	Zone-11 N	T11S, R10E 0.5 ESE OF
Unknown	Natural/Na	Imperial	Picacho (33	200	33.02489	-114.612	Zone-11 N	T13S, R22E VICINITY O
Unknown	Natural/Na	Imperial	Shell Reef (	66	33.13923	-116.055	Zone-11 N	T12S, R09E SAN FELIPE
Unknown	Natural/Na	Imperial	Kane Sprin	-30	33.20429	-115.932	Zone-11 N	T11S, R10E EAST OF CA
Unknown	Natural/Na	Imperial	Kane Sprin	41	33.18088	-115.901	Zone-11 N	T11S, R10E SOUTHEAS
Unknown	Natural/Na	Imperial	Kane Sprin	-20	33.2032	-115.974	Zone-11 N	T11S, R10E ALONG TUI
Unknown	Natural/Na	Imperial	Frink (3311	-191	33.37396	-115.684	Zone-11 N	T09S, R12E ALONG STA
Unknown	Natural/Na	Imperial	Imperial Re	191	32.90427	-114.465	Zone-11 N	T15S, R24E EAST OF SC
Unknown	Natural/Na	Imperial	Imperial Re	180	32.96957	-114.47	Zone-11 N	T14S, R24E SOUTH OF
Unknown	Natural/Na	Imperial	Imperial Re	189	32.94707	-114.475	Zone-11 N	T14S, R24E CALIFORNI
Unknown	Natural/Na	Imperial	Imperial Re	194	32.94034	-114.481	Zone-11 N	T14S, R24E CALIFORNI
Fluctuating	Natural/Na	Imperial	Imperial Re	273	32.90168	-114.484	Zone-11 N	T15S, R24E HURRICAN
Unknown	Natural/Na	Imperial	Bard (3211	154	32.83237	-114.542	Zone-11 N	T15S, R23E MISSION W
Stable	Natural/Na	Imperial	Calipatria S	-215	33.08289	-115.71	Zone-11 N	T12S, R12E ALONG VEI
Fluctuating	Natural/Na	Imperial	Niland (331	-220	33.1754	-115.625	Zone-11 N	T11S, R13E ROCK HILL
Stable	Natural/Na	Imperial	Niland (331	-224	33.18054	-115.616	Zone-11 N	T11S, R13E HEADQUAF
Stable	Natural/Na	Imperial	Niland (331	-219	33.18556	-115.589	Zone-11 N	T11S, R13E HAZARD 6
Stable	Natural/Na	Imperial	Niland (331	-221	33.19626	-115.583	Zone-11 N	T11S, R13E HAZARD 10
Unknown	Natural/Na	Imperial	Obsidian B	-221	33.16942	-115.631	Zone-11 N	T11S, R13E MCKINDRY
Unknown	Natural/Na	Imperial	Yuha Basin	15	32.74563	-115.785	Zone-11 N	T16S, R11E WEST MES
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMOR
Unknown	Natural/Na	Imperial	Carrizo Mtı	1149	32.81335	-116.033	Zone-11 N	T15S, R09E COYOTE M
Unknown	Natural/Na	Imperial	Grays Well	200	32.73237	-114.903	Zone-11 N	T16S, R20E VICINITY O
Unknown	Natural/Na	Imperial	In-ko-pah C	562	32.74805	-116.029	Zone-11 N	T16S, R09E VICINITY O
Unknown	Natural/Na	Imperial	Carrizo Mtı	400	32.88063	-116.048	Zone-11 N	T15S, R09E 3 MILES EA
Unknown	Natural/Na	Imperial | S	Carrizo Mtn. NE (3211		33.00477	-116.114	Zone-11 N	T13S, R08E NEAR SPLIT

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Wister (33:	95	33.32862	-115.541	Zone-11 N	T10S, R14E COACHELL/
Unknown	Natural/Na	Imperial	Kane Sprin	-100	33.17695	-115.857	Zone-11 N	T11S, R11E 3.5 MILES N
Unknown	Natural/Na	Imperial | S	In-ko-pah Gorge (3211		32.67397	-116.106	Zone-11 N	T17S, R08E BASE OF M
Unknown	Natural/Na	Imperial | /	Yuma East	130	32.73659	-114.628	Zone-11 N	T16S, R22E AREA OF W
Unknown	Natural/Na	Imperial | S	Carrizo Mtı	996	32.79353	-116.108	Zone-11 N	T16S, R08E ALONG THI
Unknown	Natural/Na	Imperial	Coyote We	400	32.75465	-116.003	Zone-11 N	T16S, R09E VICINITY O
Unknown	Natural/Na	Imperial	Yuma West	250	32.74686	-114.755	Zone-11 N	T16S, R21E I-8 AT JUNC
Unknown	Natural/Na	Imperial	Seventeen	230	33.288	-116.058	Zone-11 N	T10S, R09E IN VICINITY
Unknown	Natural/Na	Imperial	Seventeen	62	33.28949	-116.043	Zone-11 N	T10S, R09E NORTHERN
Unknown	Natural/Na	Imperial	Seventeen	66	33.29924	-116.022	Zone-11 N	T10S, R09E CORAL WA
Unknown	Natural/Na	Imperial	Seventeen	100	33.31203	-116.03	Zone-11 N	T10S, R09E GRAVE WA
Unknown	Natural/Na	Imperial | S	Seventeen	180	33.32218	-116.068	Zone-11 N	T10S, R09E BIG WASH,
Unknown	Natural/Na	Imperial | S	Seventeen	550	33.30473	-116.076	Zone-11 N	T10S, R09E GRAVE WA
Unknown	Natural/Na	Imperial	Grays Well	150	32.70818	-114.973	Zone-11 N	T17S, R19E 22 MILES W
Unknown	Natural/Na	Imperial	Shell Reef (	160	33.19501	-116.046	Zone-11 N	T11S, R09E E SIDE OF T
Unknown	Natural/Na	Imperial	Kane Sprin	73	33.15533	-115.977	Zone-11 N	T12S, R10E ALONG PO
Unknown	Natural/Na	Imperial	Holtville Ea	25	32.77114	-115.28	Zone-11 N	T16S, R16E 7 MILES E C
Unknown	Natural/Na	Imperial	Holtville Ea	0	32.87658	-115.293	Zone-11 N	T15S, R16E POMELO C/
Unknown	Natural/Na	Imperial	Glamis NW	100	32.97034	-115.228	Zone-11 N	T13S, R17E ABOUT 20
Unknown	Natural/Na	Imperial	Kane Sprin	30	33.1369	-115.999	Zone-11 N	T12S, R09E ALONG TAI
Unknown	Natural/Na	Imperial	Frink (3311	-150	33.37087	-115.743	Zone-11 N	T09S, R12E EAST OF BE
Unknown	Natural/Na	Imperial	Frink NW (3	98	33.38421	-115.636	Zone-11 N	T09S, R13E N OF FRINK
Unknown	Natural/Na	Imperial	Picacho Pe	200	32.9257	-114.642	Zone-11 N	T14S, R22E ABOUT 15
Unknown	Natural/Na	Imperial	Iris (331152	150	33.2201	-115.397	Zone-11 N	T11S, R15E ABOUT 1 M
Unknown	Natural/Na	Imperial	Little Picac	480	32.95768	-114.543	Zone-11 N	T14S, R23E FERGUSON
Unknown	Natural/Na	Imperial	Chuckwalla	1650	33.42183	-115.18	Zone-11 N	T09S, R17E WASH NEA
Unknown	Natural/Na	Imperial	Glamis (32:	435	32.9249	-115.071	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Glamis (32:	357	32.9842	-115.051	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Mt. Barrow	1372	33.13111	-114.949	Zone-11 N	T12S, R19E AT THE WE
Unknown	Natural/Na	Imperial	Cibola (331	230	33.37117	-114.706	Zone-11 N	T09S, R21E CIBOLA NA
Unknown	Natural/Na	Imperial	In-ko-pah C	1860	32.69382	-116.087	Zone-11 N	T17S, R09E IN-KO-PAH
Unknown	Natural/Na	Imperial	Picacho (33	178	33.0254	-114.623	Zone-11 N	T13S, R22E ALONG THI
Unknown	Natural/Na	Imperial	Picacho SW (3311416)		33.02797	-114.736	Zone-11 N	T13S, R21E GAVILAN W
Unknown	Natural/Na	Imperial	Seventeen	121	33.28954	-116.03	Zone-11 N	T10S, R09E PALM WAS
Unknown	Natural/Na	Imperial	Seventeen	355	33.28849	-116.073	Zone-11 N	T10S, R09E NORTH FOI
Unknown	Natural/Na	Imperial	Seventeen	78	33.28394	-116.015	Zone-11 N	T10S, R09E N SIDE OF /
Unknown	Natural/Na	Imperial | S	In-ko-pah Gorge (3211		32.67054	-116.104	Zone-11 N	T17S, R09E LARKENS (L
Unknown	Natural/Na	Imperial	Calipatria S	-223	33.09011	-115.701	Zone-11 N	T12S, R12E TRIFOLIUM
Unknown	Natural/Na	Imperial	Niland (331	-224	33.24915	-115.59	Zone-11 N	T11S, R13E U LATERAL
Unknown	Natural/Na	Imperial	In-ko-pah C	2250	32.66996	-116.101	Zone-11 N	T17S, R09E MOUNTAIN
Unknown	Natural/Na	Imperial	Niland (331	-221	33.24191	-115.585	Zone-11 N	T11S, R13E T DRAIN, JU
Unknown	Natural/Na	Imperial	Obsidian Bu	-225	33.14846	-115.65	Zone-11 N	T12S, R13E LACK & LIN
Unknown	Natural/Na	Imperial	Wister (33:	-222	33.29983	-115.609	Zone-11 N	T10S, R13E NILAND LA
Unknown	Natural/Na	Imperial	Frink (3311	-191	33.37362	-115.684	Zone-11 N	T09S, R12E TRIBUTARY
Unknown	Natural/Na	Imperial	In-ko-pah C	3700	32.6349	-116.092	Zone-11 N	T18S, R09E SMUGGLER
Unknown	Natural/Na	Imperial	Coyote Wells (321156		32.73846	-115.995	Zone-11 N	T16S, R09E OCOTILLO.
Unknown	Natural/Na	Imperial	Carrizo Mtı	722	32.82858	-116.04	Zone-11 N	T15S, R09E CARRIZO M

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial | S	Seventeen	500	33.35034	-116.081	Zone-11 N	T09S, R09E WONDERS
Unknown	Natural/Na	Imperial	Seventeen	50	33.34565	-116.06	Zone-11 N	T09S, R09E SOUTH OF
Unknown	Natural/Na	Imperial	Seventeen	370	33.32945	-116.059	Zone-11 N	T10S, R09E VERBENA V
Unknown	Natural/Na	Imperial	Seventeen	80	33.32832	-116.038	Zone-11 N	T10S, R09E VERBENA V
Unknown	Natural/Na	Imperial	Seventeen	40	33.3313	-116.03	Zone-11 N	T10S, R09E VERBENA V
Unknown	Natural/Na	Imperial	Seventeen	300	33.31391	-116.066	Zone-11 N	T10S, R09E IN BIG WAS
Unknown	Natural/Na	Imperial	Seventeen	100	33.31085	-116.036	Zone-11 N	T10S, R09E GRAVE WA
Unknown	Natural/Na	Imperial	Seventeen	20	33.32167	-116.02	Zone-11 N	T10S, R09E BIG WASH;
Unknown	Natural/Na	Imperial	Seventeen	420	33.30556	-116.068	Zone-11 N	T10S, R09E SMALL ARR
Unknown	Natural/Na	Imperial	Seventeen	120	33.29693	-116.031	Zone-11 N	T10S, R09E CORAL WA
Unknown	Natural/Na	Imperial	Seventeen	40	33.30138	-116.01	Zone-11 N	T10S, R09E CORAL WA
Unknown	Natural/Na	Imperial	Seventeen	140	33.28731	-116.035	Zone-11 N	T10S, R09E NORTHERN
Unknown	Natural/Na	Imperial	Seventeen	400	33.27972	-116.063	Zone-11 N	T10S, R09E NORTH SID
Unknown	Natural/Na	Imperial	Seventeen	250	33.27029	-116.035	Zone-11 N	T10S, R09E ALONG BO
Unknown	Natural/Na	Imperial	Seventeen	100	33.27083	-116.006	Zone-11 N	T10S, R09E AMEROSA
Unknown	Natural/Na	Imperial	Seventeen	100	33.28889	-116.023	Zone-11 N	T10S, R09E PALM WAS
Unknown	Natural/Na	Imperial	Seventeen	200	33.27873	-116.075	Zone-11 N	T10S, R09E ALONG HW
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E U.S. YUMA
Unknown	Natural/Na	Imperial | S	In-ko-pah (	3000	32.67397	-116.106	Zone-11 N	T17S, R08E SUMMIT O
Unknown	Natural/Na	Imperial	Coyote We	600	32.72922	-116.016	Zone-11 N	T16S, R09E BASE OF M
Unknown	Natural/Na	Imperial	Hedges (32	787	32.92112	-114.828	Zone-11 N	T14S, R20E APPROXIM
Unknown	Natural/Na	Imperial	Clyde (321	600	32.98191	-114.911	Zone-11 N	T14S, R20E APPROXIM
Unknown	Natural/Na	Imperial	Quartz Pea	1100	33.10389	-114.857	Zone-11 N	T12S, R20E BLACK MO
Unknown	Natural/Na	Imperial	Buzzards P	800	33.21673	-114.862	Zone-11 N	T11S, R20E MIDWAY W
Decreasing	Natural/Na	Imperial	Ninemile W	800	33.05931	-114.971	Zone-11 N	T13S, R19E VCR MININ
Unknown	Natural/Na	Imperial	Bard (3211	180	32.80031	-114.619	Zone-11 N	T16S, R22E PICACHO W
Unknown	Natural/Na	Imperial	Araz (3211	500	32.83313	-114.686	Zone-11 N	T15S, R22E JUST WEST
Unknown	Natural/Na	Imperial	In-ko-pah (	2174	32.67724	-116.09	Zone-11 N	T17S, R09E BETWEEN
Unknown	Natural/Na	Imperial | S	In-ko-pah (	3044	32.64828	-116.108	Zone-11 N	T17S, R08E 0.13 MILES
Unknown	Natural/Na	Imperial	Bonds Corr	40	32.67668	-115.372	Zone-11 N	T17S, R16E 0.1 MI W C
Unknown	Natural/Na	Imperial	Bonds Corr	30	32.69147	-115.358	Zone-11 N	T17S, R16E 0.25 MI SW
Unknown	Natural/Na	Imperial	Bonds Corr	30	32.70627	-115.364	Zone-11 N	T17S, R16E ABOUT 1 M
Unknown	Natural/Na	Imperial	Mount Sigr	-10	32.68875	-115.665	Zone-11 N	T17S, R13E 0.75 MILE N
Unknown	Natural/Na	Imperial	Heber (321	-10	32.68141	-115.622	Zone-11 N	T17S, R13E 0.2 MI NNW
Unknown	Natural/Na	Imperial	Heber (321	-10	32.68886	-115.615	Zone-11 N	T17S, R13E 0.6 MI SE K
Unknown	Natural/Na	Imperial	Holtville Ea	20	32.76333	-115.286	Zone-11 N	T16S, R16E W SIDE OF
Unknown	Natural/Na	Imperial	Holtville Ea	20	32.77015	-115.291	Zone-11 N	T16S, R16E 0.4 MI SW
Unknown	Natural/Na	Imperial	Holtville Ea	35	32.78968	-115.289	Zone-11 N	T16S, R16E 0.6 MI NNE
Unknown	Natural/Na	Imperial	Holtville Ea	20	32.79677	-115.291	Zone-11 N	T15S, R16E 0.8 MI SE N
Unknown	Natural/Na	Imperial	El Centro (3	-30	32.78072	-115.547	Zone-11 N	T16S, R14E 0.3 MI SE S
Unknown	Natural/Na	Imperial	El Centro (3	-30	32.76186	-115.543	Zone-11 N	T16S, R14E 0.5 MI E HW
Unknown	Natural/Na	Imperial	El Centro (3	-30	32.77307	-115.556	Zone-11 N	T16S, R14E JUST S OF I
Unknown	Natural/Na	Imperial	El Centro (3	-30	32.77281	-115.523	Zone-11 N	T16S, R14E JUST S OF I
Unknown	Natural/Na	Imperial	El Centro (3	-25	32.76207	-115.526	Zone-11 N	T16S, R14E E SIDE OF H
Unknown	Natural/Na	Imperial	Holtville NE	-60	32.95993	-115.373	Zone-11 N	T14S, R15E S OF GRIFF
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.96002	-115.364	Zone-11 N	T14S, R16E JUST S OF C
Unknown	Natural/Na	Imperial	Holtville NE	-40	32.96015	-115.35	Zone-11 N	T14S, R16E JUST S OF C

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Holtville NE	-30	32.96009	-115.344	Zone-11 NA	T14S, R16E JUST N & S
Unknown	Natural/Na	Imperial	Holtville NE	-20	32.96022	-115.338	Zone-11 NA	T14S, R16E ALONG GR
Unknown	Natural/Na	Imperial	Holtville NE	0	32.9603	-115.315	Zone-11 NA	T14S, R16E ALONG GR
Unknown	Natural/Na	Imperial	Holtville NE	0	32.96012	-115.307	Zone-11 NA	T14S, R16E S OF GRIFF
Unknown	Natural/Na	Imperial	Holtville NE	0	32.96173	-115.302	Zone-11 NA	T14S, R16E 0.1 MI N O
Unknown	Natural/Na	Imperial	Holtville NE	0	32.96742	-115.307	Zone-11 NA	T14S, R16E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	0	32.96762	-115.317	Zone-11 NA	T14S, R16E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	-10	32.96751	-115.324	Zone-11 NA	T14S, R16E AT INTERSE
Unknown	Natural/Na	Imperial	Holtville NE	-20	32.96747	-115.329	Zone-11 NA	T14S, R16E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	-20	32.9677	-115.338	Zone-11 NA	T14S, R16E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	-30	32.96791	-115.344	Zone-11 NA	T14S, R16E AREA OF ST
Unknown	Natural/Na	Imperial	Holtville NE	-30	32.96752	-115.349	Zone-11 NA	T14S, R16E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.96742	-115.357	Zone-11 NA	T14S, R16E AREA ALON
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.96727	-115.367	Zone-11 NA	T14S, R15E JUST EAST
Unknown	Natural/Na	Imperial	Holtville NE	0	32.97452	-115.321	Zone-11 NA	T13S, R16E ALONG HW
Unknown	Natural/Na	Imperial	Holtville NE	0	32.97456	-115.316	Zone-11 NA	T13S, R16E ALONG HW
Unknown	Natural/Na	Imperial	Holtville NE	0	32.9748	-115.311	Zone-11 NA	T13S, R16E ALONG HW
Unknown	Natural/Na	Imperial	Holtville NE	5	32.97459	-115.302	Zone-11 NA	T13S, R16E ALONG HW
Unknown	Natural/Na	Imperial	Holtville NE	-30	32.95311	-115.344	Zone-11 NA	T14S, R16E N SIDE OF
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.95279	-115.36	Zone-11 NA	T14S, R16E ALONG GO
Unknown	Natural/Na	Imperial	Holtville NE	-60	32.94537	-115.371	Zone-11 NA	T14S, R15E S SIDE OF N
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.9455	-115.363	Zone-11 NA	T14S, R16E ALONG NO
Unknown	Natural/Na	Imperial	Coyote We	300	32.75026	-115.925	Zone-11 NA	T16S, R10E APPROXIM
Unknown	Natural/Na	Imperial	Coyote We	300	32.75065	-115.916	Zone-11 NA	T16S, R10E APPROXIM
Unknown	Natural/Na	Imperial	Painted Go	300	32.76228	-115.881	Zone-11 NA	T16S, R11E APPROXIM
Unknown	Natural/Na	Imperial	Amos (331	-10	33.03836	-115.337	Zone-11 NA	T13S, R16E ALONG IRV
Unknown	Natural/Na	Imperial	Amos (331	-10	33.02995	-115.334	Zone-11 NA	T13S, R16E 250 METER
Unknown	Natural/Na	Imperial	Amos (331	-10	33.02499	-115.331	Zone-11 NA	T13S, R16E 0.5 MI SE C
Unknown	Natural/Na	Imperial	Wiest (331	-90	33.00087	-115.4	Zone-11 NA	T13S, R15E ALONG SHA
Unknown	Natural/Na	Imperial	Wiest (331	-100	33.00086	-115.418	Zone-11 NA	T13S, R15E ALONG SHA
Unknown	Natural/Na	Imperial	Wiest (331	-120	33.00088	-115.437	Zone-11 NA	T13S, R15E ALONG SHA
Unknown	Natural/Na	Imperial	Wiest (331	-120	33.00809	-115.43	Zone-11 NA	T13S, R15E 0.4 MI W C
Unknown	Natural/Na	Imperial	Wiest (331	-100	33.0081	-115.414	Zone-11 NA	T13S, R15E ALONG FAR
Unknown	Natural/Na	Imperial	Wiest (331	-100	33.00811	-115.405	Zone-11 NA	T13S, R15E ALONG FAR
Unknown	Natural/Na	Imperial	Wiest (331	-90	33.0081	-115.397	Zone-11 NA	T13S, R15E ALONG FAR
Unknown	Natural/Na	Imperial	Wiest (331	-120	33.01532	-115.414	Zone-11 NA	T13S, R15E 0.1 MI W C
Unknown	Natural/Na	Imperial	Wiest (331	-120	33.01537	-115.435	Zone-11 NA	T13S, R15E 0.8 MI E OF
Unknown	Natural/Na	Imperial	Wiest (331	-130	33.0153	-115.447	Zone-11 NA	T13S, R15E ALONG S SI
Unknown	Natural/Na	Imperial	Wiest (331	-130	33.02256	-115.446	Zone-11 NA	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Westmorla	-205	33.12333	-115.622	Zone-11 NA	T12S, R13E ALONG E SI
Unknown	Natural/Na	Imperial	Calipatria S	-170	33.04303	-115.665	Zone-11 NA	T13S, R13E ALONG HO
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.05046	-115.665	Zone-11 NA	T13S, R13E ALONG HO
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.05798	-115.665	Zone-11 NA	T13S, R13E ALONG HO
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.07497	-115.663	Zone-11 NA	T13S, R13E ALONG HO
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.08603	-115.665	Zone-11 NA	T12S, R13E ALONG E SI
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.09925	-115.666	Zone-11 NA	T12S, R13E ALONG TRI
Unknown	Natural/Na	Imperial	Bonds Corr	30	32.69863	-115.358	Zone-11 NA	T17S, R16E 0.9 MI ENE

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Calipatria S	-220	33.12445	-115.648	Zone-11 N	T12S, R13E ALONG LA(
Unknown	Natural/Na	Imperial	Calipatria S	-220	33.10034	-115.673	Zone-11 N	T12S, R12E 0.4 MI S OF
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.08952	-115.674	Zone-11 N	T12S, R12E 1 MI WSW
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.06574	-115.673	Zone-11 N	T13S, R13E ALONG PEL
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.05514	-115.673	Zone-11 N	T13S, R13E 0.2 MI N O
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.04565	-115.673	Zone-11 N	T13S, R13E 0.6 MI N O
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.04111	-115.673	Zone-11 N	T13S, R13E 0.25 MI N (
Unknown	Natural/Na	Imperial	Calipatria S	-170	33.03433	-115.676	Zone-11 N	T13S, R13E 0.2 ROAD M
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.08574	-115.683	Zone-11 N	T12S, R12E 0.7 MI N O
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.0732	-115.681	Zone-11 N	T13S, R12E WALKER RI
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.0629	-115.682	Zone-11 N	T13S, R12E 1.7 MI N SF
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.04878	-115.682	Zone-11 N	T13S, R12E 0.8 MI N SF
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.03963	-115.682	Zone-11 N	T13S, R12E 0.1 MI N SF
Unknown	Natural/Na	Imperial	Calipatria S	-170	33.03028	-115.684	Zone-11 N	T13S, R12E 0.7 MI SE B
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.07023	-115.693	Zone-11 N	T13S, R12E 0.3 MI S OF
Unknown	Natural/Na	Imperial	Calipatria S	-190	33.05617	-115.69	Zone-11 N	T13S, R12E 1.4 MI N O
Unknown	Natural/Na	Imperial	Calipatria S	-220	33.08186	-115.701	Zone-11 N	T12S, R12E ALONG TRI
Unknown	Natural/Na	Imperial	Calipatria S	-170	33.04516	-115.703	Zone-11 N	T13S, R12E 0.5 AIR MIL
Unknown	Natural/Na	Imperial	Obsidian Bu	-220	33.13295	-115.648	Zone-11 N	T12S, R13E JUST E OF L
Unknown	Natural/Na	Imperial	Obsidian Bu	-220	33.14103	-115.639	Zone-11 N	T12S, R13E 0.5 MI N O
Unknown	Natural/Na	Imperial	Obsidian Bu	-210	33.14543	-115.631	Zone-11 N	T12S, R13E JUST S OF \
Unknown	Natural/Na	Imperial	Obsidian Bu	-210	33.13631	-115.631	Zone-11 N	T12S, R13E 1.3 MI SE B
Unknown	Natural/Na	Imperial	Obsidian Bu	-210	33.12916	-115.631	Zone-11 N	T12S, R13E ALONG SEV
Unknown	Natural/Na	Imperial	Niland (331	-200	33.12815	-115.614	Zone-11 N	T12S, R13E JUST E OF (
Unknown	Natural/Na	Imperial	Wiest (331	-90	33.12572	-115.403	Zone-11 N	T12S, R15E ALONG E W
Unknown	Natural/Na	Imperial	Wiest (331	-130	33.12574	-115.438	Zone-11 N	T12S, R15E ALONG E W
Unknown	Natural/Na	Imperial	Iris (33115	-130	33.13295	-115.445	Zone-11 N	T12S, R15E ALONG YOU
Unknown	Natural/Na	Imperial	Iris (33115	-120	33.13292	-115.431	Zone-11 N	T12S, R15E ALONG YOU
Unknown	Natural/Na	Imperial	Iris (33115	-110	33.1329	-115.421	Zone-11 N	T12S, R15E ALONG YOU
Unknown	Natural/Na	Imperial	Iris (33115	-100	33.13293	-115.414	Zone-11 N	T12S, R15E ALONG YOU
Unknown	Natural/Na	Imperial	Seeley (3211576)		32.78099	-115.689	Zone-11 N	T16S, R12E BLUE LAKE,
Unknown	Natural/Na	Imperial	Iris (33115	-100	33.14036	-115.415	Zone-11 N	T12S, R15E ALONG WI
Unknown	Natural/Na	Imperial	Iris (33115	-100	33.14034	-115.429	Zone-11 N	T12S, R15E ALONG WI
Unknown	Natural/Na	Imperial	Iris (33115	-130	33.14015	-115.443	Zone-11 N	T12S, R15E ALONG WI
Unknown	Natural/Na	Imperial	Iris (33115	-120	33.14745	-115.435	Zone-11 N	T12S, R15E ALONG W I
Unknown	Natural/Na	Imperial	Wister (331	-70	33.29282	-115.538	Zone-11 N	T10S, R14E ALONG WI
Unknown	Natural/Na	Imperial	Wister (331	-80	33.27882	-115.532	Zone-11 N	T10S, R14E 0.9 MI SE E
Unknown	Natural/Na	Imperial	Wister (331	-120	33.27129	-115.537	Zone-11 N	T10S, R14E 1.1 MI SSE
Unknown	Natural/Na	Imperial	Wister (331	-90	33.26369	-115.522	Zone-11 N	T10S, R14E 0.7 MI WES
Unknown	Natural/Na	Imperial	Wister (331	-110	33.26304	-115.528	Zone-11 N	T10S, R14E JUST S OF L
Unknown	Natural/Na	Imperial	Wister (331	-110	33.25651	-115.523	Zone-11 N	T10S, R14E ABOUT 0.5
Unknown	Natural/Na	Imperial	Plaster City (3211577)		32.78215	-115.773	Zone-11 N	T16S, R12E DIAMOND
Unknown	Natural/Na	Imperial	Truckhaver	-130	33.27974	-115.952	Zone-11 N	T10S, R10E 0.7 MI E SR
Unknown	Natural/Na	Imperial | I	Oasis (3311	200	33.41645	-116.098	Zone-11 N	T09S, R08E EXTREME N
Unknown	Natural/Na	Imperial | S	In-ko-pah (	2952	32.64344	-116.109	Zone-11 N	T17S, R08E SOUTH OF
Unknown	Natural/Na	Imperial	Picacho SW	220	33.11315	-114.706	Zone-11 N	T12S, R21E VELIAN WA
Unknown	Natural/Na	Imperial | /	Picacho NW	220	33.2549	-114.69	Zone-11 N	T11S, R22E THREE FIN(

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Iris (33115	82	33.19193	-115.397	Zone-11 N	T11S, R15E ALONG RAI
Unknown	Natural/Na	Imperial	Cibola (331	238	33.31423	-114.732	Zone-11 N	T10S, R21E JUST NW D
Unknown	Natural/Na	Imperial	Palo Verde	245	33.41606	-114.749	Zone-11 N	T09S, R21E JUST W OF
Unknown	Natural/Na	Imperial	Wiest (331	-90	33.01535	-115.394	Zone-11 N	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Wiest (331	-80	33.01533	-115.385	Zone-11 N	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Amos (331	-70	33.02279	-115.376	Zone-11 N	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Wiest (331	-80	33.00084	-115.387	Zone-11 N	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Wiest (331	-70	33.00084	-115.382	Zone-11 N	T13S, R15E ALONG THI
Unknown	Natural/Na	Imperial	Amos (331	-60	33.00808	-115.372	Zone-11 N	T13S, R15E S SIDE OF F
Unknown	Natural/Na	Imperial	Amos (331	-60	33.01536	-115.374	Zone-11 N	T13S, R15E S SIDE OF J
Unknown	Natural/Na	Imperial	Niland (331	-220	33.17474	-115.614	Zone-11 N	T11S, R13E JUST SSE O
Unknown	Natural/Na	Imperial	Mount Sigr	-10	32.71374	-115.688	Zone-11 N	T16.5S, R1 ON WESTSI
Unknown	Natural/Na	Imperial	Seeley (321	-60	32.79813	-115.737	Zone-11 N	T16S, R12E VICINITY O
Unknown	Natural/Na	Imperial	Seeley (321	-60	32.84222	-115.738	Zone-11 N	T15S, R12E IN THE VICI
Unknown	Natural/Na	Imperial	Plaster City	-40	32.83399	-115.754	Zone-11 N	T15S, R12E ALONG THI
Unknown	Natural/Na	Imperial	Wister (331	-130	33.27779	-115.545	Zone-11 N	T10S, R14E VICINITY O
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.06911	-115.717	Zone-11 N	T13S, R12E ALONG TRI
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.09735	-115.667	Zone-11 N	T12S, R12E ALONG TRI
Unknown	Natural/Na	Imperial	Niland (331	-220	33.18768	-115.588	Zone-11 N	T11S, R13E ALONG VAI
Unknown	Natural/Na	Imperial	El Centro (3	-50	32.818	-115.518	Zone-11 N	T15S, R14E JCT OF ALD
Unknown	Natural/Na	Imperial	Amos (331	-10	33.05972	-115.341	Zone-11 N	T13S, R16E JUST S OF M
Unknown	Natural/Na	Imperial	Laguna Dar	160	32.87106	-114.477	Zone-11 N	T15S, R24E JUST N ANI
Unknown	Natural/Na	Imperial	Seeley (321	-40	32.77211	-115.744	Zone-11 N	T16S, R12E ALONG THI
Unknown	Natural/Na	Imperial	Ogilby (321	360	32.81754	-114.841	Zone-11 N	T15S, R20E OGILBY.
Unknown	Natural/Na	Imperial | S	Borrego Mountain SE (		33.02988	-116.093	Zone-11 N	T13S, R09E ACROSS FR
Unknown	Natural/Na	Imperial	Imperial Re	190	32.95316	-114.473	Zone-11 N	T14S, R24E CA SIDE OF
Unknown	Natural/Na	Imperial	El Centro (3	-40	32.80668	-115.518	Zone-11 N	T15S, R14E ALONG E SI
Unknown	Natural/Na	Imperial	El Centro (3	-50	32.82291	-115.518	Zone-11 N	T15S, R14E ALONG CO
Unknown	Natural/Na	Imperial	El Centro (3	-60	32.83269	-115.518	Zone-11 N	T15S, R14E ALONG CO
Unknown	Natural/Na	Imperial	El Centro (3	-60	32.83653	-115.519	Zone-11 N	T15S, R14E ALONG CO
Unknown	Natural/Na	Imperial	El Centro (3	-120	32.87383	-115.518	Zone-11 N	T15S, R14E ALONG WE
Unknown	Natural/Na	Imperial	El Centro (3	-120	32.87034	-115.51	Zone-11 N	T15S, R14E ALONG HW
Unknown	Natural/Na	Imperial	Brawley (32	-140	32.91428	-115.511	Zone-11 N	T14S, R14E JUST NNW
Unknown	Natural/Na	Imperial	Brawley (32	-130	32.93117	-115.51	Zone-11 N	T14S, R14E ALONG SR
Unknown	Natural/Na	Imperial	Brawley (32	-120	32.96513	-115.509	Zone-11 N	T14S, R14E ALONG SR
Unknown	Natural/Na	Imperial	Brawley (32	-120	32.97395	-115.509	Zone-11 N	T13S, R14E ALONG SR
Unknown	Natural/Na	Imperial	Westmorla	-140	33.01285	-115.509	Zone-11 N	T13S, R14E E SIDE OF E
Unknown	Natural/Na	Imperial	Westmorla	-150	33.03982	-115.509	Zone-11 N	T13S, R14E ALONG BES
Unknown	Natural/Na	Imperial	Westmorla	-160	33.06264	-115.511	Zone-11 N	T13S, R14E ALONG KEI
Unknown	Natural/Na	Imperial	Westmorla	-160	33.089	-115.509	Zone-11 N	T12S, R14E JUST SE KEI
Unknown	Natural/Na	Imperial	Plaster City	-10	32.78524	-115.793	Zone-11 N	T16S, R11E 0.4 MI SSE
Unknown	Natural/Na	Imperial	Yuha Basin	20	32.74447	-115.785	Zone-11 N	T16S, R11E ABOUT 2 M
Unknown	Natural/Na	Imperial	Plaster City	50	32.77902	-115.833	Zone-11 N	T16S, R11E ABOUT 1.8
Unknown	Natural/Na	Imperial	Plaster City	50	32.769	-115.818	Zone-11 N	T16S, R11E 1 MI W OF
Unknown	Natural/Na	Imperial	Plaster City	40	32.76871	-115.809	Zone-11 N	T16S, R11E 0.5 MI W C
Unknown	Natural/Na	Imperial	Plaster City	252	32.75728	-115.871	Zone-11 N	T16S, R11E 2.5 MI SSW
Unknown	Natural/Na	Imperial	Yuha Basin	40	32.74945	-115.799	Zone-11 N	T16S, R11E 1.3 MI S OF

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Unknown	Natural/Na	Imperial	Plaster City	30	32.78827	-115.827	Zone-11 N	T16S, R11E ABOUT 1.9
Unknown	Natural/Na	Imperial	Plaster City	30	32.77973	-115.822	Zone-11 N	T16S, R11E 1.5 MI NW
Unknown	Natural/Na	Imperial	Plaster City	180	32.77319	-115.865	Zone-11 N	T16S, R11E 1.3 MI SSW
Unknown	Natural/Na	Imperial	Holtville NE	-40	32.94569	-115.351	Zone-11 N	T14S, R16E ALONG NO
Unknown	Natural/Na	Imperial	Holtville NE	-30	32.94572	-115.342	Zone-11 N	T14S, R16E ALONG NO
Unknown	Natural/Na	Imperial	Holtville NE	-15	32.94565	-115.327	Zone-11 N	T14S, R16E ALONG NO
Unknown	Natural/Na	Imperial	Holtville NE	0	32.94545	-115.304	Zone-11 N	T14S, R16E ALONG NO
Unknown	Natural/Na	Imperial	Holtville NE	0	32.93839	-115.306	Zone-11 N	T14S, R16E ALONG HA
Unknown	Natural/Na	Imperial	Holtville NE	-20	32.93835	-115.335	Zone-11 N	T14S, R16E ALONG HA
Unknown	Natural/Na	Imperial	Holtville NE	-40	32.93826	-115.349	Zone-11 N	T14S, R16E ALONG HA
Unknown	Natural/Na	Imperial	Holtville NE	-40	32.93389	-115.353	Zone-11 N	T14S, R16E ABOUT 1.6
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.93389	-115.369	Zone-11 N	T14S, R15E ABOUT 0.3
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.93492	-115.375	Zone-11 N	T14S, R15E ABOUT 0.4
Unknown	Natural/Na	Imperial	Alamorio (3	-120	32.99368	-115.444	Zone-11 N	T13S, R15E ALONG O'B
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.99372	-115.427	Zone-11 N	T13S, R15E ALONG O B
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.99363	-115.419	Zone-11 N	T13S, R15E ALONG O'B
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.99361	-115.407	Zone-11 N	T13S, R15E ALONG O'B
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.99363	-115.388	Zone-11 N	T13S, R15E ALONG O B
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.98643	-115.382	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.98644	-115.397	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.98637	-115.418	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.98642	-115.427	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.9864	-115.436	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-120	32.98647	-115.442	Zone-11 N	T13S, R15E ALONG TAE
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.98175	-115.412	Zone-11 N	T13S, R15E ALONG SILI
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.98175	-115.397	Zone-11 N	T13S, R15E ALONG SILI
Unknown	Natural/Na	Imperial	Holtville NE	-70	32.98171	-115.384	Zone-11 N	T13S, R15E ALONG SILI
Unknown	Natural/Na	Imperial	Kane Spring	-118	33.16533	-115.828	Zone-11 N	T11S, R11E SAN FELIPE
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.97423	-115.394	Zone-11 N	T13S, R15E ALONG HW
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.9742	-115.399	Zone-11 N	T13S, R15E ALONG HW
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.97437	-115.44	Zone-11 N	T13S, R15E ALONG HW
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.96721	-115.438	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.9676	-115.426	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.96711	-115.417	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.96708	-115.399	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.96732	-115.391	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Holtville NE	-60	32.96745	-115.376	Zone-11 N	T14S, R15E ALONG STR
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.96008	-115.386	Zone-11 N	T14S, R15E ALONG GR
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.96006	-115.4	Zone-11 N	T14S, R15E ALONG GR
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.95988	-115.407	Zone-11 N	T14S, R15E ALONG GR
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.95993	-115.416	Zone-11 N	T14S, R15E ALONG GR
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.95981	-115.423	Zone-11 N	T14S, R15E ALONG GR
Unknown	Natural/Na	Imperial	Alamorio (3	-120	32.96041	-115.448	Zone-11 N	T14S, R15E ALONG WI
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.9529	-115.443	Zone-11 N	T14S, R15E ALONG GO
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.95278	-115.432	Zone-11 N	T14S, R15E ALONG GO
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.95281	-115.426	Zone-11 N	T14S, R15E ALONG GO
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.95289	-115.413	Zone-11 N	T14S, R15E ALONG GO

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Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.95288	-115.399	Zone-11 NA	T14S, R15E ALONG GO
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.95341	-115.38	Zone-11 NA	T14S, R15E ALONG GO
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.94554	-115.388	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.94559	-115.401	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial | A	Yuma East	200	32.73172	-114.616	Zone-11 NA	T16S, R22E FORT YUM
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.94561	-115.41	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.94551	-115.419	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.94557	-115.424	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.94555	-115.43	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.94553	-115.435	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Bard (3211	160	32.81796	-114.521	Zone-11 NA	T15S, R23E JUST NE OF
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.9455	-115.44	Zone-11 NA	T14S, R15E ALONG NO
Unknown	Natural/Na	Imperial	Alamorio (3	-115	32.93614	-115.449	Zone-11 NA	T14S, R15E ALONG WI
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.93779	-115.437	Zone-11 NA	T14S, R15E ALONG HA
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.93802	-115.413	Zone-11 NA	T14S, R15E ALONG HA
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.93809	-115.403	Zone-11 NA	T14S, R15E ALONG HA
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.93574	-115.396	Zone-11 NA	T14S, R15E ALONG AN
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.92365	-115.425	Zone-11 NA	T14S, R15E ALONG FIN
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.92366	-115.443	Zone-11 NA	T14S, R15E ALONG FIN
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.91647	-115.448	Zone-11 NA	T14S, R15E ALONG E K
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.91648	-115.442	Zone-11 NA	T14S, R15E ALONG E K
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.91649	-115.428	Zone-11 NA	T14S, R15E ALONG E K
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.91642	-115.416	Zone-11 NA	T14S, R15E ALONG E K
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.90936	-115.414	Zone-11 NA	T14S, R15E ALONG CO
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.90921	-115.436	Zone-11 NA	T14S, R15E ALONG CO
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.90919	-115.443	Zone-11 NA	T14S, R15E ALONG CO
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.89952	-115.449	Zone-11 NA	T14S, R15E 0.5 MI WS
Unknown	Natural/Na	Imperial	Alamorio (3	-110	32.90198	-115.444	Zone-11 NA	T14S, R15E ALONG BO
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.90202	-115.434	Zone-11 NA	T14S, R15E ALONG BO
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.90202	-115.418	Zone-11 NA	T14S, R15E ALONG BO
Unknown	Natural/Na	Imperial	Alamorio (3	-80	32.90199	-115.41	Zone-11 NA	T14S, R15E ALONG BO
Unknown	Natural/Na	Imperial	Alamorio (3	-70	32.90204	-115.394	Zone-11 NA	T14S, R15E ALONG BO
Unknown	Natural/Na	Imperial	Alamorio (3	-60	32.89482	-115.384	Zone-11 NA	T14S, R15E ALONG TO
Unknown	Natural/Na	Imperial	Alamorio (3	-90	32.89474	-115.418	Zone-11 NA	T14S, R15E ALONG TO
Unknown	Natural/Na	Imperial | I	Calexico (3	0	32.66977	-115.496	Zone-11 NA	T17S, R14E VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	405	32.8619	-114.556	Zone-11 NA	T15S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Holtville NE	-60	32.98203	-115.369	Zone-11 NA	T13S, R15E ABOUT 2.5
Unknown	Natural/Na	Imperial	Holtville NE	-50	32.98202	-115.362	Zone-11 NA	T13S, R16E ABOUT 2.7
Unknown	Natural/Na	Imperial	Holtville NE	-30	32.98196	-115.35	Zone-11 NA	T13S, R16E ABOUT 3.5
Unknown	Natural/Na	Imperial	Holtville NE	-20	32.98198	-115.339	Zone-11 NA	T13S, R16E ABOUT 3.9
Unknown	Natural/Na	Imperial	Holtville NE	0	32.98197	-115.318	Zone-11 NA	T13S, R16E ALONG SIL
Unknown	Natural/Na	Imperial	Alamorio (3	-100	32.89473	-115.435	Zone-11 NA	T14S, R15E ALONG TO
Unknown	Natural/Na	Imperial	Ogilby (321	660	32.85935	-114.787	Zone-11 NA	T15S, R21E AMERICAN
Unknown	Natural/Na	Imperial	Chuckwalla	1740	33.41464	-115.194	Zone-11 NA	T09S, R17E 1 AIR MILE
Unknown	Natural/Na	Imperial	Calipatria S	-200	33.07509	-115.697	Zone-11 NA	T12S, R12E ALONG WA
Unknown	Natural/Na	Imperial	Niland (331	-220	33.16974	-115.626	Zone-11 NA	T11S, R13E ALONG MC
Unknown	Natural/Na	Imperial	Niland (331	-220	33.1801	-115.616	Zone-11 NA	T11S, R13E 0.25 MI NN

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Unknown	Natural/Na	Imperial	Niland (331	-220	33.18395	-115.586	Zone-11 N	T11S, R13E	0.5 MI NNE
Unknown	Natural/Na	Imperial	Mt. Barrow	1310	33.18553	-114.96	Zone-11 N	T11S, R19E	0.8 MI E OF
Unknown	Natural/Na	Imperial	Mammoth Wash (331		33.18541	-115.17	Zone-11 N	T11S, R17E	AERIAL GU
Unknown	Natural/Na	Imperial	Bonds Corr	18	32.68075	-115.37	Zone-11 N	T17S, R16E	0.3 MI N O
Unknown	Natural/Na	Imperial	Bard (3211	125	32.75711	-114.589	Zone-11 N	T16S, R23E	S END OF H
Unknown	Natural/Na	Imperial	Mt. Barrow	1190	33.20909	-114.978	Zone-11 N	T11S, R19E	4.5 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1155	33.20582	-114.965	Zone-11 N	T11S, R19E	4 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1135	33.21279	-114.964	Zone-11 N	T11S, R19E	4.5 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1075	33.2129	-114.956	Zone-11 N	T11S, R19E	4.5 MI N O
Unknown	Natural/Na	Imperial	Mt. Barrow	1110	33.21833	-114.965	Zone-11 N	T11S, R19E	5 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1070	33.2209	-114.961	Zone-11 N	T11S, R19E	5 MI N OF I
Unknown	Natural/Na	Imperial	Mt. Barrow	1070	33.22453	-114.962	Zone-11 N	T11S, R19E	5 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1040	33.22666	-114.958	Zone-11 N	T11S, R19E	5.5 MI N O
Unknown	Natural/Na	Imperial	Mt. Barrow	1085	33.21061	-114.946	Zone-11 N	T11S, R19E	4 MI N OF I
Unknown	Natural/Na	Imperial	Mt. Barrow	1030	33.22511	-114.943	Zone-11 N	T11S, R19E	5 MI N OF I
Unknown	Natural/Na	Imperial	Mt. Barrow	995	33.23112	-114.947	Zone-11 N	T11S, R19E	5.5 MI N O
Unknown	Natural/Na	Imperial	Mt. Barrow	1010	33.20843	-114.915	Zone-11 N	T11S, R20E	3.5 MI WSW
Unknown	Natural/Na	Imperial	Mt. Barrow	1010	33.21245	-114.921	Zone-11 N	T11S, R19E	4 MI W OF
Unknown	Natural/Na	Imperial	Mt. Barrow	940	33.22743	-114.915	Zone-11 N	T11S, R20E	3.5 MI W C
Unknown	Natural/Na	Imperial	Mt. Barrow	960	33.23197	-114.927	Zone-11 N	T11S, R19E	4.5 MI W C
Unknown	Natural/Na	Imperial	West of Pa	940	33.26971	-114.973	Zone-11 N	T10S, R19E	7.5 MI WN
Unknown	Natural/Na	Imperial	West of Pa	940	33.26196	-114.959	Zone-11 N	T10S, R19E	7 MI WNW
Unknown	Natural/Na	Imperial	West of Pa	950	33.25554	-114.955	Zone-11 N	T10S, R19E	6.5 MI WN
Unknown	Natural/Na	Imperial	West of Pa	900	33.26083	-114.94	Zone-11 N	T10S, R19E	6 MI WNW
Unknown	Natural/Na	Imperial	West of Pa	760	33.27486	-114.907	Zone-11 N	T10S, R20E	5 MI NW O
Unknown	Natural/Na	Imperial	West of Pa	850	33.275	-114.939	Zone-11 N	T10S, R19E	6 MI NW O
Unknown	Natural/Na	Imperial	West of Pa	800	33.26265	-114.906	Zone-11 N	T10S, R20E	4.5 MI NW
Unknown	Natural/Na	Imperial	West of Pa	810	33.2513	-114.899	Zone-11 N	T11S, R20E	3.5 MI NW
Unknown	Natural/Na	Imperial	Mt. Barrow	800	33.23808	-114.879	Zone-11 N	T11S, R20E	2 MI NW O
Unknown	Natural/Na	Imperial	West of Pa	800	33.25793	-114.902	Zone-11 N	T10S, R20E	4 MI NW O
Unknown	Natural/Na	Imperial	Buzzards P	610	33.24582	-114.805	Zone-11 N	T11S, R21E	3.5 MI NE C
Unknown	Natural/Na	Imperial	Buzzards P	730	33.24274	-114.854	Zone-11 N	T11S, R20E	1.5 MI N O
Unknown	Natural/Na	Imperial	Buzzards P	700	33.24013	-114.839	Zone-11 N	T11S, R20E	1.5 MI NNE
Unknown	Natural/Na	Imperial	Buzzards P	710	33.24465	-114.845	Zone-11 N	T11S, R20E	2 MI NNE C
Unknown	Natural/Na	Imperial	Palo Verde	470	33.27121	-114.785	Zone-11 N	T10S, R21E	4 MI S OF P
Unknown	Natural/Na	Imperial	Buzzards P	730	33.25006	-114.866	Zone-11 N	T11S, R20E	2.5 MI NNW
Unknown	Natural/Na	Imperial	Palo Verde	660	33.2609	-114.852	Zone-11 N	T10S, R20E	3 MI N OF I
Unknown	Natural/Na	Imperial	Palo Verde	640	33.25855	-114.834	Zone-11 N	T10S, R20E	3 MI NNE C
Unknown	Natural/Na	Imperial	Palo Verde	600	33.26286	-114.824	Zone-11 N	T10S, R20E	3.5 MI NNE
Unknown	Natural/Na	Imperial	Palo Verde	590	33.26868	-114.828	Zone-11 N	T10S, R20E	4 MI NNE C
Unknown	Natural/Na	Imperial	Palo Verde	570	33.26869	-114.819	Zone-11 N	T10S, R20E	4 MI NNE C
Unknown	Natural/Na	Imperial	Palo Verde	690	33.26498	-114.867	Zone-11 N	T10S, R20E	3 MI NNW
Unknown	Natural/Na	Imperial	Palo Verde	690	33.26157	-114.865	Zone-11 N	T10S, R20E	3.5 MI NNW
Unknown	Natural/Na	Imperial	Palo Verde	620	33.27166	-114.846	Zone-11 N	T10S, R20E	3.5 MI N O
Unknown	Natural/Na	Imperial	Palo Verde	600	33.27156	-114.833	Zone-11 N	T10S, R20E	4 MI NNE C
Unknown	Natural/Na	Imperial	Palo Verde	540	33.27949	-114.823	Zone-11 N	T10S, R20E	4.5 MI SW
Unknown	Natural/Na	Imperial	Palo Verde	580	33.28728	-114.858	Zone-11 N	T10S, R20E	4.5 MI N O

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Unknown	Natural/Na	Imperial	Palo Verde	580	33.28616	-114.852	Zone-11 N	T10S, R20E 4.5 MI N O
Unknown	Natural/Na	Imperial	Palo Verde	590	33.28203	-114.845	Zone-11 N	T10S, R20E 4.5 MI N O
Unknown	Natural/Na	Imperial	Palo Verde	530	33.26741	-114.806	Zone-11 N	T10S, R21E 4.5 MI SSW
Unknown	Natural/Na	Imperial	Palo Verde	430	33.28196	-114.776	Zone-11 N	T10S, R21E AT MILPITA
Unknown	Natural/Na	Imperial	Palo Verde	450	33.28027	-114.791	Zone-11 N	T10S, R21E 3.5 MI S OF
Unknown	Natural/Na	Imperial	Hedges (32	620	32.90674	-114.846	Zone-11 N	T14S, R20E 0.9 MI WSW
Unknown	Natural/Na	Imperial	Hedges (32	700	32.96234	-114.861	Zone-11 N	T14S, R20E 6 MI NNW
Unknown	Natural/Na	Imperial	Hedges (32	650	32.95293	-114.855	Zone-11 N	T14S, R20E 5.5 MI NNW
Unknown	Natural/Na	Imperial	Clyde (321	690	32.9962	-114.897	Zone-11 N	T13S, R20E 7.5 MI SSW
Unknown	Natural/Na	Imperial	Clyde (321	660	32.99216	-114.918	Zone-11 N	T13S, R19E 8.5 MI SW
Unknown	Natural/Na	Imperial	Clyde (321	590	32.97523	-114.932	Zone-11 N	T14S, R19E 8.5 MI E OF
Unknown	Natural/Na	Imperial	Clyde (321	560	32.97579	-114.953	Zone-11 N	T14S, R19E 7 MI E OF C
Unknown	Natural/Na	Imperial	Clyde (321	600	32.99112	-114.953	Zone-11 N	T13S, R19E 7 MI E OF C
Unknown	Natural/Na	Imperial	Quartz Pea	1140	33.05861	-114.862	Zone-11 N	T13S, R20E 3 MI SW OF
Unknown	Natural/Na	Imperial	Quartz Pea	1150	33.06308	-114.868	Zone-11 N	T13S, R20E 3 MI SW OF
Unknown	Natural/Na	Imperial	Quartz Pea	930	33.0461	-114.868	Zone-11 N	T13S, R20E 4 MI SW OF
Unknown	Natural/Na	Imperial	Ninemile W	910	33.05425	-114.883	Zone-11 N	T13S, R20E 4.5 MI SW
Unknown	Natural/Na	Imperial	Ninemile W	920	33.06087	-114.886	Zone-11 N	T13S, R20E 3.5 MI S OF
Unknown	Natural/Na	Imperial	Ninemile W	860	33.05221	-114.917	Zone-11 N	T13S, R19E 6 MI WSW
Unknown	Natural/Na	Imperial	Ninemile W	860	33.05223	-114.929	Zone-11 N	T13S, R19E 7 MI WSW
Unknown	Natural/Na	Imperial	Ninemile W	840	33.05224	-114.936	Zone-11 N	T13S, R19E 7 MI WSW
Unknown	Natural/Na	Imperial	Ninemile W	820	33.04892	-114.946	Zone-11 N	T13S, R19E 7 MI S OF N
Unknown	Natural/Na	Imperial	Quartz Pea	1100	33.10442	-114.874	Zone-11 N	T12S, R20E 3.5 MI WNW
Unknown	Natural/Na	Imperial	Ninemile W	1070	33.09668	-114.911	Zone-11 N	T12S, R20E 5 MI SSE O
Unknown	Natural/Na	Imperial	Quartz Pea	1110	33.12095	-114.872	Zone-11 N	T12S, R20E 3.5 MI NW
Unknown	Natural/Na	Imperial	Ninemile W	1110	33.11686	-114.892	Zone-11 N	T12S, R20E 4 MI SE OF
Unknown	Natural/Na	Imperial	Ninemile W	1180	33.1168	-114.91	Zone-11 N	T12S, R20E 3 MI SE OF
Unknown	Natural/Na	Imperial	Ninemile W	1330	33.10903	-114.918	Zone-11 N	T12S, R20E 3.5 MI SSE
Unknown	Natural/Na	Imperial	Buzzards P	1120	33.15107	-114.856	Zone-11 N	T12S, R20E 5 MI NNW
Unknown	Natural/Na	Imperial	Mt. Barrow	1090	33.14812	-114.892	Zone-11 N	T12S, R20E 3 MI E OF N
Unknown	Natural/Na	Imperial	Mt. Barrow	1160	33.1346	-114.904	Zone-11 N	T12S, R20E 2.5 MI ESE
Unknown	Natural/Na	Imperial	Mt. Barrow	1150	33.13935	-114.905	Zone-11 N	T12S, R20E 2.5 MI ESE
Unknown	Natural/Na	Imperial	Mt. Barrow	1170	33.14133	-114.91	Zone-11 N	T12S, R20E 2 MI ESE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1220	33.14557	-114.919	Zone-11 N	T12S, R20E 1.5 MI E OF
Unknown	Natural/Na	Imperial	Mt. Barrow	1010	33.15946	-114.878	Zone-11 N	T12S, R20E 4 MI ENE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1080	33.15833	-114.896	Zone-11 N	T12S, R20E 3 MI ENE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1100	33.15492	-114.901	Zone-11 N	T12S, R20E 2.5 MI E OF
Unknown	Natural/Na	Imperial	Mt. Barrow	1160	33.1574	-114.919	Zone-11 N	T12S, R20E 1.5 MI ENE
Unknown	Natural/Na	Imperial	Mt. Barrow	990	33.16337	-114.878	Zone-11 N	T12S, R20E 4 MI ENE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1040	33.16615	-114.892	Zone-11 N	T11S, R20E 3.5 MI ENE
Unknown	Natural/Na	Imperial	Mt. Barrow	1070	33.166	-114.899	Zone-11 N	T11S, R20E 3 MI ENE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1110	33.16536	-114.911	Zone-11 N	T11S, R20E 2 MI ENE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1200	33.16463	-114.918	Zone-11 N	T11S, R20E 2 MI NE OF
Unknown	Natural/Na	Imperial	Buzzards P	1000	33.18919	-114.855	Zone-11 N	T11S, R20E 6 MI ENE O
Unknown	Natural/Na	Imperial	Buzzards P	810	33.18514	-114.866	Zone-11 N	T11S, R20E 5 MI NE OF
Unknown	Natural/Na	Imperial	Buzzards P	920	33.19799	-114.868	Zone-11 N	T11S, R20E 5 MI NE - E
Unknown	Natural/Na	Imperial	Mt. Barrow	980	33.18276	-114.882	Zone-11 N	T11S, R20E 4.5 MI NE O

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Unknown	Natural/Na	Imperial	Mt. Barrow	970	33.18688	-114.885	Zone-11 NA	T11S, R20E 1.3 MI ESE
Unknown	Natural/Na	Imperial	Mt. Barrow	1030	33.17495	-114.892	Zone-11 NA	T11S, R20E 3.5 MI ENE
Unknown	Natural/Na	Imperial	Mt. Barrow	1100	33.17223	-114.903	Zone-11 NA	T11S, R20E 3 MI NE OF
Unknown	Natural/Na	Imperial	Mt. Barrow	1140	33.17909	-114.914	Zone-11 NA	T11S, R20E 2.5 MI NE O
Unknown	Natural/Na	Imperial	Mt. Barrow	1180	33.1735	-114.923	Zone-11 NA	T11S, R19E 2 MI NE OF
Unknown	Natural/Na	Imperial	Mt. Barrow	1140	33.18282	-114.923	Zone-11 NA	T11S, R19E 2.5 MI NNE
Unknown	Natural/Na	Imperial	Buzzards P	790	33.22132	-114.858	Zone-11 NA	T11S, R20E 0.4 MI NE O
Unknown	Natural/Na	Imperial	Buzzards P	860	33.20581	-114.867	Zone-11 NA	T11S, R20E 0.8 MI SSW
Unknown	Natural/Na	Imperial	Palo Verde	720	33.32755	-114.869	Zone-11 NA	T10S, R20E MILPITAS W
Unknown	Natural/Na	Imperial	West of Pa	700	33.33008	-114.89	Zone-11 NA	T10S, R20E MILPITAS W
Unknown	Natural/Na	Imperial	West of Pa	780	33.32922	-114.956	Zone-11 NA	T10S, R19E IN THE VICI
Unknown	Natural/Na	Imperial	West of Pa	780	33.33269	-114.958	Zone-11 NA	T10S, R19E IN THE VICI
Unknown	Natural/Na	Imperial	West of Pa	790	33.32984	-114.961	Zone-11 NA	T10S, R19E IN THE VICI
Unknown	Natural/Na	Imperial	West of Pa	700	33.34162	-114.897	Zone-11 NA	T09S, R20E IN THE VICI
Unknown	Natural/Na	Imperial	West of Pa	700	33.34311	-114.905	Zone-11 NA	T09S, R20E 5 MI SSW O
Unknown	Natural/Na	Imperial	West of Pa	720	33.34517	-114.921	Zone-11 NA	T09S, R19E 5 MI SW OF
Unknown	Natural/Na	Imperial	West of Pa	750	33.3408	-114.942	Zone-11 NA	T10S, R19E 4 MI SE OF
Unknown	Natural/Na	Imperial	West of Pa	730	33.34959	-114.902	Zone-11 NA	T09S, R20E VICINITY O
Unknown	Natural/Na	Imperial	West of Pa	760	33.3558	-114.928	Zone-11 NA	T09S, R19E VICINITY O
Unknown	Natural/Na	Imperial	West of Pa	770	33.35952	-114.928	Zone-11 NA	T09S, R19E VICINITY O
Unknown	Natural/Na	Imperial	West of Pa	810	33.35805	-114.965	Zone-11 NA	T09S, R19E 2.5 MI SE O
Unknown	Natural/Na	Imperial	Wiley Well	900	33.40496	-114.984	Zone-11 NA	T09S, R19E 1.5 MI N O
Unknown	Natural/Na	Imperial	Wiley Well	850	33.41853	-114.971	Zone-11 NA	T09S, R19E 2.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1300	33.37246	-115.135	Zone-11 NA	T09S, R18E JUST N OF
Unknown	Natural/Na	Imperial	Little Mule	1240	33.36881	-115.119	Zone-11 NA	T09S, R18E 6 MI SSE O
Unknown	Natural/Na	Imperial	Chuckwalla	1320	33.38014	-115.131	Zone-11 NA	T09S, R18E 5 MI S OF G
Unknown	Natural/Na	Imperial	Little Chucl	1290	33.38001	-115.122	Zone-11 NA	T09S, R18E 5 MI SSE O
Unknown	Natural/Na	Imperial	Little Chucl	1290	33.3881	-115.116	Zone-11 NA	T09S, R18E 4.5 MI SSE
Unknown	Natural/Na	Imperial	Chuckwalla	1410	33.38404	-115.149	Zone-11 NA	T09S, R17E 5 MI S OF G
Unknown	Natural/Na	Imperial	Chuckwalla	1390	33.39457	-115.137	Zone-11 NA	T09S, R17E 4 MI S OF G
Unknown	Natural/Na	Imperial	Chuckwalla	1360	33.39431	-115.13	Zone-11 NA	T09S, R18E 4 MI S OF G
Unknown	Natural/Na	Imperial	Chuckwalla	1370	33.39801	-115.13	Zone-11 NA	T09S, R18E 3.5 MI S OF
Unknown	Natural/Na	Imperial	Chuckwalla	1570	33.39575	-115.17	Zone-11 NA	T09S, R17E 4.5 MI SSW
Unknown	Natural/Na	Imperial	Chuckwalla	1520	33.39559	-115.161	Zone-11 NA	T09S, R17E 4 MI SSW O
Unknown	Natural/Na	Imperial	Chuckwalla	1560	33.4004	-115.166	Zone-11 NA	T09S, R17E 4 MI SSW O
Unknown	Natural/Na	Imperial	Chuckwalla	1530	33.40341	-115.159	Zone-11 NA	T09S, R17E 2 MI SE OF
Unknown	Natural/Na	Imperial	Chuckwalla	1550	33.41257	-115.158	Zone-11 NA	T09S, R17E 1.8 MI ESE
Unknown	Natural/Na	Imperial	Little Chucl	1360	33.38712	-115.068	Zone-11 NA	T09S, R18E 4 MILES W
Unknown	Natural/Na	Imperial	Little Chucl	1310	33.39608	-115.061	Zone-11 NA	T09S, R18E 4.5 MILES W
Unknown	Natural/Na	Imperial	Little Chucl	1230	33.40056	-115.093	Zone-11 NA	T09S, R18E 5 MILES W
Unknown	Natural/Na	Imperial	Little Chucl	1210	33.41116	-115.068	Zone-11 NA	T09S, R18E 4.5 MILES E
Unknown	Natural/Na	Imperial	Chuckwalla	1700	33.42087	-115.184	Zone-11 NA	T09S, R17E AT RAINEY
Unknown	Natural/Na	Imperial	Chuckwalla	1760	33.4182	-115.194	Zone-11 NA	T09S, R17E ABOUT 0.5
Unknown	Natural/Na	Imperial	Chuckwalla	1830	33.42006	-115.207	Zone-11 NA	T09S, R17E ABOUT 1.2
Unknown	Natural/Na	Imperial	Chuckwalla	1590	33.41596	-115.238	Zone-11 NA	T09S, R17E 3 MI WSW
Unknown	Natural/Na	Imperial	Chuckwalla	1970	33.41501	-115.243	Zone-11 NA	T09S, R17E 3.2 MI WSW
Unknown	Natural/Na	Imperial	Chuckwalla	2000	33.42098	-115.244	Zone-11 NA	T09S, R16E 3.2 MI W O

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Unknown	Natural/Na	Imperial	Augustine I	2040	33.41964	-115.255	Zone-11 NA	T09S, R16E 3.8 MI W C
Unknown	Natural/Na	Imperial	Augustine I	2000	33.42501	-115.262	Zone-11 NA	T09S, R16E ABOUT 2 M
Unknown	Natural/Na	Imperial | I	Augustine I	2120	33.42851	-115.268	Zone-11 NA	T08S, R16E ABOUT 2 M
Unknown	Natural/Na	Imperial	Yuma West	260	32.74848	-114.743	Zone-11 NA	T16S, R21E ALONG S P/
Unknown	Natural/Na	Imperial | /	Imperial Re	185	33.02577	-114.519	Zone-11 NA	T13S, R23E IMPERIAL N
Unknown	Natural/Na	Imperial | /	Yuma East	120	32.75808	-114.528	Zone-11 NA	T16S, R23E COLORADC
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.21882	-115.016	Zone-11 NA	T11S, R19E 5.5 MI ESE
Unknown	Natural/Na	Imperial	Blue Moun	1180	33.22531	-115.013	Zone-11 NA	T11S, R19E 5.5 MI E BL
Unknown	Natural/Na	Imperial	Blue Moun	1150	33.2328	-115.016	Zone-11 NA	T11S, R19E 5.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1150	33.22519	-115.003	Zone-11 NA	T11S, R19E 6 MI NW O
Unknown	Natural/Na	Imperial	Mt. Barrow	1000	33.23546	-114.994	Zone-11 NA	T11S, R19E 6.5 MI NNV
Unknown	Natural/Na	Imperial	West of Pa	1050	33.25335	-114.996	Zone-11 NA	T10S, R19E 6.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1060	33.24985	-115.002	Zone-11 NA	T11S, R19E 6 MI E OF E
Unknown	Natural/Na	Imperial	Little Mule	1060	33.25484	-115.01	Zone-11 NA	T10S, R19E 6 MI E OF E
Unknown	Natural/Na	Imperial	Little Mule	1050	33.25896	-115.015	Zone-11 NA	T10S, R19E 5.5 MI ENE
Unknown	Natural/Na	Imperial	Little Mule	1040	33.26378	-115.016	Zone-11 NA	T10S, R19E 5.5 MI ENE
Unknown	Natural/Na	Imperial	Blue Moun	1420	33.2019	-115.069	Zone-11 NA	T11S, R18E 3.5 MI SE C
Unknown	Natural/Na	Imperial	Blue Moun	1370	33.20688	-115.063	Zone-11 NA	T11S, R18E 3.5 MI SE C
Unknown	Natural/Na	Imperial	Blue Moun	1300	33.21621	-115.056	Zone-11 NA	T11S, R18E 3.5 MI ESE
Unknown	Natural/Na	Imperial	Blue Moun	1280	33.22009	-115.054	Zone-11 NA	T11S, R18E 3.5 MI ESE
Unknown	Natural/Na	Imperial	Blue Moun	1220	33.22975	-115.051	Zone-11 NA	T11S, R18E 3.5 MI ESE
Unknown	Natural/Na	Imperial	Blue Moun	1200	33.23716	-115.051	Zone-11 NA	T11S, R18E 3.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1170	33.23724	-115.039	Zone-11 NA	T11S, R18E 4 MI E OF E
Unknown	Natural/Na	Imperial	Blue Moun	1140	33.24082	-115.029	Zone-11 NA	T11S, R18E 4.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1150	33.2451	-115.042	Zone-11 NA	T11S, R18E 3.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1130	33.24615	-115.033	Zone-11 NA	T11S, R18E 4.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1400	33.21357	-115.084	Zone-11 NA	T11S, R18E 2.5 MI ESE
Unknown	Natural/Na	Imperial	Blue Moun	1360	33.21546	-115.075	Zone-11 NA	T11S, R18E 3 MI ESE O
Unknown	Natural/Na	Imperial	Blue Moun	1170	33.25121	-115.058	Zone-11 NA	T11S, R18E 3 MI ENE C
Unknown	Natural/Na	Imperial	Little Mule	990	33.27154	-115.005	Zone-11 NA	T10S, R19E 6 MI ENE C
Unknown	Natural/Na	Imperial	West of Pa	900	33.29095	-114.988	Zone-11 NA	T10S, R19E 6.5 MI S OF
Unknown	Natural/Na	Imperial	Little Mule	920	33.29411	-115.005	Zone-11 NA	T10S, R19E 6.5 MI S OF
Unknown	Natural/Na	Imperial	Little Mule	930	33.29725	-115.014	Zone-11 NA	T10S, R19E 6 MI S OF T
Unknown	Natural/Na	Imperial	Little Mule	900	33.3056	-115.004	Zone-11 NA	T10S, R19E 5.5 MI S OF
Unknown	Natural/Na	Imperial	Little Mule	1100	33.26417	-115.052	Zone-11 NA	T10S, R18E 3.5 MI NE C
Unknown	Natural/Na	Imperial	Little Mule	1120	33.26421	-115.06	Zone-11 NA	T10S, R18E 2.8 MI NE C
Unknown	Natural/Na	Imperial	Little Mule	1110	33.27099	-115.074	Zone-11 NA	T10S, R18E 2.5 MI NE C
Unknown	Natural/Na	Imperial	Little Mule	1090	33.27444	-115.07	Zone-11 NA	T10S, R18E 3 MI NE OF
Unknown	Natural/Na	Imperial	Little Mule	1080	33.27457	-115.065	Zone-11 NA	T10S, R18E 3.25 MI NE
Unknown	Natural/Na	Imperial	Little Mule	1030	33.29137	-115.057	Zone-11 NA	T10S, R18E 4.25 MI NE
Unknown	Natural/Na	Imperial	Little Mule	1140	33.30411	-115.094	Zone-11 NA	T10S, R18E 4.25 MI N C
Unknown	Natural/Na	Imperial	Little Mule	990	33.32301	-115.049	Zone-11 NA	T10S, R18E 5.5 MI SW
Unknown	Natural/Na	Imperial	Little Mule	1060	33.32212	-115.079	Zone-11 NA	T10S, R18E 5.5 MI NNE
Unknown	Natural/Na	Imperial	Little Mule	1160	33.32801	-115.082	Zone-11 NA	T10S, R18E 6 MI NNE C
Unknown	Natural/Na	Imperial	Little Mule	1200	33.33044	-115.102	Zone-11 NA	T10S, R18E 6 MI N OF I
Unknown	Natural/Na	Imperial	Little Mule	1180	33.32578	-115.105	Zone-11 NA	T10S, R18E VICINITY O
Unknown	Natural/Na	Imperial	Little Mule	1080	33.3489	-115.061	Zone-11 NA	T09S, R18E 4.5 MI WSV

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Unknown	Natural/Na	Imperial	Little Mule	980	33.33629	-115.041	Zone-11 N	T10S, R18E 4.5 MI SW
Unknown	Natural/Na	Imperial	Little Mule	960	33.3365	-115.036	Zone-11 N	T10S, R18E 4 MI SW OI
Unknown	Natural/Na	Imperial	Little Mule	980	33.34256	-115.034	Zone-11 N	T09S, R18E 4 MI SW OI
Unknown	Natural/Na	Imperial	Little Mule	960	33.34312	-115.029	Zone-11 N	T09S, R18E 3.5 MI SW
Unknown	Natural/Na	Imperial	Little Mule	1010	33.35238	-115.033	Zone-11 N	T09S, R18E 3.5 MI SW
Unknown	Natural/Na	Imperial	Little Mule	940	33.34275	-115.023	Zone-11 N	T09S, R19E 3.5 MI SSW
Unknown	Natural/Na	Imperial	Little Mule	960	33.35688	-115.019	Zone-11 N	T09S, R19E 2.5 MI SW
Unknown	Natural/Na	Imperial	Niland (331	-222	33.19892	-115.605	Zone-11 N	T11S, R13E ALAMO RIV
Unknown	Natural/Na	Imperial	Seeley (321	-40	32.76544	-115.711	Zone-11 N	T16S, R12E MARSH AR
Unknown	Natural/Na	Imperial	Holtville Ea	-15	32.81449	-115.382	Zone-11 N	T15S, R15E VICINITY O
Unknown	Natural/Na	Imperial	Wister (331	-85	33.29276	-115.545	Zone-11 N	T10S, R14E DRAINS AL
Unknown	Natural/Na	Imperial	Blue Moun	1520	33.20729	-115.108	Zone-11 N	T11S, R18E 2.5 MI S OF
Unknown	Natural/Na	Imperial	Blue Moun	1480	33.21325	-115.108	Zone-11 N	T11S, R18E 2 MI S OF E
Unknown	Natural/Na	Imperial	Blue Moun	1380	33.22666	-115.098	Zone-11 N	T11S, R18E 1.5 MI SSE
Unknown	Natural/Na	Imperial	Blue Moun	1460	33.23428	-115.106	Zone-11 N	T11S, R18E 0.5 MI SW
Unknown	Natural/Na	Imperial	Blue Moun	1240	33.24558	-115.081	Zone-11 N	T11S, R18E 1.5 MI E OF
Unknown	Natural/Na	Imperial	Blue Moun	1220	33.2494	-115.086	Zone-11 N	T11S, R18E 1.5 MI ENE
Unknown	Natural/Na	Imperial	Little Mule	1210	33.25586	-115.097	Zone-11 N	T10S, R18E 1 MI ENE O
Unknown	Natural/Na	Imperial	Little Mule	1180	33.25679	-115.083	Zone-11 N	T10S, R18E 2 MI NE OF
Unknown	Natural/Na	Imperial	Little Mule	1140	33.26476	-115.079	Zone-11 N	T10S, R18E 2.5 MI NE O
Unknown	Natural/Na	Imperial	Little Mule	1180	33.26069	-115.092	Zone-11 N	T10S, R18E 1.5 MI NE O
Unknown	Natural/Na	Imperial	Little Mule	1180	33.26498	-115.096	Zone-11 N	T10S, R18E 1.5 MI N O
Unknown	Natural/Na	Imperial	Little Mule	1220	33.2651	-115.106	Zone-11 N	T10S, R18E 1.5 MI N O
Unknown	Natural/Na	Imperial	Little Mule	1220	33.2691	-115.107	Zone-11 N	T10S, R18E 1.5 MI N O
Unknown	Natural/Na	Imperial	Mammoth	1540	33.23038	-115.165	Zone-11 N	T11S, R17E 3.75 MI WS
Unknown	Natural/Na	Imperial	Mammoth	1560	33.23246	-115.181	Zone-11 N	T11S, R17E 3.5 MI ESE
Unknown	Natural/Na	Imperial	Mammoth	1560	33.23448	-115.205	Zone-11 N	T11S, R17E 2.5 MI SE O
Unknown	Natural/Na	Imperial	Mammoth	1490	33.24077	-115.197	Zone-11 N	T11S, R17E 2.5 MI ESE
Unknown	Natural/Na	Imperial	Mammoth	1530	33.24404	-115.211	Zone-11 N	T11S, R17E 1.5 MI SE O
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.25629	-115.226	Zone-11 N	T10S, R17E IN THE VICI
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.2557	-115.235	Zone-11 N	T10S, R17E IN THE VICI
Unknown	Natural/Na	Imperial	Mammoth	1460	33.24745	-115.188	Zone-11 N	T11S, R17E 2.5 MI ESE
Unknown	Natural/Na	Imperial	Pegleg Wel	1460	33.25379	-115.199	Zone-11 N	T10S, R17E 2 MI E OF F
Unknown	Natural/Na	Imperial	Pegleg Wel	1400	33.27086	-115.215	Zone-11 N	T10S, R17E 1.5 MI NE O
Unknown	Natural/Na	Imperial	Pegleg Wel	1400	33.27001	-115.22	Zone-11 N	T10S, R17E 1 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.26899	-115.23	Zone-11 N	T10S, R17E 0.8 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1320	33.26821	-115.235	Zone-11 N	T10S, R17E 0.75 MI NN
Unknown	Natural/Na	Imperial	Pegleg Wel	1300	33.28056	-115.241	Zone-11 N	T10S, R17E 1.5 MI NNV
Unknown	Natural/Na	Imperial	Pegleg Wel	1410	33.26278	-115.191	Zone-11 N	T10S, R17E 2.5 MI E OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1400	33.26659	-115.19	Zone-11 N	T10S, R17E 2.5 MI ENE
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.27004	-115.194	Zone-11 N	T10S, R17E 2.5 MI ENE
Unknown	Natural/Na	Imperial	Pegleg Wel	1330	33.27225	-115.2	Zone-11 N	T10S, R17E 2.25 MI EN
Unknown	Natural/Na	Imperial	Pegleg Wel	1380	33.27445	-115.205	Zone-11 N	T10S, R17E 2 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1350	33.27869	-115.221	Zone-11 N	T10S, R17E 1.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1350	33.25975	-115.144	Zone-11 N	T10S, R17E 2.5 MI WN
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.26873	-115.17	Zone-11 N	T10S, R17E 3.5 MI ENE
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.27711	-115.19	Zone-11 N	T10S, R17E 3 MI ENE O

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Unknown	Natural/Na	Imperial	Pegleg Wel	1340	33.28654	-115.219	Zone-11 N	T10S, R17E 2 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.29102	-115.22	Zone-11 N	T10S, R17E 2.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1370	33.28817	-115.21	Zone-11 N	T10S, R17E 2.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.29485	-115.211	Zone-11 N	T10S, R17E 3 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.29435	-115.202	Zone-11 N	T10S, R17E 3 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1385	33.30049	-115.203	Zone-11 N	T10S, R17E 3.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.30783	-115.187	Zone-11 N	T10S, R17E 4.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.30231	-115.219	Zone-11 N	T10S, R17E 3 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.30491	-115.212	Zone-11 N	T10S, R17E 3.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1440	33.31017	-115.211	Zone-11 N	T10S, R17E 4 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1420	33.31686	-115.196	Zone-11 N	T10S, R17E 4.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1320	33.27225	-115.152	Zone-11 N	T10S, R17E 3 MI NW O
Unknown	Natural/Na	Imperial	Pegleg Wel	1310	33.27198	-115.147	Zone-11 N	T10S, R17E 3 MI NW O
Unknown	Natural/Na	Imperial	Pegleg Wel	1280	33.27833	-115.145	Zone-11 N	T10S, R17E 3 MI NW O
Unknown	Natural/Na	Imperial	Pegleg Wel	1260	33.28464	-115.145	Zone-11 N	T10S, R17E 3.5 MI NW
Unknown	Natural/Na	Imperial	Pegleg Wel	1240	33.2873	-115.137	Zone-11 N	T10S, R17E 3 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1200	33.29553	-115.13	Zone-11 N	T10S, R18E 3.5 MI NNV
Unknown	Natural/Na	Imperial	Little Mule	1170	33.30272	-115.119	Zone-11 N	T10S, R18E 4 MI NNW
Unknown	Natural/Na	Imperial	Little Mule	1200	33.30436	-115.107	Zone-11 N	T10S, R18E 4 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1310	33.28415	-115.166	Zone-11 N	T10S, R17E 4.5 MI NW
Unknown	Natural/Na	Imperial	Pegleg Wel	1280	33.29043	-115.161	Zone-11 N	T10S, R17E 4.5 MI NW
Unknown	Natural/Na	Imperial	Pegleg Wel	1250	33.29729	-115.152	Zone-11 N	T10S, R17E 4.5 MI NW
Unknown	Natural/Na	Imperial	Pegleg Wel	1210	33.303	-115.141	Zone-11 N	T10S, R17E 4.5 MI NNV
Unknown	Natural/Na	Imperial	Pegleg Wel	1240	33.30889	-115.151	Zone-11 N	T10S, R17E 5 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1190	33.3108	-115.134	Zone-11 N	T10S, R18E 5 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1290	33.30539	-115.169	Zone-11 N	T10S, R17E 5 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1300	33.29931	-115.173	Zone-11 N	T10S, R17E 4.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1330	33.30066	-115.181	Zone-11 N	T10S, R17E 4 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1340	33.30518	-115.181	Zone-11 N	T10S, R17E 4.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1320	33.30924	-115.174	Zone-11 N	T10S, R17E 5 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1340	33.31493	-115.177	Zone-11 N	T10S, R17E 5 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1350	33.31962	-115.176	Zone-11 N	T10S, R17E 5.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1320	33.32152	-115.167	Zone-11 N	T10S, R17E 6 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1340	33.32634	-115.167	Zone-11 N	T10S, R17E 6 MI NE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1340	33.3318	-115.168	Zone-11 N	T10S, R17E 6.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1370	33.33092	-115.173	Zone-11 N	T10S, R17E 6 MI NNE C
Unknown	Natural/Na	Imperial	Lion Head I	1600	33.30823	-115.288	Zone-11 N	T10S, R16E 4.5 MI NW
Unknown	Natural/Na	Imperial	Pegleg Wel	1290	33.3263	-115.158	Zone-11 N	T10S, R17E 6.5 MI NNV
Unknown	Natural/Na	Imperial	Pegleg Wel	1260	33.32281	-115.151	Zone-11 N	T10S, R17E 6 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1220	33.323	-115.141	Zone-11 N	T10S, R17E 5.5 MI NNV
Unknown	Natural/Na	Imperial	Pegleg Wel	1230	33.32899	-115.141	Zone-11 N	T10S, R17E 6 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1210	33.33078	-115.134	Zone-11 N	T10S, R18E 6 MI NNW
Unknown	Natural/Na	Imperial	Little Mule	1170	33.33074	-115.126	Zone-11 N	T10S, R18E 6 MI NNW
Unknown	Natural/Na	Imperial	Little Mule	1170	33.33663	-115.122	Zone-11 N	T10S, R18E 6.5 MI N O
Unknown	Natural/Na	Imperial	Lion Head I	1290	33.2801	-115.255	Zone-11 N	T10S, R16E 2 MI NW O
Unknown	Natural/Na	Imperial	Lion Head I	1280	33.27912	-115.264	Zone-11 N	T10S, R16E 2.5 MI NW
Unknown	Natural/Na	Imperial	Lion Head I	1690	33.2882	-115.269	Zone-11 N	T10S, R16E 3 MI NW O

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Unknown	Natural/Na	Imperial	Lion Head I	1370	33.28961	-115.278	Zone-11 N	T10S, R16E 3.5 MI NW
Unknown	Natural/Na	Imperial	Lion Head I	1450	33.29373	-115.277	Zone-11 N	T10S, R16E 3.5 MI NW
Unknown	Natural/Na	Imperial	Lion Head I	1440	33.2952	-115.285	Zone-11 N	T10S, R16E 4 MI NW O
Unknown	Natural/Na	Imperial	Lion Head I	1450	33.31521	-115.286	Zone-11 N	T10S, R16E 5 MI NW O
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Frink (3311	-225	33.35533	-115.699	Zone-11 N	T09S, R12E MARSH AR
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.2941	-115.239	Zone-11 N	T10S, R17E 2.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.29491	-115.245	Zone-11 N	T10S, R16E 2.5 MI NNV
Unknown	Natural/Na	Imperial	Pegleg Wel	1370	33.2907	-115.251	Zone-11 N	T10S, R16E 2.5 MI NNV
Unknown	Natural/Na	Imperial	Lion Head I	1400	33.29528	-115.252	Zone-11 N	T10S, R16E 3 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.29963	-115.245	Zone-11 N	T10S, R16E 3 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1450	33.30279	-115.25	Zone-11 N	T10S, R16E 3.5 MI NNV
Unknown	Natural/Na	Imperial	Lion Head I	1440	33.29878	-115.26	Zone-11 N	T10S, R16E 3.5 MI NNV
Unknown	Natural/Na	Imperial	Lion Head I	1530	33.3056	-115.268	Zone-11 N	T10S, R16E 4 MI NW O
Unknown	Natural/Na	Imperial	Pegleg Wel	1450	33.30507	-115.227	Zone-11 N	T10S, R17E 3.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1460	33.30506	-115.232	Zone-11 N	T10S, R17E 3.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1470	33.30863	-115.23	Zone-11 N	T10S, R17E 3.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1490	33.31575	-115.222	Zone-11 N	T10S, R17E 4 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1550	33.31481	-115.255	Zone-11 N	T10S, R16E 4 MI NNW
Unknown	Natural/Na	Imperial	Pegleg Wel	1570	33.32007	-115.241	Zone-11 N	T10S, R17E 4.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1600	33.32402	-115.247	Zone-11 N	T10S, R16E 4.5 MI NNV
Unknown	Natural/Na	Imperial	Lion Head I	1610	33.32255	-115.267	Zone-11 N	T10S, R16E 5 MI NNW
Unknown	Natural/Na	Imperial	Lion Head I	1640	33.32751	-115.257	Zone-11 N	T10S, R16E 5 MI NNW
Unknown	Natural/Na	Imperial	Lion Head I	1720	33.33652	-115.264	Zone-11 N	T10S, R16E 5 MI SSE O
Unknown	Natural/Na	Imperial	Lion Head I	1700	33.33695	-115.257	Zone-11 N	T10S, R16E 5 MI SSE O
Unknown	Natural/Na	Imperial	Pegleg Wel	1430	33.33306	-115.186	Zone-11 N	T10S, R17E 6 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1450	33.32598	-115.195	Zone-11 N	T10S, R17E 5 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1470	33.32338	-115.202	Zone-11 N	T10S, R17E 5 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1500	33.32409	-115.212	Zone-11 N	T10S, R17E 4.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1540	33.32657	-115.219	Zone-11 N	T10S, R17E 5 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1560	33.32753	-115.227	Zone-11 N	T10S, R17E 5 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1570	33.33232	-115.229	Zone-11 N	T10S, R17E 5 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1400	33.36094	-115.162	Zone-11 N	T09S, R17E 8 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1370	33.35632	-115.159	Zone-11 N	T09S, R17E 8 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1390	33.3555	-115.163	Zone-11 N	T09S, R17E 8 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1370	33.35033	-115.164	Zone-11 N	T09S, R17E 7.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1310	33.3443	-115.154	Zone-11 N	T09S, R17E 7.5 MI NE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1350	33.34738	-115.159	Zone-11 N	T09S, R17E 7.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1360	33.34304	-115.165	Zone-11 N	T09S, R17E 7 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1410	33.34295	-115.176	Zone-11 N	T09S, R17E 6.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1450	33.34725	-115.18	Zone-11 N	T09S, R17E 7 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1440	33.34284	-115.182	Zone-11 N	T09S, R17E 6.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1470	33.34266	-115.187	Zone-11 N	T09S, R17E 6.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1530	33.344	-115.199	Zone-11 N	T09S, R17E 6.5 MI NNE
Unknown	Natural/Na	Imperial	Pegleg Wel	1520	33.35196	-115.192	Zone-11 N	T09S, R17E 7 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1570	33.37281	-115.187	Zone-11 N	T09S, R17E 6.5 MI ESE
Unknown	Natural/Na	Imperial	Chuckwalla	1590	33.3779	-115.185	Zone-11 N	T09S, R17E 6.5 MI ESE

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Unknown	Natural/Na	Imperial	Pegleg Wel	1540	33.33356	-115.213	Zone-11 N	T10S, R17E 5.5 MI N O
Unknown	Natural/Na	Imperial	Pegleg Wel	1540	33.34017	-115.206	Zone-11 N	T10S, R17E 6 MI NNE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1570	33.34124	-115.213	Zone-11 N	T09S, R17E 6 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1640	33.34288	-115.229	Zone-11 N	T09S, R17E 6 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1610	33.34478	-115.218	Zone-11 N	T09S, R17E 6 MI N OF I
Unknown	Natural/Na	Imperial	Pegleg Wel	1620	33.35003	-115.215	Zone-11 N	T09S, R17E 6 MI SE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1700	33.36057	-115.227	Zone-11 N	T09S, R17E 5 MI SE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1650	33.35996	-115.214	Zone-11 N	T09S, R17E 5.5 MI ESE
Unknown	Natural/Na	Imperial	Pegleg Wel	1700	33.36646	-115.219	Zone-11 N	T09S, R17E 5 MI ESE O
Unknown	Natural/Na	Imperial	Pegleg Wel	1710	33.37446	-115.213	Zone-11 N	T09S, R17E 5 MI ESE O
Unknown	Natural/Na	Imperial	Chuckwalla	1690	33.37742	-115.208	Zone-11 N	T09S, R17E 5.5 MI ESE
Unknown	Natural/Na	Imperial	Pegleg Wel	1680	33.34345	-115.238	Zone-11 N	T09S, R17E 5.5 MI SE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1720	33.34845	-115.243	Zone-11 N	T09S, R16E 5 MI SE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1730	33.35244	-115.241	Zone-11 N	T09S, R17E 5 MI SE OF
Unknown	Natural/Na	Imperial	Pegleg Wel	1740	33.3515	-115.248	Zone-11 N	T09S, R16E 4.5 MI SE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1770	33.36512	-115.239	Zone-11 N	T09S, R17E 4.5 MI SE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1760	33.3719	-115.23	Zone-11 N	T09S, R17E 4.5 MI ESE
Unknown	Natural/Na	Imperial	Chuckwalla	1760	33.37604	-115.227	Zone-11 N	T09S, R17E 4.5 MI ESE
Unknown	Natural/Na	Imperial	Chuckwalla	1810	33.38092	-115.231	Zone-11 N	T09S, R17E 4 MI ESE O
Unknown	Natural/Na	Imperial	Lion Head I	1860	33.37255	-115.3	Zone-11 N	T09S, R16E 2.5 MI S OF
Unknown	Natural/Na	Imperial	Lion Head I	1880	33.36678	-115.263	Zone-11 N	T09S, R16E 3.5 MI SE C
Unknown	Natural/Na	Imperial	Pegleg Wel	1840	33.37314	-115.247	Zone-11 N	T09S, R16E 3.5 MI SE C
Unknown	Natural/Na	Imperial	Augustine I	1910	33.3781	-115.263	Zone-11 N	T09S, R16E 2.5 MI SE C
Unknown	Natural/Na	Imperial	Augustine I	2060	33.38342	-115.263	Zone-11 N	T09S, R16E 2.5 MI SE C
Unknown	Natural/Na	Imperial	Augustine I	1880	33.38287	-115.253	Zone-11 N	T09S, R16E 3 MI ESE O
Unknown	Natural/Na	Imperial	Augustine I	1990	33.39046	-115.266	Zone-11 N	T09S, R16E 2 MI ESE O
Unknown	Natural/Na	Imperial	Augustine I	2080	33.39121	-115.284	Zone-11 N	T09S, R16E 1 MI SSE O
Unknown	Natural/Na	Imperial	Lion Head I	1570	33.33543	-115.314	Zone-11 N	T10S, R16E ABOUT 1 M
Unknown	Natural/Na	Imperial	Lion Head I	1520	33.34651	-115.313	Zone-11 N	T09S, R16E ABOUT 1.2
Unknown	Natural/Na	Imperial	Lion Head I	1480	33.35037	-115.327	Zone-11 N	T09S, R16E ABOUT 1 M
Unknown	Natural/Na	Imperial	Lion Head I	1510	33.3539	-115.324	Zone-11 N	T09S, R16E ABOUT 1.2
Unknown	Natural/Na	Imperial	Lion Head I	1580	33.35328	-115.309	Zone-11 N	T09S, R16E ABOUT 1.6
Unknown	Natural/Na	Imperial	Lion Head I	1680	33.36618	-115.308	Zone-11 N	T09S, R16E ABOUT 2.3
Unknown	Natural/Na	Imperial	Lion Head I	1740	33.37251	-115.306	Zone-11 N	T09S, R16E 2.5 MI SSW
Unknown	Natural/Na	Imperial	Lion Head I	1840	33.35879	-115.266	Zone-11 N	T09S, R16E 3.5 MI SSE
Unknown	Natural/Na	Imperial | S	Carrizo Mtı	900	32.79361	-116.112	Zone-11 N	T16S, R08E MORTERO
Unknown	Natural/Na	Imperial	Painted Gorge (32115		32.7802	-116.001	Zone-11 N	T16S, R09E SOUTH OF
Unknown	Natural/Na	Imperial	Augustine I	1860	33.38594	-115.31	Zone-11 N	T09S, R16E 1.5 MI SW
Unknown	Natural/Na	Imperial	Augustine I	1850	33.38737	-115.316	Zone-11 N	T09S, R16E 2 MI SW OI
Unknown	Natural/Na	Imperial	Augustine I	1930	33.39513	-115.317	Zone-11 N	T09S, R16E 1.5 MI SSW
Unknown	Natural/Na	Imperial	Augustine I	2080	33.3937	-115.297	Zone-11 N	T09S, R16E ABOUT 1.2
Unknown	Natural/Na	Imperial	Augustine I	2060	33.3974	-115.297	Zone-11 N	T09S, R16E ABOUT 1 M
Unknown	Natural/Na	Imperial	Augustine I	1980	33.39833	-115.309	Zone-11 N	T09S, R16E 1 MI SW OI
Unknown	Natural/Na	Imperial	Augustine I	1990	33.40292	-115.314	Zone-11 N	T09S, R16E 1 MI WSW
Unknown	Natural/Na	Imperial	Augustine I	2070	33.40864	-115.321	Zone-11 N	T09S, R16E 1.5 MI W C
Unknown	Natural/Na	Imperial	Augustine I	2200	33.4152	-115.312	Zone-11 N	T09S, R16E 1 MI WNW
Unknown	Natural/Na	Imperial	Chuckwalla	1720	33.40112	-115.197	Zone-11 N	T09S, R17E ABOUT 1.6

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Unknown	Natural/Na	Imperial	Chuckwalla	1690	33.3916	-115.197	Zone-11 N	T09S, R17E ABOUT 2 M
Unknown	Natural/Na	Imperial	Chuckwalla	1760	33.38837	-115.212	Zone-11 N	T09S, R17E 2.7 MI SW
Unknown	Natural/Na	Imperial	Chuckwalla	1920	33.40077	-115.24	Zone-11 N	T09S, R17E 4 MI E OF S
Unknown	Natural/Na	Imperial	Chuckwalla	1890	33.40319	-115.227	Zone-11 N	T09S, R17E 2.5 MI SW
Unknown	Natural/Na	Imperial	Chuckwalla	1940	33.40094	-115.247	Zone-11 N	T09S, R16E 2.5 MI E OF
Unknown	Natural/Na	Imperial	Chuckwalla	1900	33.39162	-115.247	Zone-11 N	T09S, R16E 3 MI ESE O
Unknown	Natural/Na	Imperial	Augustine I	200	33.40342	-115.263	Zone-11 N	T09S, R16E 1.5 MI E OF
Unknown	Natural/Na	Imperial	Augustine I	1990	33.40881	-115.253	Zone-11 N	T09S, R16E 2.5 MI E OF
Unknown	Natural/Na	Imperial	Augustine I	2020	33.40847	-115.262	Zone-11 N	T09S, R16E 2 MI E OF S
Unknown	Natural/Na	Imperial	Augustine I	2040	33.41306	-115.262	Zone-11 N	T09S, R16E 2 MI E OF S
Unknown	Natural/Na	Imperial	Augustine I	2050	33.40143	-115.277	Zone-11 N	T09S, R16E 1 MI ESE O
Unknown	Natural/Na	Imperial	Augustine I	2100	33.40618	-115.283	Zone-11 N	T09S, R16E IN THE VICI
Unknown	Natural/Na	Imperial	Augustine I	2170	33.42045	-115.285	Zone-11 N	T09S, R16E 1 MI NNE C
Unknown	Natural/Na	Imperial	Augustine I	2230	33.42412	-115.298	Zone-11 N	T09S, R16E 1 MI NNW
Unknown	Natural/Na	Imperial | I	Augustine I	2240	33.42822	-115.296	Zone-11 N	T09S, R16E 1.5 MI N O
Unknown	Natural/Na	Imperial | I	Augustine I	2280	33.42821	-115.304	Zone-11 N	T09S, R16E 1.5 MI NNE
Unknown	Natural/Na	Imperial	Augustine I	2290	33.42698	-115.308	Zone-11 N	T09S, R16E 1.5 MI NNE
Unknown	Natural/Na	Imperial | I	Augustine I	2320	33.42958	-115.312	Zone-11 N	T08S, R16E 2 MI NNE C
Unknown	Natural/Na	Imperial	Ogilby (321	470	32.85686	-114.839	Zone-11 N	T15S, R20E 1 MI SSW C
Unknown	Natural/Na	Imperial	Ogilby (321	490	32.86414	-114.839	Zone-11 N	T15S, R20E 1 MI SSW C
Unknown	Natural/Na	Imperial	Hedges (32	540	32.88853	-114.848	Zone-11 N	T15S, R20E 1.5 MI WN
Unknown	Natural/Na	Imperial	Clyde (321	580	32.94573	-114.89	Zone-11 N	T14S, R20E 6 MI NW O
Unknown	Natural/Na	Imperial	Clyde (321	600	32.9569	-114.895	Zone-11 N	T14S, R20E WEST SIDE
Unknown	Natural/Na	Imperial	Clyde (321	620	32.9681	-114.894	Zone-11 N	T14S, R20E ALONG OG
Unknown	Natural/Na	Imperial	Clyde (321	660	32.98398	-114.897	Zone-11 N	T14S, R20E ALONG OG
Unknown	Natural/Na	Imperial	Clyde (321	670	32.98876	-114.9	Zone-11 N	T13S, R20E EAST SIDE (
Unknown	Natural/Na	Imperial	Buzzards P	1000	33.17407	-114.864	Zone-11 N	T11S, R20E VICINITY O
Unknown	Natural/Na	Imperial	Buzzards P	950	33.18606	-114.861	Zone-11 N	T11S, R20E 2.7 MI ESE
Unknown	Natural/Na	Imperial	Buzzards P	860	33.21376	-114.853	Zone-11 N	T11S, R20E JUST E OF E
Unknown	Natural/Na	Imperial	Buzzards P	630	33.2476	-114.818	Zone-11 N	T11S, R20E 3 MI NE OF
Unknown	Natural/Na	Imperial	Ninemile W	980	33.07559	-114.927	Zone-11 N	T12S, R19E ABOUT 1 M
Unknown	Natural/Na	Imperial	Buzzards P	780	33.22822	-114.845	Zone-11 N	T11S, R20E ABOUT 0.8
Unknown	Natural/Na	Imperial	Cibola (331	350	33.3391	-114.726	Zone-11 N	T10S, R21E ABOUT 2 M
Unknown	Natural/Na	Imperial	Cibola (331	260	33.36499	-114.733	Zone-11 N	T09S, R21E 0.5 MI NW
Unknown	Natural/Na	Imperial	Cibola (331	250	33.37198	-114.738	Zone-11 N	T09S, R21E 1 MI NW O
Unknown	Natural/Na	Imperial	Mt. Barrow	1070	33.15555	-114.899	Zone-11 N	T12S, R20E WEST OF 4
Unknown	Natural/Na	Imperial	Mt. Barrow	1336	33.12946	-114.95	Zone-11 N	T12S, R19E OFF A TRAI
Unknown	Natural/Na	Imperial	Clyde (321	560	32.93231	-114.886	Zone-11 N	T14S, R20E 6 MI NW O
Unknown	Natural/Na	Imperial	Ninemile W	790	33.02234	-114.906	Zone-11 N	T13S, R20E EAST SIDE (
Unknown	Natural/Na	Imperial	Ninemile W	1030	33.09312	-114.889	Zone-11 N	T12S, R20E 1.5 MI NE C
Unknown	Transplant	Imperial	In-ko-pah C	1770	32.6997	-116.068	Zone-11 N	T17S, R09E IN-KO PAH
Unknown	Natural/Na	Imperial	Ninemile W	830	33.04311	-114.913	Zone-11 N	T13S, R20E ON OGILBY
Unknown	Natural/Na	Imperial	Ninemile W	850	33.04694	-114.906	Zone-11 N	T13S, R20E EAST SIDE (
Unknown	Natural/Na	Imperial	Ninemile W	930	33.07042	-114.895	Zone-11 N	T13S, R20E 1.5 MI SE C
Unknown	Natural/Na	Imperial	Ninemile W	1100	33.12105	-114.884	Zone-11 N	T12S, R20E E SIDE OF E
Unknown	Natural/Na	Imperial	Buzzards P	1060	33.14821	-114.879	Zone-11 N	T12S, R20E VICINITY O
Unknown	Natural/Na	Imperial	Buzzards P	780	33.22859	-114.851	Zone-11 N	T11S, R20E JUST N OF

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Ogilby (321	450	32.84778	-114.841	Zone-11 N	T15S, R20E 2 MI N OF (
Unknown	Natural/Na	Imperial	Chuckwalla	1740	33.41464	-115.194	Zone-11 N	T09S, R17E 1 MILE SW
Unknown	Natural/Na	Imperial	Grays Well	200	32.74501	-114.855	Zone-11 N	T16S, R20E ALONG THI
Unknown	Natural/Na	Imperial	Plaster City	0	32.79061	-115.802	Zone-11 N	T16S, R11E ALONG EV/
Unknown	Natural/Na	Imperial | I	Grays Well	155	32.70815	-114.942	Zone-11 N	T17S, R20E SE END OF
Unknown	Natural/Na	Imperial	Coyote We	300	32.74931	-115.924	Zone-11 N	T16S, R10E NORTH SID
Unknown	Natural/Na	Imperial	Coyote We	550	32.71186	-115.989	Zone-11 N	T16.5S, R9. APPROXIM
Unknown	Natural/Na	Imperial	Plaster City	150	32.76538	-115.849	Zone-11 N	T16S, R11E APPROXIM
Unknown	Natural/Na	Imperial	Plaster City	75	32.764	-115.829	Zone-11 N	T16S, R11E NORTH SID
Unknown	Natural/Na	Imperial	Plaster City	50	32.7696	-115.817	Zone-11 N	T16S, R11E APPROXIM
Unknown	Natural/Na	Imperial	Plaster City	0	32.75576	-115.777	Zone-11 N	T16S, R12E APPROXIM
Unknown	Natural/Na	Imperial	Painted Go	320	32.75093	-115.914	Zone-11 N	T16S, R10E NORTH SID
Unknown	Natural/Na	Imperial	In-ko-pah (	700	32.7114	-116.007	Zone-11 N	T16.5S, R0 APPROXIM
Unknown	Natural/Na	Imperial	Carrizo Mtı	1200	32.80854	-116.075	Zone-11 N	T16S, R09E DOMELANI
Unknown	Natural/Na	Imperial	Carrizo Mtı	849	32.7879	-116.042	Zone-11 N	T16S, R09E SMALL CAN
Unknown	Natural/Na	Imperial	Carrizo Mtı	443	32.77875	-116.014	Zone-11 N	T16S, R09E MOUTH OF
Unknown	Natural/Na	Imperial	Glamis NW	300	32.97156	-115.187	Zone-11 N	T13S, R17E 7 MILES WI
Unknown	Natural/Na	Imperial | I	Calexico (3211564) | H		32.66977	-115.496	Zone-11 N	T17S, R14E CALEXICO.
Unknown	Natural/Na	Imperial	Mount Sigr	0	32.7088	-115.754	Zone-11 N	T17S, R12E 2.0 MILES N
Unknown	Natural/Na	Imperial	Kane Spring	-200	33.12405	-115.855	Zone-11 N	T12S, R11E SAN FELIPE
Unknown	Natural/Na	Imperial	Harpers W	-70	33.10382	-115.939	Zone-11 N	T12S, R10E 0-2 KM N C
Unknown	Natural/Na	Imperial	Niland (3311525) | Wi		33.24069	-115.518	Zone-11 N	T11S, R14E IMPERIAL J
Unknown	Natural/Na	Imperial	Glamis NW	100	32.94769	-115.241	Zone-11 N	T14S, R17E SOUTH OF
Unknown	Natural/Na	Imperial	Coyote We	900	32.67937	-116.008	Zone-11 N	T17S, R10E 4 MILES SS
Unknown	Natural/Na	Imperial	In-ko-pah (	1731	32.69751	-116.083	Zone-11 N	T17S, R09E WEST SIDE
Unknown	Natural/Na	Imperial	Picacho NV	220	33.25048	-114.693	Zone-11 N	T11S, R22E IN THE VICI
Unknown	Natural/Na	Imperial	Picacho NV	210	33.16161	-114.68	Zone-11 N	T12S, R22E ALONG THI
Unknown	Natural/Na	Imperial	Westmorla	-180	33.13276	-115.545	Zone-11 N	T12S, R14E ENGLISH RI
Unknown	Natural/Na	Imperial	Seeley (321	-70	32.76588	-115.702	Zone-11 N	T16S, R12E FIG LAGOO
Unknown	Natural/Na	Imperial	Mount Sigr	-30	32.74597	-115.695	Zone-11 N	T16S, R12E IN THE VICI
Unknown	Natural/Na	Imperial	Brawley NV	-50	32.88983	-115.675	Zone-11 N	T14S, R13E IN THE VICI
Unknown	Natural/Na	Imperial	Alamorio (3	-130	32.96493	-115.48	Zone-11 N	T14S, R14E IN THE VICI
Unknown	Natural/Na	Imperial	Wiest (331	-170	33.0705	-115.503	Zone-11 N	T13S, R14E IN THE VICI
Unknown	Natural/Na	Imperial	Westmorla	-150	33.04443	-115.553	Zone-11 N	T13S, R14E ALONG RU
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E IN THE VICI
Unknown	Natural/Na	Imperial	Calipatria S	-160	33.02492	-115.65	Zone-11 N	T13S, R13E IN THE VICI
Unknown	Natural/Na	Imperial	Calipatria S	-180	33.0518	-115.647	Zone-11 N	T13S, R13E IN THE VICI
Unknown	Natural/Na	Imperial | S	In-ko-pah (	3000	32.67397	-116.106	Zone-11 N	T17S, R08E MOUNTAIN
Unknown	Natural/Na	Imperial	Mount Sigr	30	32.65332	-115.684	Zone-11 N	T17S, R13E WEST MES/
Unknown	Natural/Na	Imperial	Mount Sigr	40	32.67845	-115.708	Zone-11 N	T17S, R12E WEST MES/
Unknown	Natural/Na	Imperial	Mount Sigr	-5	32.69953	-115.696	Zone-11 N	T17S, R12E WEST MES/
Unknown	Natural/Na	Imperial	Yuha Basin	0	32.74129	-115.772	Zone-11 N	T16S, R12E WEST MES/
Unknown	Natural/Na	Imperial	Yuha Basin	0	32.74892	-115.783	Zone-11 N	T16S, R11E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	20	32.75151	-115.791	Zone-11 N	T16S, R11E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	10	32.75454	-115.787	Zone-11 N	T16S, R11E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	-10	32.75557	-115.778	Zone-11 N	T16S, R12E WEST MES/
Unknown	Natural/Na	Imperial	Plaster City	10	32.77601	-115.801	Zone-11 N	T16S, R11E WEST MES/

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Unknown	Natural/Na	Imperial	Plaster City (3211577)		32.79105	-115.839	Zone-11 N	T16S, R11E 1 MILE EAS
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.11534	-115.642	Zone-11 N	T12S, R13E IN THE VICI
Unknown	Natural/Na	Imperial	Wiest (331	-140	33.11152	-115.449	Zone-11 N	T12S, R15E ALONG HW
Unknown	Natural/Na	Imperial	Wiest (331	-100	33.10221	-115.405	Zone-11 N	T12S, R15E VICINITY O
Unknown	Natural/Na	Imperial	Niland (331	-210	33.1475	-115.617	Zone-11 N	T12S, R13E IN THE VICI
Unknown	Natural/Na	Imperial	Niland (331	-200	33.16974	-115.59	Zone-11 N	T11S, R13E ALONG HA
Unknown	Natural/Na	Imperial	Tortuga (33	-160	33.15481	-115.484	Zone-11 N	T12S, R14E AGRICULTU
Unknown	Natural/Na	Imperial	In-ko-pah C	1275	32.72916	-116.1	Zone-11 N	T16S, R09E PALM CAN
Unknown	Natural/Na	Imperial	Niland (331	-200	33.17721	-115.545	Zone-11 N	T11S, R14E VICINITY O
Unknown	Natural/Na	Imperial	Iris (331152	-140	33.22835	-115.513	Zone-11 N	T11S, R14E VICINITY O
Unknown	Natural/Na	Imperial	Niland (331	-180	33.16953	-115.519	Zone-11 N	T11S, R14E ALONG HW
Unknown	Natural/Na	Imperial	Kane Spring	-190	33.22316	-115.86	Zone-11 N	T11S, R11E IN THE VICI
Unknown	Natural/Na	Imperial | I	Durmid (33	-200	33.4131	-115.819	Zone-11 N	T09S, R11E ABOUT 1.3
Unknown	Natural/Na	Imperial	In-ko-pah C	1800	32.70066	-116.066	Zone-11 N	T17S, R09E IN-KO-PAH
Unknown	Natural/Na	Imperial	In-ko-pah C	1200	32.7053	-116.053	Zone-11 N	T17S, R09E IN-KO-PAH
Unknown	Natural/Na	Imperial | A	Yuma West	120	32.73224	-114.644	Zone-11 N	T16S, R22E S BANK OF
Unknown	Natural/Na	Imperial | A	Imperial Re	190	33.00531	-114.502	Zone-11 N	T13S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Westmorla	-160	33.03509	-115.62	Zone-11 N	T13S, R13E WESTMOR
Unknown	Natural/Na	Imperial	Brawley (32	-120	32.98392	-115.525	Zone-11 N	T13S, R14E BRAWLEY.
Unknown	Natural/Na	Imperial	Bard (3211	130	32.77059	-114.587	Zone-11 N	T16S, R23E HAUGHTEL
Unknown	Natural/Na	Imperial | A	Laguna Dar	140	32.82561	-114.497	Zone-11 N	T15S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Laguna Dar	180	32.86831	-114.486	Zone-11 N	T15S, R24E W SIDE ALL
Unknown	Natural/Na	Imperial | I	Palo Verde	235	33.43201	-114.736	Zone-11 N	T09S, R21E VICINITY O
Unknown	Natural/Na	Imperial	Palo Verde	240	33.40866	-114.702	Zone-11 N	T09S, R22E ON COLOR/
Unknown	Natural/Na	Imperial | A	Yuma West	130	32.72955	-114.717	Zone-11 N	T16S, R21E COLORADC
Unknown	Natural/Na	Imperial	Picacho NV	200	33.14415	-114.687	Zone-11 N	T12S, R22E LIGHTHOU
Unknown	Natural/Na	Imperial | A	Yuma West	120	32.72955	-114.717	Zone-11 N	T16S, R21E ALONG THI
Unknown	Natural/Na	Imperial | A	Cibola (331	220	33.29406	-114.728	Zone-11 N	T10S, R21E COLORADC
Unknown	Natural/Na	Imperial | A	Imperial Re	180	32.8951	-114.465	Zone-11 N	T15S, R24E COLORADC
Unknown	Natural/Na	Imperial | I	Mule Wash	240	33.43435	-114.628	Zone-11 N	T08S, R22E COLORADC
Unknown	Natural/Na	Imperial | A	Picacho NV	210	33.17988	-114.674	Zone-11 N	T99X, R99X EAST SIDE (
Unknown	Natural/Na	Imperial | A	Picacho (33	195	33.02479	-114.598	Zone-11 N	T13S, R23E ABOUT 0.7
Unknown	Natural/Na	Imperial	Wister (331	-200	33.30095	-115.592	Zone-11 N	T10S, R13E NILAND LA
Unknown	Natural/Na	Imperial	Wiest (331	-170	33.05734	-115.5	Zone-11 N	T13S, R14E IN THE VICI
Unknown	Natural/Na	Imperial	Frink NW (3	50	33.41028	-115.667	Zone-11 N	T09S, R12E COACHELLA
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211	190	32.83176	-114.547	Zone-11 N	T15S, R23E ALONG THI
Unknown	Natural/Na	Imperial | A	Yuma East	200	32.73172	-114.616	Zone-11 N	T16S, R22E FORT YUMA
Unknown	Natural/Na	Imperial | A	Laguna Dar	160	32.88393	-114.471	Zone-11 N	T15S, R24E 1 MI SW OI
Unknown	Natural/Na	Imperial | A	Laguna Dar	180	32.88393	-114.471	Zone-11 N	T15S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Bard (3211475)		32.78948	-114.554	Zone-11 N	T16S, R23E BARD, FOR
Unknown	Natural/Na	Imperial	Cibola (331	689	33.35361	-114.83	Zone-11 N	T09S, R20E PALO VERD
Unknown	Natural/Na	Imperial	Picacho Pe	1000	32.96143	-114.674	Zone-11 N	T14S, R22E SOUTHWES
Unknown	Natural/Na	Imperial	Bard (3211	135	32.78948	-114.554	Zone-11 N	T16S, R23E VICINITY O
Unknown	Natural/Na	Imperial	Picacho SW	220	33.11172	-114.706	Zone-11 N	T12S, R21E ALONG THI
Unknown	Natural/Na	Imperial	Cibola (331	220	33.25481	-114.689	Zone-11 N	T11S, R22E VICINITY O
Unknown	Natural/Na	Imperial | A	Picacho (33	140	33.02351	-114.615	Zone-11 N	T13S, R22E VICINITY O

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Unknown	Natural/Na	Imperial	Picacho SW	200	33.02943	-114.637	Zone-11 NA	T13S, R22E VICINITY O
Unknown	Natural/Na	Imperial	Niland (331	-220	33.14777	-115.623	Zone-11 NA	T12S, R13E SE SALTON
Unknown	Natural/Na	Imperial	Calipatria S	-210	33.08282	-115.693	Zone-11 NA	T12S, R12E SE SALTON
Unknown	Natural/Na	Imperial	Shell Reef (	270	33.19777	-116.068	Zone-11 NA	T11S, R09E ABOUT 1.5
Unknown	Natural/Na	Imperial	Shell Reef (	100	33.17118	-116.006	Zone-11 NA	T11S, R09E ABOUT 1 M
Unknown	Natural/Na	Imperial	Shell Reef (	80	33.1452	-116.006	Zone-11 NA	T12S, R09E 8.9 MILES \
Unknown	Natural/Na	Imperial	Shell Reef (	80	33.14527	-116.061	Zone-11 NA	T12S, R09E ALONG SAI
Unknown	Natural/Na	Imperial	Shell Reef (	80	33.14726	-116.067	Zone-11 NA	T12S, R09E NEAR SAN
Unknown	Natural/Na	Imperial	Kane Spring	110	33.1784	-115.993	Zone-11 NA	T11S, R09E ABOUT 0.3
Unknown	Natural/Na	Imperial	Kane Spring	90	33.15931	-115.977	Zone-11 NA	T12S, R10E POLE LINE
Unknown	Natural/Na	Imperial | A	Imperial Re	190	33.00531	-114.502	Zone-11 NA	T13S, R24E VICINITY O
Unknown	Natural/Na	Imperial	Kane Spring	50	33.13417	-115.979	Zone-11 NA	T12S, R09E POLE LINE
Unknown	Natural/Na	Imperial	Kane Spring	-10	33.12578	-115.962	Zone-11 NA	T12S, R10E STATE HIGH
Unknown	Natural/Na	Imperial | A	Imperial Re	180	32.8951	-114.465	Zone-11 NA	T15S, R24E COLORADC
Unknown	Natural/Na	Imperial	Plaster City	130	32.90684	-115.916	Zone-11 NA	T14S, R10E ABOUT 5.5
Unknown	Natural/Na	Imperial	Wister (331	-60	33.29867	-115.543	Zone-11 NA	T10S, R14E ALONG THI
Unknown	Natural/Na	Imperial | S	Shell Reef (	140	33.18275	-116.085	Zone-11 NA	T11S, R08E VICINITY O
Unknown	Natural/Na	Imperial | A	Picacho NV	220	33.2549	-114.69	Zone-11 NA	T11S, R22E IN THE VICI
Unknown	Natural/Na	Imperial	Laguna Dar	160	32.8605	-114.489	Zone-11 NA	T15S, R24E E SIDE OF A
Unknown	Natural/Na	Imperial	Painted Go	320	32.78444	-115.967	Zone-11 NA	T16S, R10E ABOUT 3.1
Unknown	Natural/Na	Imperial	Painted Go	150	32.79113	-115.882	Zone-11 NA	T16S, R11E E SIDE OF F
Unknown	Natural/Na	Imperial	Plaster City	100	32.77871	-115.857	Zone-11 NA	T16S, R11E ABOUT 1 M
Unknown	Natural/Na	Imperial	Plaster City	90	32.76995	-115.84	Zone-11 NA	T16S, R11E ABOUT 1.9
Unknown	Natural/Na	Imperial	Mount Sigr	0	32.74052	-115.767	Zone-11 NA	T16S, R12E FROM ABO
Unknown	Natural/Na	Imperial	Plaster City	30	32.76492	-115.8	Zone-11 NA	T16S, R11E ABOUT 0.2
Unknown	Natural/Na	Imperial	Plaster City	0	32.76342	-115.785	Zone-11 NA	T16S, R11E FROM 0.3 I
Unknown	Natural/Na	Imperial	Plaster City	-10	32.77833	-115.791	Zone-11 NA	T16S, R11E ABOUT 0.7
Unknown	Natural/Na	Imperial	Kane Spring	-160	33.11198	-115.882	Zone-11 NA	T12S, R10E ALONG SAI
Unknown	Natural/Na	Imperial	Picacho SW	220	33.11315	-114.706	Zone-11 NA	T12S, R21E ALONG PAI
Unknown	Natural/Na	Imperial	Mount Sigr	100	32.68347	-115.757	Zone-11 NA	T17S, R12E 0.2 TO 0.6
Unknown	Natural/Na	Imperial	Yuha Basin	150	32.66625	-115.782	Zone-11 NA	T17S, R12E 5 TO 6 MIL
Unknown	Natural/Na	Imperial	Plaster City	50	32.7867	-115.839	Zone-11 NA	T16S, R11E ABOUT 1 M
Unknown	Natural/Na	Imperial	Plaster City	40	32.77361	-115.82	Zone-11 NA	T16S, R11E ABOUT 1.2
Unknown	Natural/Na	Imperial	Mount Sigr	0	32.71894	-115.711	Zone-11 NA	T16.5S, R1 WEST MES
Unknown	Natural/Na	Imperial	Mount Sigr	30	32.7016	-115.721	Zone-11 NA	T17S, R12E ABOUT 2 M
Unknown	Natural/Na	Imperial	Mount Sigr	60	32.70414	-115.735	Zone-11 NA	T17S, R12E ABOUT 3 M
Unknown	Natural/Na	Imperial	Mount Sigr	90	32.69516	-115.751	Zone-11 NA	T17S, R12E ABOUT 3.4
Unknown	Natural/Na	Imperial	Mount Sigr	120	32.66606	-115.729	Zone-11 NA	T17S, R12E ABOUT 2.3
Unknown	Natural/Na	Imperial	Mount Sigr	50	32.66075	-115.688	Zone-11 NA	T17S, R13E ABOUT 1.2
Unknown	Natural/Na	Imperial	Mount Sigr	15	32.66338	-115.683	Zone-11 NA	T17S, R13E ABOUT 1.2
Unknown	Natural/Na	Imperial	Glamis SW	50	32.76858	-115.246	Zone-11 NA	T16S, R17E 0.6 MILE N
Unknown	Natural/Na	Imperial	Wister (331	-220	33.28187	-115.604	Zone-11 NA	T10S, R13E ABOUT 1.5
Unknown	Natural/Na	Imperial	Kane Spring	-230	33.32851	-115.941	Zone-11 NA	T10S, R10E ABOUT 20
Unknown	Natural/Na	Imperial	Wister (331	-210	33.25738	-115.576	Zone-11 NA	T10S, R13E GENERAL A
Unknown	Natural/Na	Imperial	Calipatria S	-230	33.12004	-115.766	Zone-11 NA	T12S, R12E SOUTHERN
Unknown	Natural/Na	Imperial	Niland (331	-230	33.25491	-115.599	Zone-11 NA	T10S, R13E ABOUT 8 M
Unknown	Natural/Na	Imperial | A	Laguna Dar	300	32.82892	-114.506	Zone-11 NA	T15S, R23E VICINITY O

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Unknown	Natural/Na	Imperial	Kane Sprin	-230	33.32851	-115.941	Zone-11 N	T10S, R10E DESERT SH
Unknown	Natural/Na	Imperial	Niland (331	-230	33.30582	-115.622	Zone-11 N	T10S, R13E BOMBAY B
Unknown	Natural/Na	Imperial	Coyote We	958	32.65599	-115.944	Zone-11 N	T17S, R10E APPROXIM
Unknown	Natural/Na	Imperial	Coyote We	670	32.65901	-115.939	Zone-11 N	T17S, R10E APPROXIM
Unknown	Natural/Na	Imperial	Harpers W	-65	33.07985	-115.976	Zone-11 N	T12S, R10E ALONG N S
Unknown	Natural/Na	Imperial	Harpers W	-148	33.10185	-115.91	Zone-11 N	T12S, R10E SOUTH EDG
Unknown	Natural/Na	Imperial	Hedges (32	800	32.90129	-114.817	Zone-11 N	T14S, R20E ENTRENCH
Unknown	Natural/Na	Imperial	East of Acolita (331151		33.02188	-115.108	Zone-11 N	T13S, R18E MESQUITE,
Unknown	Natural/Na	Imperial	Buzzards P	1011	33.14771	-114.869	Zone-11 N	T12S, R20E APPROX 0.4
Unknown	Natural/Na	Imperial	Carrizo Mtı	1030	32.79656	-116.054	Zone-11 N	T16S, R09E UNNAMED
Unknown	Natural/Na	Imperial	Carrizo Mtı	1030	32.79656	-116.054	Zone-11 N	T16S, R09E CANYON A
Unknown	Natural/Na	Imperial	Coyote We	600	32.72922	-116.016	Zone-11 N	T16S, R09E APPROXIM
Unknown	Natural/Na	Imperial	In-ko-pah C	1290	32.72894	-116.099	Zone-11 N	T16S, R09E PALM CAN
Unknown	Natural/Na	Imperial	In-ko-pah C	1290	32.72894	-116.099	Zone-11 N	T16S, R09E PALM CAN
Unknown	Natural/Na	Imperial	In-ko-pah C	1639	32.68607	-116.058	Zone-11 N	T17S, R09E NARROW C
Unknown	Natural/Na	Imperial	In-ko-pah C	2174	32.67724	-116.09	Zone-11 N	T17S, R09E BETWEEN
Unknown	Natural/Na	Imperial	In-ko-pah C	1909	32.66615	-116.077	Zone-11 N	T17S, R09E ALONG BO
Unknown	Natural/Na	Imperial	In-ko-pah C	3636	32.63122	-116.088	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	1910	32.66615	-116.077	Zone-11 N	T17S, R09E ALONG BO
Unknown	Natural/Na	Imperial	In-ko-pah C	4200	32.6234	-116.098	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	3636	32.63122	-116.088	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	4200	32.6234	-116.098	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial | S	In-ko-pah C	3100	32.64215	-116.106	Zone-11 N	T17S, R08E IN-KO-PAH
Unknown	Natural/Na	Imperial	In-ko-pah C	1639	32.68607	-116.058	Zone-11 N	T17S, R09E NARROW C
Unknown	Natural/Na	Imperial	In-ko-pah C	1909	32.66615	-116.077	Zone-11 N	T17S, R09E ALONG BO
Unknown	Natural/Na	Imperial	In-ko-pah C	4201	32.6234	-116.098	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	1639	32.68607	-116.058	Zone-11 N	T17S, R09E NARROW C
Unknown	Natural/Na	Imperial	Cibola (331	240	33.34658	-114.723	Zone-11 N	T09S, R21E ALONG HIG
Unknown	Natural/Na	Imperial	In-ko-pah C	1130	32.73641	-116.089	Zone-11 N	T16S, R09E PALM CAN
Unknown	Natural/Na	Imperial	Amos (331	220	33.1247	-115.276	Zone-11 N	T12S, R16E APPROXIM
Unknown	Natural/Na	Imperial	Tortuga (33	220	33.13166	-115.28	Zone-11 N	T12S, R16E APPROXIM
Unknown	Natural/Na	Imperial	Harpers W	0	33.1259	-115.998	Zone-11 N	T12S, R09E ALONG HIG
Unknown	Natural/Na	Imperial	Shell Reef (	55	33.12964	-116.07	Zone-11 N	T12S, R09E APPROXIM
Unknown	Natural/Na	Imperial	Shell Reef (	40	33.12636	-116.045	Zone-11 N	T12S, R09E JUST EAST
Unknown	Natural/Na	Imperial	Carrizo Mtı	1640	32.82455	-116.01	Zone-11 N	T15S, R09E ABOUT 0.3
Unknown	Natural/Na	Imperial	In-ko-pah C	3636	32.63122	-116.088	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	4200	32.6234	-116.098	Zone-11 N	T18S, R09E 0.4 AIR MIL
Unknown	Natural/Na	Imperial	In-ko-pah C	1639	32.68607	-116.058	Zone-11 N	T17S, R09E NARROW C
Unknown	Natural/Na	Imperial	Buzzards P	1210	33.1544	-114.856	Zone-11 N	T12S, R20E ABOUT 0.9
Unknown	Natural/Na	Imperial	Cibola (3311436) | Pal		33.35361	-114.83	Zone-11 N	T09S, R20E PALO VERD
Unknown	Natural/Na	Imperial | A	Picacho SW	200	33.09	-114.709	Zone-11 N	T12S, R21E MOUTH OF
Stable	Introduced	Imperial | A	Cibola (331	223	33.33481	-114.702	Zone-11 N	T99X, R99X ISOLATED F
Unknown	Natural/Na	Imperial | A	Cibola (331	225	33.31908	-114.717	Zone-11 N	T10S, R21E COLORADO
Unknown	Introduced	Imperial | A	Cibola (331	223	33.33481	-114.702	Zone-11 N	T99X, R99X ISOLATED F
Unknown	Natural/Na	Imperial	Wister (331	-60	33.27616	-115.525	Zone-11 N	T10S, R14E GALLEANO
Unknown	Natural/Na	Imperial	Westmorla	-174	33.07752	-115.512	Zone-11 N	T12S, R14E RAMER LAI
Unknown	Natural/Na	Imperial	Frink (3311	-230	33.3533	-115.713	Zone-11 N	T09S, R12E BOMBAY B

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Unknown	Natural/Na	Imperial	Niland (331	-228	33.19666	-115.59	Zone-11 NA	T11S, R13E	VICINITY O
Unknown	Natural/Na	Imperial | A	Laguna Dar	142	32.8255	-114.501	Zone-11 NA	T15S, R24E	VICINITY O
Unknown	Natural/Na	Imperial | I	Oasis (3311	-200	33.4257	-116.054	Zone-11 NA	T09S, R09E	TRAVERTIN
Unknown	Natural/Na	Imperial	Westmorla	-205	33.118	-115.563	Zone-11 NA	T12S, R13E	BRANDT RI
Unknown	Natural/Na	Imperial | I	Thumb Pea	363	33.43335	-114.795	Zone-11 NA	T09S, R21E	ABOUT 3.5
Unknown	Natural/Na	Imperial | I	Thumb Pea	326	33.43431	-114.776	Zone-11 NA	T08S, R21E	ABOUT 2.5
Unknown	Natural/Na	Imperial	Amos (331	200	33.11666	-115.276	Zone-11 NA	T12S, R16E	5.6 AIR MIL
Unknown	Natural/Na	Imperial	Thumb Pea	256	33.42337	-114.757	Zone-11 NA	T09S, R21E	ABOUT 1.5
Unknown	Natural/Na	Imperial	Thumb Pea	390	33.42833	-114.795	Zone-11 NA	T09S, R21E	ABOUT 3.6
Unknown	Natural/Na	Imperial	Palo Verde	258	33.42799	-114.761	Zone-11 NA	T09S, R21E	ABOUT 1.6
Unknown	Natural/Na	Imperial	Thumb Pea	1300					*SENSITIVE
Unknown	Natural/Na	Imperial	In-ko-pah C	1370	32.69458	-116.054	Zone-11 NA	T17S, R09E	CANYON BI
Unknown	Natural/Na	Imperial | A	Yuma East (3211465) |		32.73269	-114.633	Zone-11 NA	T16S, R22E	SANDBARS
Unknown	Natural/Na	Imperial	Clyde (321	380	32.94363	-115	Zone-11 NA	T14S, R19E	APPROXIM
Unknown	Natural/Na	Imperial	Amos (331	197	33.11116	-115.286	Zone-11 NA	T12S, R16E	N SECTION
Unknown	Natural/Na	Imperial	In-ko-pah C	1370	32.69457	-116.054	Zone-11 NA	T17S, R09E	APPROX 1.:
Unknown	Natural/Na	Imperial	Bard (3211	140	32.78948	-114.554	Zone-11 NA	T16S, R23E	VICINITY O
Unknown	Natural/Na	Imperial	Bonds Corr	40	32.69396	-115.293	Zone-11 NA	T17S, R16E	VICINITY O
Unknown	Natural/Na	Imperial | I	Palo Verde	240	33.43201	-114.736	Zone-11 NA	T09S, R21E	VICINITY O
Unknown	Natural/Na	Imperial	East of Acolita (331151		33.02188	-115.108	Zone-11 NA	T13S, R18E	MESQUITE.
Unknown	Natural/Na	Imperial	In-ko-pah C	1339	32.7104	-116.077	Zone-11 NA	T17S, R09E	FOOT OF D
Unknown	Natural/Na	Imperial | A	Yuma East	120	32.73269	-114.633	Zone-11 NA	T16S, R22E	RIVER BAN
Unknown	Natural/Na	Imperial | A	Laguna Dar	140	32.82561	-114.497	Zone-11 NA	T15S, R24E	LAGUNA DA
Unknown	Natural/Na	Imperial	Glamis NW	250	32.98615	-115.173	Zone-11 NA	T13S, R17E	0.7 MILE N
Unknown	Natural/Na	Imperial	Imperial Re	355	32.91597	-114.506	Zone-11 NA	T14S, R23E	ABOUT 3.3
Unknown	Natural/Na	Imperial	Hedges (32	830	32.8809	-114.816	Zone-11 NA	T15S, R20E	ABOUT 1.4
Unknown	Natural/Na	Imperial | A	Yuma East	200	32.73172	-114.616	Zone-11 NA	T16S, R22E	FORT YUM.
Unknown	Natural/Na	Imperial	Ogilby (321	310	32.81475	-114.847	Zone-11 NA	T15S, R20E	IMPERIAL D
Unknown	Natural/Na	Imperial	Ninemile W	1000	33.08507	-114.914	Zone-11 NA	T12S, R20E	JUST WEST
Unknown	Natural/Na	Imperial	Ninemile W	885	33.05949	-114.915	Zone-11 NA	T13S, R20E	ALONG OG
Unknown	Natural/Na	Imperial	Mammoth Wash (331:		33.20676	-115.247	Zone-11 NA	T11S, R16E	MAMMOU
Unknown	Natural/Na	Imperial	Chuckwalla	1676	33.41369	-115.181	Zone-11 NA	T09S, R17E	1 KM SE OF
Unknown	Natural/Na	Imperial	Coyote We	344	32.66973	-115.891	Zone-11 NA	T17S, R11E	CRUCIFIXIC
Unknown	Natural/Na	Imperial	Coyote We	838	32.64073	-115.953	Zone-11 NA	T17S, R10E	SKULL VALI
Unknown	Natural/Na	Imperial	Picacho Pe	343	32.99878	-114.629	Zone-11 NA	T13S, R22E	IN THE VICI
Unknown	Natural/Na	Imperial	Picacho Pe	422	32.98674	-114.63	Zone-11 NA	T13.5S, R2:	ARRASTRA
Unknown	Natural/Na	Imperial	Coyote We	720	32.65658	-115.938	Zone-11 NA	T17S, R10E	UNNAMED
Unknown	Natural/Na	Imperial	In-ko-pah C	1330	32.72894	-116.099	Zone-11 NA	T16S, R09E	PALM CAN'
Unknown	Natural/Na	Imperial	Wiley Well (3311448)		33.42044	-114.904	Zone-11 NA	T09S, R20E	5.1 MILES S
Unknown	Natural/Na	Imperial	Painted Go	686	32.82221	-115.991	Zone-11 NA	T15S, R09E	ROCKY HILI
Unknown	Natural/Na	Imperial	Coyote We	838	32.64073	-115.953	Zone-11 NA	T17S, R10E	SKULL VALI
Unknown	Natural/Na	Imperial	In-ko-pah C	1330	32.69964	-116.059	Zone-11 NA	T17S, R09E	ALONG EAS
Unknown	Natural/Na	Imperial	Amos (331	75	33.01732	-115.302	Zone-11 NA	T13S, R16E	SOUTH OF
Unknown	Natural/Na	Imperial | A	Picacho NV	210	33.19577	-114.678	Zone-11 NA	T11S, R22E	SOUTHEAS'
Unknown	Natural/Na	Imperial	Borrego M	100	33.03991	-116.062	Zone-11 NA	T13S, R09E	ALONG RO.
Unknown	Natural/Na	Imperial	Borrego M	60	33.04176	-116.042	Zone-11 NA	T13S, R09E	3.3 MI EAS'
Unknown	Natural/Na	Imperial	Borrego M	70	33.03613	-116.048	Zone-11 NA	T13S, R09E	ALONG RO.

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Unknown	Natural/Na	Imperial	Coyote We	290	32.74348	-115.933	Zone-11 N	T16S, R10E 0.2 MILE S(
Unknown	Natural/Na	Imperial	Yuha Basin	60	32.7283	-115.768	Zone-11 N	T16S, R12E 3.1 AIR MIL
Unknown	Natural/Na	Imperial	Yuha Basin	50	32.72327	-115.758	Zone-11 N	T16.5S, R1 3.4-3.8 AIR
Unknown	Natural/Na	Imperial	Mount Sigr	45	32.70889	-115.73	Zone-11 N	T17S, R12E 3.9 AIR MIL
Unknown	Natural/Na	Imperial	Mount Sigr	70	32.6627	-115.7	Zone-11 N	T17S, R12E 1.5 TO 2 M
Unknown	Natural/Na	Imperial	Amos (331	90	33.04333	-115.284	Zone-11 N	T13S, R16E 7.5 AIR MIL
Unknown	Natural/Na	Imperial	Glamis NW	75	32.95287	-115.245	Zone-11 N	T14S, R17E 3.8 AIR MIL
Unknown	Natural/Na	Imperial	Glamis NW	90	32.94391	-115.227	Zone-11 N	T14S, R17E 3.1 AIR MIL
Unknown	Natural/Na	Imperial	Durmid (33	-150	33.37846	-115.775	Zone-11 N	T09S, R11E 0.8 MILE N
Unknown	Natural/Na	Imperial	Yuha Basin	100	32.70465	-115.771	Zone-11 N	T17S, R12E 4.7 AIR MIL
Unknown	Natural/Na	Imperial	Glamis SW	115	32.7912	-115.149	Zone-11 N	T16S, R18E 7.4 AIR MIL
Unknown	Natural/Na	Imperial	Glamis SE (	120	32.84192	-115.101	Zone-11 N	T15S, R18E 12.8 AIR M
Unknown	Natural/Na	Imperial	Glamis SE (	120	32.82814	-115.101	Zone-11 N	T15S, R18E 12.1 AIR M
Unknown	Natural/Na	Imperial	Glamis SE (	125	32.77457	-115.108	Zone-11 N	T16S, R18E ABOUT 4.3
Unknown	Natural/Na	Imperial	Midway W	100	32.713	-115.184	Zone-11 N	T16S, R17E ABOUT 6 M
Unknown	Natural/Na	Imperial	Midway W	100	32.74982	-115.181	Zone-11 N	T16S, R17E 0.6 MILE N
Unknown	Natural/Na	Imperial	Glamis SW	100	32.79829	-115.177	Zone-11 N	T15S, R17E ABOUT 6.4
Unknown	Natural/Na	Imperial	Glamis SW	100	32.82176	-115.175	Zone-11 N	T15S, R17E 7.2 MILES N
Unknown	Natural/Na	Imperial	Midway W	85	32.70124	-115.215	Zone-11 N	T17S, R17E 0.3 MILE S(
Unknown	Natural/Na	Imperial	Midway W	80	32.69449	-115.219	Zone-11 N	T17S, R17E 0.8 MILE S(
Unknown	Natural/Na	Imperial	Midway W	115	32.73271	-115.155	Zone-11 N	T16S, R18E NEAR INTE
Unknown	Natural/Na	Imperial	Midway W	125	32.71535	-115.102	Zone-11 N	T16S, R18E NEAR INTE
Unknown	Natural/Na	Imperial	Midway W	125	32.71094	-115.083	Zone-11 N	T16S, R18E VICINITY O
Unknown	Natural/Na	Imperial	Midway W	120	32.7508	-115.11	Zone-11 N	T16S, R18E 3.0 MILES N
Unknown	Natural/Na	Imperial	Midway W	140	32.73882	-115.057	Zone-11 N	T16S, R19E ABOUT 2.6
Unknown	Natural/Na	Imperial	Midway W	140	32.7309	-115.032	Zone-11 N	T16S, R19E ABOUT 3.5
Unknown	Natural/Na	Imperial	Midway W	130	32.70947	-115.04	Zone-11 N	T16S, R19E 2.9 MILES E
Unknown	Natural/Na	Imperial	Yuha Basin	190	32.65374	-115.795	Zone-11 N	T17S, R12E PINTO WAS
Unknown	Natural/Na	Imperial	Mount Sigr	45	32.7136	-115.739	Zone-11 N	T16.5S, R1 4.5 AIR MIL
Unknown	Natural/Na	Imperial	Mount Sigr	-10	32.71607	-115.703	Zone-11 N	T16.5S, R1 WEST MES
Unknown	Natural/Na	Imperial	Mount Sigr	0	32.67114	-115.685	Zone-11 N	T17S, R13E SW OF POI
Unknown	Natural/Na	Imperial	Mount Sigr	70	32.6883	-115.743	Zone-11 N	T17S, R12E 0.7 MILE N
Unknown	Natural/Na	Imperial	Yuha Basin	200	32.6462	-115.797	Zone-11 N	T17S, R12E YUHA DESE
Unknown	Natural/Na	Imperial	Yuha Basin	180	32.6525	-115.787	Zone-11 N	T17S, R12E JUST SE OF
Unknown	Natural/Na	Imperial	Yuha Basin	200	32.65072	-115.822	Zone-11 N	T17S, R11E PINTO WAS
Unknown	Natural/Na	Imperial	Yuha Basin	75	32.7208	-115.781	Zone-11 N	T16.5S, R1 6.9 AIR MIL
Unknown	Natural/Na	Imperial	Yuha Basin	200	32.7358	-115.847	Zone-11 N	T16S, R11E 5.0 AIR MIL
Unknown	Natural/Na	Imperial	Coyote We	350	32.7015	-115.894	Zone-11 N	T17S, R11E YUHA DESE
Unknown	Natural/Na	Imperial	Yuha Basin	350	32.6658	-115.869	Zone-11 N	T17S, R11E YUHA DESE
Unknown	Natural/Na	Imperial	Yuha Basin	130	32.68528	-115.768	Zone-11 N	T17S, R12E 0.5 MILE N
Unknown	Natural/Na	Imperial	Painted Go	300	32.76449	-115.973	Zone-11 N	T16S, R10E 0.4 MILE N
Unknown	Natural/Na	Imperial	Plaster City	80	32.85088	-115.85	Zone-11 N	T15S, R11E 4.1 MILES N
Unknown	Natural/Na	Imperial	Plaster City	80	32.8691	-115.836	Zone-11 N	T15S, R11E 5.5 MILES N
Unknown	Natural/Na	Imperial	Plaster City	65	32.87767	-115.822	Zone-11 N	T15S, R11E 6 MILES NN
Unknown	Natural/Na	Imperial	Superstitio	60	32.89237	-115.809	Zone-11 N	T15S, R11E 4.4 MILES S
Unknown	Natural/Na	Imperial	Superstitio	100	32.93088	-115.818	Zone-11 N	T14S, R11E 1.7 MILES S
Unknown	Natural/Na	Imperial	Superstitio	80	32.92116	-115.875	Zone-11 N	T14S, R11E ABOUT 4 M

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Superstitio	75	32.9461	-115.863	Zone-11 N	T14S, R11E ABOUT 2.3
Unknown	Natural/Na	Imperial	Plaster City	70	32.96464	-115.89	Zone-11 N	T14S, R10E ABOUT 3 M
Unknown	Natural/Na	Imperial	Superstitio	220	32.97172	-115.807	Zone-11 N	T14S, R11E NORTH SID
Unknown	Natural/Na	Imperial	Brawley NV	150	32.96751	-115.754	Zone-11 N	T14S, R12E NORTH OF
Unknown	Natural/Na	Imperial	Brawley NV	70	32.94022	-115.713	Zone-11 N	T14S, R12E NEAR HUFF
Unknown	Natural/Na	Imperial	Superstitio	300	32.93591	-115.788	Zone-11 N	T14S, R11E SE EDGE OI
Unknown	Natural/Na	Imperial	Kane Spring	150	33.03066	-115.821	Zone-11 N	T13S, R11E SUPERSTITI
Unknown	Natural/Na	Imperial	Superstitio	100	32.99523	-115.857	Zone-11 N	T13S, R11E ABOUT 3 M
Unknown	Natural/Na	Imperial	Plaster City	120	32.93652	-115.943	Zone-11 N	T14S, R10E ABOUT 7 M
Unknown	Natural/Na	Imperial	Plaster City	180	32.90713	-115.96	Zone-11 N	T14S, R10E ABOUT 8.5
Unknown	Natural/Na	Imperial	Kane Spring	-200	33.19841	-115.848	Zone-11 N	T11S, R11E 5.0 MILES N
Unknown	Natural/Na	Imperial	Kane Spring	5	33.2199	-115.994	Zone-11 N	T11S, R09E 3.7 MI WSW
Unknown	Natural/Na	Imperial	Shell Reef (	30	33.2164	-116.003	Zone-11 N	T11S, R09E 4.2 MILES W
Unknown	Natural/Na	Imperial	Shell Reef (	130	33.17955	-116.076	Zone-11 N	T11S, R09E 0.5 MILE ES
Unknown	Natural/Na	Imperial	Shell Reef (	120	33.1763	-116.068	Zone-11 N	T11S, R09E 1.0 MILE ES
Unknown	Natural/Na	Imperial | S	Shell Reef (	100	33.15518	-116.081	Zone-11 N	T12S, R09E 1.8 MILES S
Unknown	Natural/Na	Imperial	Shell Reef (	70	33.13448	-116.075	Zone-11 N	T12S, R09E 0.3 MILE N
Unknown	Natural/Na	Imperial	Plaster City	100	32.86477	-115.856	Zone-11 N	T15S, R11E ABOUT 5 M
Unknown	Natural/Na	Imperial	Plaster City	10	32.77563	-115.805	Zone-11 N	T16S, R11E 0.6 MILE N
Unknown	Natural/Na	Imperial	Plaster City	-30	32.77573	-115.776	Zone-11 N	T16S, R12E 0.25 MILE N
Unknown	Natural/Na	Imperial	Plaster City	-10	32.7742	-115.787	Zone-11 N	T16S, R11E 0.9 MILE EN
Unknown	Natural/Na	Imperial	Harpers We	-15	33.11306	-115.995	Zone-11 N	T12S, R09E 0.9 MILE SC
Unknown	Natural/Na	Imperial	Borrego Mi	-25	33.09722	-116.022	Zone-11 N	T12S, R09E 0.7 MILE N
Unknown	Natural/Na	Imperial	Midway We	85	32.7505	-115.215	Zone-11 N	T16S, R17E ABOUT 10.
Unknown	Natural/Na	Imperial	Harpers We	0	33.12548	-116.001	Zone-11 N	T12S, R09E SOUTH SID
Unknown	Natural/Na	Imperial	Borrego Mi	-30	33.11038	-116.005	Zone-11 N	T12S, R09E NE OF SAN
Unknown	Natural/Na	Imperial	Borrego Mi	-15	33.1075	-116.022	Zone-11 N	T12S, R09E ALONG SAN
Unknown	Natural/Na	Imperial	Borrego Mi	-30	33.10317	-116.01	Zone-11 N	T12S, R09E NEAR SAN
Unknown	Natural/Na	Imperial	Borrego Mi	-40	33.09722	-116.005	Zone-11 N	T12S, R09E SOUTH OF
Unknown	Natural/Na	Imperial	Glamis SW	100	32.84651	-115.187	Zone-11 N	T15S, R17E ABOUT 2 M
Unknown	Natural/Na	Imperial	Brawley (32	-120	32.98392	-115.525	Zone-11 N	T13S, R14E BRAWLEY.
Unknown	Natural/Na	Imperial	Glamis (321	300	32.99335	-115.08	Zone-11 N	T13S, R18E GLAMIS SA
Unknown	Natural/Na	Imperial	Truckhaver	-200	33.27046	-115.9	Zone-11 N	T10S, R10E ABOUT 1.6
Unknown	Natural/Na	Imperial | S	Carrizo Mtn	455	32.87596	-116.104	Zone-11 N	T15S, R08E CARRIZO CI
Unknown	Natural/Na	Imperial	Coyote We	280	32.73672	-115.964	Zone-11 N	T16S, R10E COYOTE W
Unknown	Natural/Na	Imperial	Harpers We	-114	33.09514	-115.913	Zone-11 N	T12S, R10E VICINITY O
Unknown	Natural/Na	Imperial | I	Palo Verde	230	33.43201	-114.736	Zone-11 N	T09S, R21E PALO VERD
Unknown	Natural/Na	Imperial	Heber (321	-21	32.75942	-115.638	Zone-11 N	T16S, R13E SILSBEE.
Unknown	Natural/Na	Imperial	Bard (3211	135	32.77059	-114.587	Zone-11 N	T16S, R23E ABOUT 5 M
Unknown	Natural/Na	Imperial	Shell Reef (	75	33.22307	-116.033	Zone-11 N	T11S, R09E NORTH OF
Unknown	Natural/Na	Imperial	Seventeen	377	33.27156	-116.057	Zone-11 N	T10S, R09E SOUTH OF
Unknown	Natural/Na	Imperial	Painted Go	360	32.76575	-115.99	Zone-11 N	T16S, R09E ABOUT 1.5
Unknown	Natural/Na	Imperial	Niland (331	-223	33.20941	-115.583	Zone-11 N	T11S, R13E EXPERIMEN
Unknown	Natural/Na	Imperial	Niland (331	-224	33.2233	-115.585	Zone-11 N	T11S, R13E DRAIN Q, A
Unknown	Natural/Na	Imperial	Wister (331	-224	33.2637	-115.593	Zone-11 N	T10S, R13E W LATERAL
Unknown	Natural/Na	Imperial	Calipatria S	-218	33.10287	-115.685	Zone-11 N	T12S, R12E TRIFOLIUM
Unknown	Natural/Na	Imperial	Coyote We	600				*SENSITIVE

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Niland (331	-227	33.17665	-115.619	Zone-11 N	T11S, R13E W SINCLAI
Unknown	Natural/Na	Imperial | S	In-ko-pah C	2500				*SENSITIVE
Unknown	Natural/Na	Imperial | S	In-ko-pah C	2495	32.66797	-116.106	Zone-11 N	T17S, R09E ROADWAY
Unknown	Natural/Na	Imperial | S	In-ko-pah C	3152	32.6416	-116.105	Zone-11 N	T17S, R09E IN THE VICI
Unknown	Natural/Na	Imperial | S	Carrizo Mtı	454	32.87461	-116.106	Zone-11 N	T15S, R08E ALONG CAI
Unknown	Natural/Na	Imperial | A	Yuma East	200	32.73172	-114.616	Zone-11 N	T16S, R22E FORT YUM
Unknown	Natural/Na	Imperial	Niland (331	-220	33.18549	-115.582	Zone-11 N	T11S, R13E VICINITY O
Unknown	Natural/Na	Imperial	Quartz Pea	1000	33.03448	-114.837	Zone-11 N	T13S, R20E ABOUT 1.5
Unknown	Natural/Na	Imperial	Yuma West	120	32.74995	-114.697	Zone-11 N	T16S, R22E 3.6 MILES \
Unknown	Natural/Na	Imperial | A	Laguna Dar	160	32.82561	-114.497	Zone-11 N	T15S, R24E NORTH OF
Unknown	Natural/Na	Imperial	Picacho Pe	1000	32.94491	-114.634	Zone-11 N	T14S, R22E MILKWEED
Unknown	Natural/Na	Imperial	Carrizo Mtı	1000	32.79475	-116.024	Zone-11 N	T16S, R09E FOSSIL CAN
Unknown	Natural/Na	Imperial | F	Frink NW (3	200	33.43162	-115.68	Zone-11 N	T08S, R12E CANYON B
Unknown	Natural/Na	Imperial	Carrizo Mtı	1640	32.9983	-116.095	Zone-11 N	T13S, R09E PEAK 1.2 A
Unknown	Natural/Na	Imperial	Niland (331	-185	33.20645	-115.526	Zone-11 N	T11S, R14E MANAGED
Unknown	Natural/Na	Imperial	Bonds Corr	37	32.72172	-115.289	Zone-11 N	T16S, R16E BETWEEN I
Unknown	Natural/Na	Imperial	In-ko-pah C	4250	32.62181	-116.094	Zone-11 N	T18S, R09E AROUND T
Unknown	Natural/Na	Imperial	In-ko-pah C	900	32.70437	-116.019	Zone-11 N	T17S, R09E 3 AIRLINE N
Unknown	Natural/Na	Imperial	In-ko-pah C	1390	32.69267	-116.055	Zone-11 N	T17S, R09E APPROXIM
Unknown	Natural/Na	Imperial	In-ko-pah C	1400	32.71377	-116.082	Zone-11 N	T17S, R09E WEST SIDE
Unknown	Natural/Na	Imperial	In-ko-pah C	1230	32.71874	-116.074	Zone-11 N	T17S, R09E WEST SIDE
Unknown	Natural/Na	Imperial	In-ko-pah C	950	32.73029	-116.05	Zone-11 N	T16S, R09E SOUTH SID
Unknown	Natural/Na	Imperial	Carrizo Mtı	780	32.75646	-116.061	Zone-11 N	T16S, R09E APPROXIM
Unknown	Natural/Na	Imperial	Borrego M	200	33.04668	-116.098	Zone-11 N	T13S, R09E SPLIT MOU
Unknown	Natural/Na	Imperial	In-ko-pah C	4250	32.62181	-116.094	Zone-11 N	T18S, R09E AROUND T
Unknown	Natural/Na	Imperial	Borrego M	60	33.03417	-116.039	Zone-11 N	T13S, R09E NORTH ED
Unknown	Natural/Na	Imperial	Acolita (33	275	33.08554	-115.209	Zone-11 N	T12S, R17E NORTH ALC
Unknown	Natural/Na	Imperial	Tortuga (33	240	33.1324	-115.274	Zone-11 N	T12S, R16E IMPERIAL S
Unknown	Natural/Na	Imperial	Little Mule	960	33.31739	-115.039	Zone-11 N	T10S, R18E SMOKETRE
Unknown	Natural/Na	Imperial	Little Chucl	1360	33.4003	-115.127	Zone-11 N	T09S, R18E SOUTH OF
Unknown	Natural/Na	Imperial	Kane Spring	-157	33.10877	-115.86	Zone-11 N	T12S, R11E FROM ABO
Unknown	Natural/Na	Imperial	Kane Spring	-137	33.10706	-115.872	Zone-11 N	T12S, R11E ABOUT 1.6
Unknown	Natural/Na	Imperial | A	Laguna Dam	(3211474	32.88393	-114.471	Zone-11 N	T15S, R24E WASTE GR
Unknown	Transplant	Imperial	Coyote We	983	32.68026	-116.001	Zone-11 N	T17S, R10E DAVIES VAI
Unknown	Natural/Na	Imperial	Glamis NW	191	32.95953	-115.166	Zone-11 N	T14S, R17E GECKO RD,
Unknown	Natural/Na	Imperial	Superstitio	75	32.94413	-115.863	Zone-11 N	T14S, R11E SW OF SUP
Unknown	Natural/Na	Imperial	Glamis SW	77	32.78983	-115.224	Zone-11 N	T16S, R17E EAST MESA
Unknown	Natural/Na	Imperial	Superstitio	143	32.95165	-115.753	Zone-11 N	T14S, R12E ALONG UN
Unknown	Natural/Na	Imperial	Yuha Basin	150	32.66176	-115.779	Zone-11 N	T17S, R12E PINTO WAS
Unknown	Natural/Na	Imperial	Brawley NV	135	32.95302	-115.75	Zone-11 N	T14S, R12E NORTH SID
Unknown	Natural/Na	Imperial	Brawley NV	31	32.92399	-115.699	Zone-11 N	T14S, R12E IMLER RD A
Unknown	Natural/Na	Imperial	Yuma East	164	32.73851	-114.638	Zone-11 N	T16S, R22E ALONG WI
Unknown	Natural/Na	Imperial	Tortuga (33	143	33.14817	-115.334	Zone-11 N	T12S, R16E ABOUT 0.7
Unknown	Natural/Na	Imperial	Frink NW (3	-120	33.40874	-115.742	Zone-11 N	T09S, R12E ABOUT 3.0
Unknown	Natural/Na	Imperial	Palo Verde	960	33.33422	-114.816	Zone-11 N	T10S, R20E 0.4 KM SOU
Unknown	Natural/Na	Imperial	In-ko-pah C	723	32.73975	-116.042	Zone-11 N	T16S, R09E ABOUT 1.5
Unknown	Natural/Na	Imperial	Grays Well	300	32.91623	-115.089	Zone-11 N	T14S, R18E ALGODONE

EEC ORIGINAL PKG

Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE
Unknown	Natural/Na	Imperial	Grays Well	250	32.90558	-115.055	Zone-11 N	T14S, R18E ALGODONE

EEC ORIGINAL PKG

LocDetails	Ecological	ThreatList	Threat	General	OwnerMgt	LastUpdate	KeyQuad	UTMZone	UTME
ELL, BETWEEN HARPER	WELL AND	BORREGO S		ONLY SOUI	UNKNOWN	########	Borrego M	11	588863
ONE OF TH	HABITAT C	Recreation	POSSIBLE T	6 ADULT FE	BLM	########	Bard (3211	11	733439
: CARGO MI	HABITAT C	Mining | O	POSSIBLE T	3 INDIVIDU	BLM	########	Ogilby (321	11	707905
THIS MINE	HABITAT C	Mining | O	POSSIBLE T	132 INDIVS	BLM	########	Ogilby (321	11	707835
RGO MINE,"	HABITAT	CONSISTS OF	CREOSOTE	1 ADULT O	BLM	########	Ogilby (321	11	708291
ONE PORTI	HABITAT C	Mining | O	POSSIBLE T	ROOST SITI	BLM	########	Ogilby (321	11	706624
2006 OBSE	HABITAT C	Mining | O	POSSIBLE T	10 FEMALE	BLM	########	Ogilby (321	11	709123
INCLUDES I	HABITAT C	Mining | O	POSSIBLE T	HISTORIC S	BLM	########	Ogilby (321	11	707137
LOCATED II	HABITAT C	Mining	THREATEN	ONE PAIR (	UNKNOWN	########	Coyote We	11	596958
LOCATED II	HABITAT C	Mining	THREATEN	ONE PAIR (	UNKNOWN	########	Coyote We	11	597586
NE, IN JACK	HABITAT	CONSISTS OF	CREOSOTE	MINE SITE	BLM	########	Ogilby (321	11	707853
INE, IN TUN	HABITAT	CONSISTS OF	CREOSOTE	MASTIFF B	BLM	########	Hedges (32	11	704305
SITE: LARG	HABITAT	CONSISTS OF	CREOSOTE	TWO MAST	BLM	########	Hedges (32	11	703890
THIS SITE I	HABITAT SI	Landfill | R	POSSIBLE D	1 INDIV, 1 /	DOD-CHOC	########	Blue Moun	11	680957
AGRICULTU	SLOW FLO\	Biocides | I	THREATS IN	1 PUPFISH	PVT-IMPER	########	Obsidian B	11	625200
: VAIL LATEI	SHALLOW /	Biocides | I	THREATS IN	26 PUPFISH	PVT-IMPER	########	Obsidian B	11	626791
OOL ABOUT	AN INSHOF	Non-native	THREATS IN	24 PUPFISH	UNKNOWN	########	Frink (3311	11	620475
POOL AT TI	A SHALLOV	Biocides | I	THREATS IN	3 PUPFISH	PVT-IMPER	########	Wister (331	11	629935
OOL AT THE	AN INSHOF	Biocides | I	MOSQUITC	1 PUPFISH,	PVT-IMPER	########	Wister (331	11	629333
OOL 0.1 MI	A LARGE IN	Non-native	POSSIBLY T	9 PUPFISH	UNKNOWN	########	Wister (331	11	628842
OOL ABOUT	A LONG, ELONGATED	INSHORE PC		30 PUPFISH	UNKNOWN	########	Wister (331	11	628182
: THE NILAN	SLOW MOVING, MURKY	WATER V		19 PUPFISH	PVT-IMPER	########	Wister (331	11	628629
OBSERVED	GROWING IN LOWER	FAN OF DRY		50-100 PLA	UNKNOWN	########	Ogilby (321	11	704098
MAPPED G	FROM AIR PHOTOS (1992-2010) A			GAINES NC	UNKNOWN	########	Bard (3211	11	729107
LOCALE STATED AS "BARD."				SDNHM #3	UNKNOWN	########	Bard (3211	11	729107
LOCALE STATED AS "BARD."				UCLA MUS	UNKNOWN	########	Bard (3211	11	729107
LOCALE STATED AS "BARD."				SDNHM #3	UNKNOWN	########	Bard (3211	11	729107
LOCALE STATED AS "BARD."				UCLA #E14	UNKNOWN	########	Bard (3211	11	729107
A, NW EDGI	NEST SITE I	Other | Re	MAIN THRE	ESTIMATEI	PVT-IMPER	########	Obsidian B	11	626655
COLONY ES	SUBSTRATE	Recreation	MAIN THRE	ESTIMATEI	PVT-IMPER	########	Niland (331	11	629644
SINGLE POI	FLAT DOMI	Road/trail (	THIS AREA	THIS SURR(	BLM-ACEC	########	Coyote We	11	603595
LARGE POL	SAND DUN	ORV activit	ORV USE. E	PLANTS OB	BLM	########	Glamis (321	11	681328
JUST W OF	SAND DUN	ORV activit	OHV USE.	BETWEEN I	BLM	########	Grays Well	11	707824
SCATTERE[	SAND DUN	ORV activit	OHV USE, E	POP #S FOI	BLM	########	Glamis (321	11	680006
SCATTERE[	SAND DUN	ORV activit	OHV USE G	EO #2 & #1	BLM	########	Glamis (321	11	678720
SCATTERE[	SAND DUN	ORV activit	ORV USE.	>3,000 PLA	BLM	########	Glamis (321	11	681072
WITHIN TH	ON SPARSE	ORV activit	AREA IS HE	ONE PLANT	BLM	########	Mt. Barrow	11	694641
OOL SOUTH	INSHORE P	Non-native	THREATS IN	IN 1978, 38	USFWS-SOI	########	Calipatria S	11	621955
OOL WEST (	INSHORE P	Non-native	THREATS IN	IN 1978, 38	UNKNOWN	########	Calipatria S	11	622898
DRAIN 1 O	WIDE, FAIR	Biocides | I	THREATS IN	9 PUPFISH	USFWS-SOI	########	Calipatria S	11	619648
2.5 MILES N	1991: STOF	Biocides | I	THREATS IN	2 CAPTURE	BLM	########	Calipatria S	11	618831
8 OWLS OB	ALFALFA FI	Road/trail (	POTENTIAL	THREATS F	PVT-IMPER	########	El Centro (3	11	629988
MAPPED A	OBSERVED	Military op	SOME COL	20-30 PLAN	DOD-NAVY	########	Pegleg Wel	11	665824
ALONG WA	PLANTS IN	Military op	POSSIBLE D	AREA MAY	USBOR	########	Kane Spring	11	609767
1969-70: FI	STATIONS \	Recreation	EXCESSIVE	AREA CONS	USFWS-IMI	########	Imperial Re	11	736079
SH, IMMEDI	IN SONORAN	CREOSOTE	BUSH SCI	2 PLANTS F	BLM	########	Yuha Basin	11	615851

EEC ORIGINAL PKG

MOUTH OF	AGRICULTU	Non-native	NON-NATIV	5 PUPFISH	UNKNOWN	########	Kane Spring	11	612688
MAPPED ACCORDING TO A 1983 E		FEW DISTU	RECORDED	DOD-CHOC	########	East of Aco		11	681321
MAPPED A	PARASITIC ON DALEA EMORYI.		CREOSOTE BU	BLM	########	Shell Reef (		11	589309
MAPPED G	HABITAT DESCRIBED A	INVASIVE S	5 COLLECTI	USBOR, BLI	########	Laguna Dar		11	735251
MAPPED A	HABITAT TYPE LISTED AS CATTAILS		2 RESPONE	BLM, UNKN	########	Iris (33115		11	650444
ALL AMERI	HABITAT AREA IS THE MARSHY AR		9 RAILS DE	BLM	########	Midway W		11	671321
CIBOLA DIV	SITE SURROUNDED A	DREDGED B	THE MARSI	USFWS-CIB	########	Cibola (331		11	715395
PLEASE CONTACT THE CALIFORNIA NATURAL DIVERSITY DATABASE,					########	Little Chucl		0	
ONE FISH (2170 GRAMS) NETTED IN 1973. A 1			RECRUITM	BLM	########	Imperial Re		11	736636
1986: GENI	CATTAIL M	Agriculture	POSSIBLE T	1 DETECTE	BLM, OTHE	########	Bard (3211		11	729893
OBS IN 197	SALT CEDAR, MESQUIT	FLOODING	& PROLON	DPR-PICAC	########	Picacho (33		11	723001
AG DRAIN	UNIFORML	Non-native	NON-NATIV	6 PUPFISH	PVT-IMPER	########	Kane Spring	11	613718
A-QUECHAN	EXTIRPATED. FORMERLY DOMINA		OWNED BY	BIA-YUMA	########	Yuma West		11	715496
MAPPED B	ON NON-A	ORV activit	AREA FENC	APPROXIM	BLM	########	Coyote We	11	603506
MAPPED B	AN OPEN, S	ORV activit	OHV, HEAV	DATE OBSE	BLM	########	Coyote We	11	598300
1979: LOCA	CREOSOTE	ORV activit	OHV TRAFF	1 LIZARD A	BLM	########	Ogilby (321	11	703835
MAPPED T	DUNE HABITAT.			1 COLLECTI	BLM	########	Ogilby (321	11	702395
SDNHM LO	1980: CREOSOTE AND BURSAGE V			SDNHM #5	BLM	########	Ogilby (321	11	701038
OTE WELLS, COLORADO DESERT.				ONLY SOUI	UNKNOWN	########	Coyote We	11	597024
EXACT LOCATION UNKNOWN. MAPPED AS BE				MAIN SOUI	UNKNOWN	########	In-ko-pah G	11	584265
MAPPED B	ALONG SAI	Mining	ENTIRE ARI	2 PLANTS S	BLM-EL CEI	########	Picacho Pe	11	720952
1977 SURV	PRIMARILY	Altered flo	RECENT (19	UP TO 3 DE	BLM	########	Laguna Dar	11	734758
E COLORAD	PRIMARILY	Altered flo	FLOODING	12+ INDIVI	BLM, USBC	########	Laguna Dar	11	735447
ELL.				MVZ SPECI	UNKNOWN	########	Coyote We	11	597024
MAPPED IN	PLANTS GR	Military op	IN AREA IN	50-90 SEEN	DOD-NAVY	########	Brawley NV	11	617091
3 COLONIE	PLANTS ON	Military op	MILITARY E	IN AREA IN	DOD-NAVY	########	Brawley NV	11	616851
MAPPED A	PLANTS IN	Military op	POSSIBLE D	AREA MAY	USBOR	########	Kane Spring	11	613018
MAPPED V	PLANTS FO	Military op	POSSIBLE M	IN AREA IN	DOD-NAVY	########	Brawley NV	11	618386
MAPPED A	PARASITIC ON DALEA EMORYI.		CR	EO 17 LUM	BLM-EL CEI	########	Kane Spring	11	594025
SHEEP CONCENTRATE AT THE NORTHERN EN				POPULATIC	DOD-CHOC	########	Blue Moun	11	687539
EAKS.				POPULATIC	BLM	########	Quartz Pea	11	708582
SHEEP CON	SHEEP ARE	Other	BURRO CO	POPULATIC	DOD-CHOC	########	Iris Pass (33	11	657443
TRANSIENT INDIVIDUALS IN TIERRA BLANCO,				POPULATIC	BLM, PVT	########	In-ko-pah G	11	588155
RECOVERY	AREA OF U	Other | Vel	MORTALIT	POPULATIC	DPR-ANZA-	########	In-ko-pah G	11	585035
NOT OBS D	SALT CEDAR, MESQUITE, WILLOW			MIX W/SAL	DPR-PICAC	########	Picacho (33	11	723001
TATE RECRE	SALT CEDAR, MESQUIT		SOME DIST	TWO INDIV	DPR-PICAC	########	Picacho (33	11	723001
CAN CANAL	SCATTERED, MATURE COTTONWC			ONE OBS D	BIA-FORT Y	########	Bard (3211	11	730387
ONE MALE	SCATTERED	Agriculture	SURROUNDED BY SALT		BIA-FORT Y	########	Bard (3211	11	730387
TATE RECRE	SALT CEDAR, MESQUITE, AND WIL			NONE OBSI	DPR-PICAC	########	Picacho (33	11	723001
CAN CANAL	HABITAT IS SCATTERED	SALT CEDA		FOUR OBSE	BIA-FORT Y	########	Bard (3211	11	730387
TATE RECRE	HABITAT IS SALT CEDA		FLOODING	OBSERVATI	DPR-PICAC	########	Picacho (33	11	723001
1986: OBSE	1986: SCAT	Non-native	BURROS US	FOUR OBSE	USBOR	########	Bard (3211	11	730351
1938 COLLI	SOME COT	Altered flo	FLOODING	UP TO 3 DE	DPR-PICAC	########	Picacho (33	11	723001
CAN CANAL	HABITAT IS SCATTERED, MATURE			PAIR OF CU	BIA-FORT Y	########	Bard (3211	11	730387
MAPPED T	SMALL HAE	Recreation	CAMPING A	0 DETECTE	DPR-PICAC	########	Picacho (33	11	722961
WILDLIFE A	1989: HABI	Altered flo	POSSIBLE T	86 IN 1974	DFG-IMPER	########	Wister (331	11	631826
MOUTH OF	FRESH WA	Altered flo	DECLINE DI	THE AREA I	USFWS-SOI	########	Calipatria S	11	620743

EEC ORIGINAL PKG

IMPERIAL [	THIS AREA HAS CONSISTENTLY SU	MARSH AR	USFWS-IMI	########	Picacho (33	11	723564
LAGUAN DI	RAILS KNO'	Altered flo(	1985: HABI	MARSHES /	BLM	########	Laguna Dar	11	735414
YUMA DIVI	1990: WITH	Altered flo(	1984: FLOC	MARSH AR	BLM, USBC	########	Yuma West	11	719330
IMPERIAL [	RAILS HAVE BEEN CONSISTENTLY I	MARSH AR	USFWS-IMI	########	Picacho NV	11	716389
MARSH AR	MARSH FROM MITCHELL'S CAMP	DETECTED	USFWS-CIB	########	Cibola (331	11	712621
1979 AND :	MAINLY HA	ORV activit	OHV TRESP	1 LIZARD D	DOD-NAVY	########	Superstitio	11	615647
1979 DETECTION LOCATION GIVEN AS T16S R				1 LIZARD O	BLM	########	Yuha Basin	11	610819
1952 LOCA	1984: VEGETATION DC	SOME SECT	2 COLLECTI	BLM	########	Glamis SW	11	667066
MAPPED A(	CREOSOTE	Developme	DISTURBAN	3 FOUND II	BLM	########	Mount Sigr	11	620797
1 OF 4 PRI	AREA COVE	Developme	INCREASING	OFF-ROAI	BLM, PVT, S	########	Iris Wash (3	11	671839
FROM SAN	ONLY NATI	Non-native	TAMARISK,	CAS #1170	BLM, PVT, I	########	Harpers W(	11	602271
1910 DETE(	HABITAT CONSISTED OF EXPANSIV			GRINNELL (	USBOR, PV	########	Palo Verde	11	711449
MAPPED BY	CNDDB A(	ORV activit	IN AREA OF	MAJORITY	DPR-ANZA-	########	Shell Reef (	11	584228
MAPPED B'	IN THE WASHES, ON GRAVELLY TE			SITE BASED	DPR-OCOT	########	Shell Reef (	11	590089
AREA IS M/	EXTENSIVE	ORV activit	ORVS USE S	SEE WWW.	DPR-ANZA-	########	Sweeney P	11	579006
E OF ALL AN	MATURE POPULUS FRI		SITE MAY H	SEE WWW.	BIA-FORT Y	########	Bard (3211	11	730387
D OF FERGU	COTTONWOOD-WILLOW TYPE;<1(			SEE WWW.	USFWS-IMI	########	Imperial Re	11	733400
SURVIVING	MOSTLY DEAD OR SENESCENT PO			SITE IS OW	USBOR	########	Laguna Dar	11	734817
SITE NOW I	FORMERLY ISOLATED STANDS OF			SEE WWW.	UNKNOWN	########	Cibola (331	11	716414
STANDS AP	IN 1983, SALIX GOODDINGII W/VE			SEE WWW.	DPR-PICAC	########	Picacho SW	11	719425
THE MARSI	SCIRPUS OI	ORV activit	LIGHT GRA	THIS AREA	BLM-ACEC,	########	Harpers W(	11	599245
MAPPED B'	IN SAND.			ONLY SOUI	UNKNOWN	########	Yuma West	11	712159
MAPPED B'	ON SAND HILLS.			ONLY SOUI	BLM	########	Midway W(	11	685952
MAPPED BY	CNDDB AS BEST GUESS ABOUT 1(			ONLY SOUI	BLM	########	Holtville NE	11	662988
TILLO.	GROWING IN SANDY, MESQUITE H			ONLY SOUI	UNKNOWN	########	Coyote We	11	594207
MAPPED B'	ALKALINE FLAT.			ONLY SOUI	DPR-ANZA-	########	Carrizo Mtı	11	587423
MAPPED B'	SMALL WA	ORV activit	IN AREA OF	SITE BASED	STATE LAN	########	Carrizo Mtı	11	588200
NORTH OF	BARREN, S/	ORV activit	IN AREA OF	SITE BASED	DPR-ANZA-	########	Carrizo Mtı	11	584798
MAPPED B'	SPARSE CREOSOTE BUSH SCRUB V			SITE BASED	BLM	########	Ogilby (321	11	702645
MAPPED AT	THE EAST END OF SMALL DUNE S			ONLY SOUI	UNKNOWN	########	Kane Spring	11	606864
OFF APPROXIMATELY 11.5 MILES WEST OF M(				SITE BASED	UNKNOWN	########	Yuha Basin	11	609570
TARGET AR	LONGITUD	Non-native	MILITARY E	105 FLOWE	DOD-NAVY	########	Glamis NW	11	665058
MAPPED BY	CNDDB AS BEST GUESS ALONG TI			ONLY SOUI	BLM	########	Coyote We	11	604841
MAPPED A	ON ROCKY GRANITIC SLOPE WITH			ONE PLANT	BLM	########	In-ko-pah (	11	586702
INCLUDES (	HABITAT SI	Mining	THREATEN	1 M COLL 1	BLM	########	Hedges (32	11	703630
ALLEY; APPI	IN SANDY SOIL.			FEWER THA	BLM-EL CEI	########	In-ko-pah (	11	588362
UGGLERS C	ON MID-SLOPE OF STEEP ROCKY H			FEWER THA	PVT	########	In-ko-pah (	11	584648
THE WORK	HABITAT SI	Landfill | R	POSSIBLE D	5 OBS & 4 I	DOD-CHOC	########	Blue Moun	11	680957
WHERE PO	1991: FAIR	Non-native	NON-NATI\	11 CAPTUR	PVT-IMPER	########	Kane Spring	11	616421
23 NORTH	AGRICULTURAL DRAIN WITH A FIR			2 PUPFISH	PVT-IMPER	########	Kane Spring	11	611454
WHERE TRI	1991: DRAI	Non-native	POSSIBLY T	13 CAUGHT	UNKNOWN	########	Kane Spring	11	612422
OOL IMMEI	INSHORE P	Non-native	POSSIBLY T	UNKNOWN	UNKNOWN	########	Kane Spring	11	612316
TWEEN BAR	SOFT, MUC	Biocides | I	THREATS IN	ON 5/15/9	UNKNOWN	########	Kane Spring	11	615836
MAPPED T(	POND FED	Biocides | I	COMPETITI	18 PUPFISH	PVT-IMP IR	########	Obsidian B(	11	627597
SOUTH OF	POND & AC	Non-native	POSSIBLY T	ONE PUPFI	USFWS-SOI	########	Niland (331	11	628308
COLLECTED AT 900 METERS (ABOUT 2950 FEE				MAIN SOUI	UNKNOWN	########	In-ko-pah (	11	583784
TWO 1989	ALONG A WASH. ASSOCIATED WIT			BETTER MA	DOD-CHOC	########	Lion Head I	11	661699

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MAPPED BY CNDDB AS BEST GUESS ALONG P.	SITE BASED	DOD-CHOC	########	Pegleg Wel	11	666925
MAPPED B' THIS PLANT COMPRISES APPROXI	THERE IS A	DOD-CHOC	########	Lion Head I	11	653303
MAPPED BY CNDDB AS BEST GUESS ALONG M	SITE BASED	DOD-CHOC	########	Lion Head I	11	655960
MAPPED B' IN A CREOSOTE BUSH SCRUB COM	MAIN SOUI	DOD-CHOC	########	Blue Moun	11	679918
MAPPED B' ROCKY HILLSIDE.	PHYSICAL D	UNKNOWN	########	Palo Verde	11	711932
MAPPED BY CNDDB BASED ON A 1986 BLM M	25 OR FEW	BLM	########	Harpers W	11	599348
BOUNDAR\ CRESCENT DUNES W/H	UNKNOWN	SEE WWW.	DOD, BLM,	########	Kane Spring	11	603917
BOUNDAR\ CRESCENTIC DUNES W	UNSURE SI	SEE WWW.	DOD, BLM,	########	Kane Spring	11	603917
MAPPED IN ON DALEA Military op	IN AREA IN	6 PLANTS S	DOD-NAVY	########	Superstitio	11	612766
MAPPED A: PLANTS GR Military op	IN AREA IN	FEWER TH/	DOD-NAVY	########	Brawley NV	11	617306
MAPPED IN PLANTS GR Military op	IN AREA IN	<100 PLAN	DOD-NAVY	########	Brawley NV	11	620127
MAPPED AT CORNER OF SECTIONS 25, 26, 35	UNKNOWN	BLM-EL CEI	########	Kane Spring	11	603408
MAPPED AS PER OLECH MAP AT CORNER OF I	UNKNOWN	BLM-EL CEI	########	Kane Spring	11	613157
MAPPED SITE BASED ON MAP FROM LILIAN C	UNKNOWN	BLM-EL CEI	########	Kane Spring	11	609702
MAPPED AS PER MAP FROM OLECH IN SW 1/4	UNKNOWN	BLM-EL CEI	########	Kane Spring	11	606900
2 COLONIE ON DALEA Military op	MILITARY E	100+ PLAN	DOD-NAVY	########	Superstitio	11	608195
2 COLONIE PARASITIC ON DALEA EMORYI. CR	TWO POPU	BLM	########	Shell Reef (	11	590310
PLASTER CI PARASITIC ON DALEA EMORYI. DESERT WASH	BLM	########	Painted Go	11	604147
NORTH SID PARASITIC ON DALEA EMORYI. CREOSOTE BU	BLM-EL CEI	########	Carrizo Mtı	11	586224
POPULATIC PARASITIC ON DALEA EMORYI.	COLLECTIO	BLM	########	Yuha Basin	11	615851
MAPPED IN PARASITIC ON DALEA EMORYI.	BLM-EL CEI	########	Kane Spring	11	603104
COLLECTIO PARASITIC ON DALEA EMORYI. OPEN SANDY I	BLM-EL CEI	########	Kane Spring	11	610071
MAPPED IN PARASITIC IN DALEA EMORYI. SAN	WITHIN TH	BLM	########	Kane Spring	11	607157
THE NESTIN THE ERODE Altered flo	POTENTIAL	TERNS WEI	UNKNOWN	########	Kane Spring	11	613325
COLONY SI HABITAT C Other	POTENTIAL	MORTON E	PVT-IMPER	########	Niland (331	11	631349
COULD NOT LOCATE PROVIDED LOCALITY "SP	SDMNH SP	UNKNOWN	########	Ogilby (321	11	705959
MAPPED ALONG THE CALIFORNIA SIDE OF TH	SITE BASED	UNKNOWN	########	Yuma West	11	721786
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Clyde (321	11	688031
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Clyde (321	11	687265
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	685778
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	685193
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	681517
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	686099
ENDEMIC T FLIGHT ACTIVITY 10-30	MINUTES /	ADULTS SV	BLM	########	Acolita (33	11	665098
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	686691
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	684413
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	684206
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Glamis (32	11	682935
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Cactus (32	11	694226
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Ogilby (321	11	700427
ENDEMIC T FLIGHT ACTIVITY 10-30	MINUTES /	ADULTS SV	BLM	########	Amos (331	11	659420
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Cactus (32	11	696607
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Cactus (32	11	692337
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Cactus (32	11	695118
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Clyde (321	11	689252
ENDEMIC T FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SV	BLM	########	Cactus (32	11	692536
ENDEMIC T FLIGHT ACTIVITY 10-30	MINUTES /	ADULTS SV	BLM	########	Amos (331	11	660913

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ENDEMIC T	FLIGHT ACTIVITY 10-30 MINUTES /	ADULTS SW	BLM	########	Acolita (33	11	666867
ENDEMIC T	FLIGHT ACTIVITY 10-30 MINUTES /	ADULTS SW	BLM	########	Amos (331	11	661950
ENDEMIC T	FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SW	BLM	########	Glamis (32	11	682306
ENDEMIC T	FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SW	BLM	########	Glamis (32	11	685728
ENDEMIC T	FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SW	BLM	########	Glamis (32	11	683799
ENDEMIC T	FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SW	BLM	########	Glamis (32	11	685896
ENDEMIC T	FLIGHT ACTIVITY 10-3(	OHVS. THE	ADULTS SW	BLM	########	Glamis (32	11	683343
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	6 SPECIME	BLM	########	Amos (331	11	661950
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Cactus (32	11	692536
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	8 SPECIME	BLM	########	Acolita (33	11	666867
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Acolita (33	11	668929
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Acolita (33	11	665098
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Amos (331	11	659420
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Glamis SE (	11	680875
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Glamis (32	11	675903
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	6 SPECIME	BLM	########	Glamis (32	11	685728
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Glamis (32	11	685896
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Cactus (32	11	692337
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Ogilby (321	11	700427
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Cactus (32	11	696607
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Cactus (32	11	695118
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	56 SPECIM	BLM	########	Clyde (321	11	688031
ES DUNE SY	NO KNOWN HOST PLANT. ADULTS	HAVE BEE	BLM	########	Glamis (32	11	683799
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Acolita (33	11	671584
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Amos (331	11	661950
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Acolita (33	11	666867
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Acolita (33	11	668929
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Acolita (33	11	665098
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Amos (331	11	659420
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis SE (	11	676532
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Cactus (32	11	693149
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis SE (	11	680875
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis (32	11	675903
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis (32	11	685728
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis (32	11	685896
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Cactus (32	11	692337
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Cactus (32	11	696607
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Cactus (32	11	695118
ES DUNE SY	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Clyde (321	11	688031
ES DUNES S	VIRTUALLY NOTHING IS KNOWN A	FOR YEARS	BLM	########	Glamis (32	11	683799
AL 6 DRAIN	AGRICULTU Biocides | I	THREATS IN	2 PUPFISH	PVT-IMPER	########	Obsidian Bu	11	625995
SPECIMEN LOCATION STATED AS "8 MI BELO			1 MALE CO	USFWS	########	Picacho (33	11	733380
SDMNH RECORD GIVES LOCATION ONLY AS "I			SDMNH #1	BLM, UNKN	########	Yuma West	11	711453
PERIAL.			MVZ #7173	UNKNOWN	########	Seeley (321	11	624462
MVZ #161983 GIVES LOCATION AS "0.5 MI W			SDMNH #1	UNKNOWN	########	Harpers We	11	602064
MAPPED TO GEOREFERENCED COORDINATES			2 COLLECTI	UNKNOWN	########	Bard (3211	11	730522
ZO STAGE STATION.			CSULB #30	UNKNOWN	########	Carrizo Mtı	11	584088

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IILES NORTHEAST OF YUMA, ALONG THE COL(	3 FEMALES	UNKNOWN	########	Bard (3211	11	731265
TWO 1989 ALLUVIAL FAN BESIDE A WASH. AS	SEEN IN 19	DOD-CHOC	########	Pegleg Wel	11	668413
EXACT LOCATION UNKNOWN. MAPPED IN TH	1 FEMALE (	PVT-SDGE,	########	Palo Verde	11	710433
MAPPED TO PROVIDED LOCALITY PICACHO M	1 MALE CO	UNKNOWN	########	Picacho Pe	11	720171
MAPPED APPROXIMATELY TO "2 MI N OF BAI	SPECIMEN	UNKNOWN	########	Bard (3211	11	729175
MAPPED T(KNOWN MATERNITY COLONY AT S	#6712 UCL	BLM, UNKN	########	Imperial Re	11	735554
ONE ADUL 2-3 ACRES OF MATURE WILLOWS.	GREAT BLU	USFWS-IMI	########	Picacho SW	11	717344
	UCLA SPEC	BLM, BIA-F	########	Bard (3211	11	733478
ASH, AT HWY S-34, APPROX 12.5 MI N OF I-80 ,	NESTING B	BLM	########	Hedges (32	11	700809
NESTING BIRDS OBS DURING SUMMER 1977	STUDY; ESTI	BLM	########	Palo Verde	11	703782
3 INDIVIDU 160 ACRE S ORV activit	MODERATE ORV USE.	UNKNOWN	########	Picacho NV	11	715543
MAPPED T(MESQUITE WOODLAND W/SOME	ONE OBSEI	USFWS-CIB	########	Cibola (331	11	713108
LAKE, COLORADO RIVER. THREATS F	TWO OBS I	USFWS-IMI	########	Imperial Re	11	733750
	UCLA SPEC	UNKNOWN	########	Brawley (3	11	637820
D, IMPERIAL VALLEY, 9.5 MI SW OF NILAND.	#S-4510 SB	DFG-IMPEI	########	Niland (331	11	631199
4 MILES NORTHEAST OF BARD.	BLM, BIA-F	########	Bard (3211	11	733478
WESTMORELAND.	#S-1949 SB	UNKNOWN	########	Calipatria S	11	620895
ON THE MAP, THE NAME OF THE LAKE AT THI	CAS SPECIN	UNKNOWN	########	Bard (3211	11	726046
AM.	UCLA SPEC	UNKNOWN	########	Laguna Dar	11	734306
LAND.	#S-706 SBC	UNKNOWN	########	Westmorla	11	628845
ASH, AT HWY S-34, APPROX 12.5 MI N OF I-80 ,	NESTING B	BLM	########	Hedges (32	11	700809
VASH, 2 MI W OF HWY 78 ON ARMY ROAD, AT	NESTING B	BLM	########	Palo Verde	11	703782
ONE YOUN DESERT HABITAT - PALO VERDE AI	EO FROM N	UNKNOWN	########	Glamis (32	11	680042
TY.	EGG SET FF	UNKNOWN	########	Plaster City	11	606770
WESTMORELAND. (SOUTHERN PORTION OF TI	SBCM SPEC	UNKNOWN	########	Obsidian B	11	617568
COYOTE WELL.	EGG SET. A	BLM	########	Coyote We	11	602361
OF KANE SPRINGS.	LACM SPEC	UNKNOWN	########	Kane Spring	11	600504
	CAS SPECIN	UNKNOWN	########	Ogilby (321	11	702138
NE SPRING.	LACM SPEC	UNKNOWN	########	Kane Spring	11	603017
F, COACHELLA VALLEY. (IN THE HILLS BETWEE	LACM SPEC	UNKNOWN	########	Seventeen	11	588884
LAND.	SBCM #5-2	UNKNOWN	########	Westmorla	11	628432
3 MI NE OF BARD.	UCLA SPEC	BLM, BIA-F	########	Bard (3211	11	733478
10 INDIVID SITE PROBABLY USED FOR BREEDING. SALT CI		DPR-PICAC	########	Picacho SW	11	716186
4 INDIVIDU PROBABLY Other	BURROW DAMAGE; M	USFWS-IMI	########	Picacho SW	11	715509
5 INDIVIDU GOOD HAB ORV activit	ORV ACTIVITY.	DPR-PICAC	########	Picacho SW	11	720596
5 INDIVIDU SCATTERED ORV activity		DFG-COLOI	########	Picacho SW	11	713564
SIX OBS IN MESQUITE/ Non-native	THREATS FROM INUNI	USFWS-IMI	########	Imperial Re	11	733750
MAPPED T(MESQUITE WOODLAND W/SOME	4 OBSERVE	USFWS-CIB	########	Cibola (331	11	713108
3 OBS DUR 9 YEAR OLD, SMALL REVEG PLOT	OF COTTON'	USBOR	########	Cibola (331	11	713993
EACH, SALTON SEA.	SBCM #S-2	UNKNOWN	########	Frink (3311	11	618166
ILAND.	SBCM #S-3	UNKNOWN	########	Wister (33	11	629204
	SDMNH #1	BLM, BIA-F	########	Bard (3211	11	733478
	UCLA #J648	UNKNOWN	########	Calexico (3	11	641015
NILAND.	SBCM #2-1	UNKNOWN	########	Niland (331	11	632998
MAPPED W HABITAT CONSISTED OF EXPANSIV	GRINNELL I	UNKNOWN	########	Cibola (331	11	712695
1980 DATA HABITAT INCLUDED A MANY COV	1 SINGING	USBOR	########	Laguna Dar	11	734878
OWNSTREAM OF POTHOLES ON COLORADO RI	FROM BLM	UNKNOWN	########	Bard (3211	11	731265

EEC ORIGINAL PKG

	FROM BLM	BLM, BIA-F	########	Bard (3211	11	733478
SH, AT HWY S-34, APPROX 12.5 MI N OF I-80 ,	NESTING B	BLM	########	Hedges (32	11	700809
VASH, 2 MI W OF HWY 78 ON ARMY ROAD, AT	NESTING B	BLM	########	Palo Verde	11	703782
D, IMPERIAL WATERFOWL MANAGEMENT ARI	SBCM SPEC	DFG-IMPEF	########	Niland (331	11	631199
.	LACM SPEC	UNKNOWN	########	Niland (331	11	638682
OF PALO VERDE.	CAS SPECIN	BLM, UNKN	########	Palo Verde	11	709193
	WFVZ EGG	BLM, BIA-F	########	Bard (3211	11	733478
LAND.	SBCM SPEC	UNKNOWN	########	Westmorla	11	628845
E.	WFVZ EGG	PVT-SDGE,	########	Palo Verde	11	710433
LAKE, COL(HABITAT IS A SMALL, Y THREATS F	TWO OBSE	USFWS-IMI	########	Imperial Re	11	733750
MAPPED T(HABITAT DESCRIBED AS MESQUIT	ONE OBSEF	USFWS-CIB	########	Cibola (331	11	713108
VEGETATIOI HABITAT IS A 9-YEAR-OLD, SMALL	2-5 INDIVIL	USBOR	########	Cibola (331	11	713993
DAM, S OF CHOCOLATE MOUNTAINS.	MVZ SPECI	BLM	########	Imperial Re	11	736636
	5 SPECIMEI	BLM, BIA-F	########	Bard (3211	11	733478
MAPPED W HABITAT CONSISTED OF EXPANSIV	GRINNELL I	UNKNOWN	########	Cibola (331	11	712695
MVZ LOCATION GIVEN AS "COLORADO RIVER	MVZ BIRD ;	UNKNOWN	########	Bard (3211	11	731265
MAPPED TO LOCATION DESCRIBED AS "POTH	7 MALES, 3	BLM, BIA-F	########	Bard (3211	11	733478
ETATION SI HABITAT CONSISTS OF COTTONW	UNKNOWN	USBOR	########	Cibola (331	11	712494
E ALL AMER HABITAT C(ORV activit THREATS IN	1-2 INDIVIL	BIA-FORT Y	########	Bard (3211	11	725444
MAPPED T(1986: YOU Non-native THREATS F	4 DETECTEI	USFWS-IMI	########	Little Picacl	11	733473
VEGETATIOI HABITAT IS A 9-YEAR-OLD, SMALL	ONE PAIR (	USBOR	########	Cibola (331	11	713993
MAPPED T(HABITAT DESCRIBED AS MESQUIT	1 DETECTEI	USFWS-CIB	########	Cibola (331	11	713108
ARTIFICIAL OWLS NEST IN THE DIRT BANKS O	AT LEAST 2	PVT, USFW	########	Calipatria S	11	620978
NTRY RD, SW OF CALIPATRIA.	AT LEAST A	UNKNOWN	########	Westmorla	11	629360
MAPPED T(GOOD QUA Developme HEAVY OR\	3 ADULTS F	USFWS-CIB	########	Picacho NV	11	715543
LAND.	CSULB #15!	UNKNOWN	########	Westmorla	11	628845
MAPPED T(HABITAT DESCRIBED AS MESQUIT	ONE OBSEF	USFWS-CIB	########	Cibola (331	11	713108
SERVATION HABITAT CONSISTS OF NO IMMED	ONE INDIV	BIA-YUMA	########	Yuma West	11	715496
ABOUT 1.1 MARGINAL Vehicle col VISIBLE DIS	PRESENT 1!	USBOR, US	########	Cibola (331	11	713832
MAPPED G AREA IMMEDIATELY SURROUNDIN	ONE POSSI	PVT, USFW	########	Cibola (331	11	715209
OUTH OF 38TH STREET COUNTY PARK, CIBOLA	SITE CR13 (	BLM	########	Palo Verde	11	720012
MAPPED B' DENSE RIPARIAN WILLOW GROVE	10 CUCKOC	USFWS-IMI	########	Picacho NV	11	716168
MAPPED BY CNDDB ACCORDING TO MULTIPL	8 CUCKOO!	DPR-PICAC	########	Picacho SW	11	719881
IORES LANDING TRAILER PARK, CIBOLA DIVISI(	SITE CR16 (	PVT	########	Picacho NV	11	716354
1977: MAP BIRD DETE(Non-native INUNDATIC	1 BIRD, PO!	BLM, UNKN	########	Imperial Re	11	734213
WEST OF W HABITAT CONSISTS OF WILLOWS \	SITE CR23 (	USBOR	########	Yuma West	11	719064
W OF WES' HABITAT IS RIVER DELTA SHORELI	ADULTS AN	UNKNOWN	########	Calipatria S	11	621923
LAND. HABITAT IS ALKALI MUDFLAT ON /	TWO EGGS	PVT-IMPER	########	Niland (331	11	629644
D NEAR WINTERHAVEN.	MANY HEA	UNKNOWN	########	Yuma West	11	720494
MAPPED T(HABITAT T\ Altered flo(POSSIBLE II	2 RESPONI	UNKNOWN	########	Iris (331152	11	647517
MAPPED T(HABITAT TYPE DESCRIBED AS "CA1	5 RESPONI	UNKNOWN	########	Iris (331152	11	647942
MAPPED A POSSIBLE IMPACTS TO HYDROLOG	3 RESPONI	BLM	########	Amos (331	11	659048
MAPPED T(DESCRIBED Agriculture POSSIBLY T	TWO RESP(	BLM, UNKN	########	Tortuga (33	11	653109
MAPPED T(HABITAT T\ Agriculture AIR PHOTO	ONE RESPC	BLM, UNKN	########	Tortuga (33	11	652507
MAPPED T(HABITAT T\ Agriculture SOUTHEAS	TWO RESP(	BLM, UNKN	########	Tortuga (33	11	651683
MAPPED T(HABITAT TYPE DESCRIBED AS "CA1	2 DETECTEI	BLM, UNKN	########	Amos (331	11	655079
MAIN DRAIN, AROUND HWY 115, APPROX 7 M	FOUR DUE	UNKNOWN	########	Alamorio (3	11	647660

EEC ORIGINAL PKG

MAPPED TO POW85U0002 MPA FOR 1978 SL	2 RAILS EST	USFWS-SOI	########	Niland (331	11	628344
IMPERIAL WILDLIFE AREA DIVISION. 1974 & 1	86 DETECTI	DFG-IMPEF	########	Westmorla	11	639180
IMPERIAL I	RAILS HAVE BEEN CONSISTENTLY I	MARSH AR	USFWS-IMI	########	Picacho SW	11	713683
CAN CANAL; JUST ACROSS AND E OF INFLOW (	5 YUMA CL	USBOR	########	Bonds Corr	11	662116
2000: NEW RIVER, CURTIS RD. MAPPED TO P(	RAILS RESP	UNKNOWN	########	Seeley (321	11	621398
CIBOLA DIV	A MANAGEMENT PLAN IS BEING F	5 RAILS DE	IMP COUN	########	Palo Verde	11	711421
PALO VERI	HABITAT CONSISTS OF AGRICULTU	20 PAIRS O	UNKNOWN	########	Palo Verde	11	715214
PALO VERI	HABITAT C	Agriculture	AGRICULTU	5 PAIRS OB	UNKNOWN	########	Palo Verde	11	715214
AT LEAST 6 ACTIVE NESTS CONTAINING YOUN	10 ADULTS	UNKNOWN	########	Bard (3211	11	729853
NESTS ARE LOCATED IN TWO COTTONWOOD	10 ADULTS	UNKNOWN	########	Bard (3211	11	729245
PLEASE CONTACT THE CALIFORNIA NATURAL	DIVERSITY DATABASE,	########	In-ko-pah (	0	
PLEASE CONTACT THE CALIFORNIA NATURAL	DIVERSITY DATABASE,	########	Borrego M	0	
PLEASE CO	NEST LOCATED AT 200-300 FEET IN	A GRANITE	OUTCROP	########	In-ko-pah (	0	
PLEASE CO	POTHOLE NEST LOCATED AT 300 FT,	IN A POTHOLE,	IN A	########	Picacho Pe	0	
PLEASE CONTACT THE CALIFORNIA NATURAL	DIVERSITY DATABASE,	########	Carrizo Mtı	0	
SURVEY AR	HABITAT W	Non-native	MAIN THRE	5 DETECTE	USFWS-IMI	########	Imperial Re	11	733705
SSES LAGUNA DAM AND POTHOLES ALONG C(	MVZ #126	BLM, BIA-F	########	Bard (3211	11	733478
YUMA.	MVZ #126	UNKNOWN	########	Bard (3211	11	727985
DETECTED	CREOSOTE BUSH SCRUB.	1 COLLECTI	DOD-NAVY	########	Superstitio	11	609623
MAPPED T(	DESERT HORNED LIZARDS & FRIN(	1 FLAT-TAI	BLM	########	Coyote We	11	603623
LOCATIONS STATED AS "1 MI N GLAMIS, ALG(	MUSEUM S	UNKNOWN	########	East of Aco	11	680295
SDNHM #3	HABITAT C(	ORV activit	OHV RECRE	MUSEUM S	DPR-OCOTI	########	Shell Reef (	11	586777
MAPPED T(	DESERT HORNED LIZARDS & FRIN(	0 FLAT-TAI	BLM	########	Glamis SW	11	674913
DIRECTIONS IN "LOCATION" FIELD DEVELOPM	1 FEMALE (	UNKNOWN	########	Brawley (3	11	636400
MAPPED TO SPECIMEN	Developme	SUITABLE H	FEMALE M	UNKNOWN	########	Holtville W	11	651477
LOCALITY STATED AS "HARPER'S WELL".	SDNHM CA	UNKNOWN	########	Harpers W(	11	602064
1941 SPECI	2011-2012	ORV activit	CONSTRUC	SDNHM CA	BLM	########	Painted Go	11	601188
MAPPED TO LOCALITY "10 MI. SW (AIRLINE) (	LACM #123	UNKNOWN	########	Seeley (321	11	626384
MAPPED T(	MOUNT SI(	Agriculture	REMOVAL (	1 WAS COL	UNKNOWN	########	Mount Sigr	11	627326
ON WEST SIDE OF COACHELLA CANAL, ABOU	ONE OBSEF	BLM	########	Grays Well	11	690771
1955-1964	AERIAL IM/	Vehicle col	THREAT FR	MANY COL	BLM, PVT	########	Glamis NW	11	666210
PLOT 16: S\	DOMINANT PLANTS; CRYPTANTH/	4 OBSERVE	UNKNOWN	########	Harpers W(	11	595733
1978 DETE(	DOMINANT PLANTS INCLUDED LA	3 OBSERVE	BLM, UNKN	########	Holtville NE	11	660316
LIZARD SEEN ON DIRT ROAD, SEVERAL SCAT A	ONE LIZARI	UNKNOWN	########	Durmid (33	11	615020
1979: EXAC	CREOSOTE	ORV activit	OHV RECRE	1 OBSERVE	DPR, BLM,	########	Kane Spring	11	603458
LIZARD ENCOUNTERED DURING "SECTION SE/	1 LIZARD O	BLM	########	Kane Spring	11	605741
"PROAD" A	2002-2006	ORV activit	OHV RECRE	1 OBS IN T:	DPR-OCOTI	########	Kane Spring	11	595751
EXACT LOC	2002: CREC	ORV activit	POSSIBLY T	1 FLAT-TAI	BLM, DPR-(	########	Kane Spring	11	595387
KLAUBER (1939) GAVE LOCALITY OF "20 MILE	OBSERVED	BLM	########	Glamis SE (	11	685854
AREA IS PRIMARILY EAST OF THE OLD OVERLA	ONE OBSEF	UNKNOWN	########	Painted Go	11	600543
T14S, R10E, SECTIONS 4 & 9. LOCATION MAPI	USNM SPE(	BLM, UNKN	########	Plaster City	11	598766
LOCATION MAPPED ACCORDING TO PROVIDE	ONE OBSEF	UNKNOWN	########	Carrizo Mtı	11	591146
PLEASE CO	ASSOCIATE	Over-collec	THREATENED	BY POACHING	AND	########	In-ko-pah (	0	
PLEASE CONTACT THE	ORV activit	THREATENED	BY COLLECTION	(PO	########	In-ko-pah (	0	
PLEASE CONTACT THE	ORV activit	THREATENED	BY POACHING	AND	########	In-ko-pah (	0	
PLEASE CO	"...TAKEN (	ORV activit	AREA HAS	LONG HISTORY	OF USE	########	Carrizo Mtı	0	
PLEASE CONTACT THE	ORV activit	THREATENED	BY POACHING	AND	########	In-ko-pah (	0	

EEC ORIGINAL PKG

E COLORAD	VEGETATIC	Altered flo	FLOODING	2 INDIVIDU	BLM, USBC	########	Laguna Dar	11	735447
E COLORAD	VEGETATION	INCLUDES GOODDIN	ONE PAIR (	BLM, USBC	########	Laguna Dar	11	735447	
) SPRING RE	25 PUPFISH	TRANSPLANTED FROM	SALTON S	DOD-CHOC	########	Buzzards P	11	708992	
ONE 680 G	FISH CAUGHT	IN 1975. A SMALL #	A 1981 CDF	USBOR, US	########	Picacho NV	11	715543	
LINE CANAL	AND PONDS,	NILAND.	SIX CAPTUI	PVT	########	Iris (33115	11	641050	
DOCUMEN	2 COLLECTI	Dam/Inunc	DAMS, CH/	7 COLLECTI	USBOR	########	Imperial Re	11	735478
ELY BELOW	PLENTIFUL.			UNKNOWN	########	Laguna Dar	11	734110	
WASHINGT	UNABLE TO	CONVERT TO FLORIST	SEE WWW.	UNKNOWN	########	In-ko-pah (	11	585764	
WASHINGT	SPRING DRY	IN SUMMER. UNABLE	SEE WWW.	UNKNOWN	########	In-ko-pah (	11	586339	
WASHINGT	UNABLE TO	CONVERT TO FLORIST	SEE WWW.	UNKNOWN	########	In-ko-pah (	11	588583	
WASHINGT	UNABLE TO	CONVERT TO FLORIST	SEE WWW.	UNKNOWN	########	In-ko-pah (	11	586700	
66 PALMS (	WASHINGT	Non-native	TAMARISK	SEE WWW.	UNKNOWN	########	Oasis (3311	11	585366
U/S, DESER	SMALL BUT	DENSE STAND (100% (	SEE WWW.	DPR-PICAC	########	Picacho SW	11	717311	
COLORADO	YOUNG DENSE	STAND (APPROX 7!	SITE OWNE	USBOR	########	Yuma West	11	719064	
E OF COLOF	SALIX GOODDINGII	W/FEW COTTC	SEE WWW.	DPR-PICAC	########	Picacho (33	11	724533	
FERGUSON	DOMINATED BY	SALIX GOODDING	SEE WWW.	USFWS-IMI	########	Picacho (33	11	733211	
TYPED FRO	COTTONWOOD-WILLOW	TYPE W/	SEE WWW.	USFWS-IMI	########	Little Picac	11	733492	
MAPPED A	2010 AIR PHOTO	SHOWS EXTENSI	3-4 DETECT	UNKNOWN	########	Bard (3211	11	730916	
MAPPED T(	2003: AREA OF	OBSERVATION WA	UP TO 3 IN	BLM, USFW	########	Picacho NV	11	716047	
) RIVER FROM	WALKER LAKE	DOWNSTREAM T	UNKNOWN	USFWS-IMI	########	Picacho NV	11	716389	
E COLORADO	RIVER FROM	WALKER LAKE DOW	UNKNOWN	USFWS-IMI	########	Picacho NV	11	716389	
E COLORADO	RIVER FROM	WALKER LAKE TO L	FEWER TH/	USFWS-IMI	########	Picacho NV	11	716389	
) RIVER FROM	WALKER LAKE	DOWNSTREAM T	UNKNOWN	USFWS-IMI	########	Picacho NV	11	716389	
E COLORADO	RIVER BETWEEN	LAGUNA AND I	FEWER TH/	BLM, USBC	########	Laguna Dar	11	735447	
E POLYGON	GROWING	Mining	MINING AC	W POLYGO	BLM?	########	Ogilby (321	11	706926
EXACT LOC	GRAVELLY	SLOPES AND RUNNEL-I	MAIN SOUI	BLM	########	Ogilby (321	11	702214	
ALONG RO.	LOW TOTAL	COVER (<5%) IN SMA	FEWER TH/	BLM	########	Hedges (32	11	706948	
NEAR RAILI	ROCKY WASH	CHANNEL. CREOSOT	ONLY SOUI	BLM	########	Ogilby (321	11	699398	
EXACT LOC	IN SMALL	GULLIES.	SITE KNOW	BLM	########	Hedges (32	11	704289	
MAPPED BY	CNDDB AS	BEST GUESS ABOUT 4.	SITE BASEI	BLM	########	Cactus (321	11	697500	
MAPPED ABOUT	2 MILES	EAST OF RADIO FAC	ONLY SOUI	BLM	########	Quartz Pea	11	706387	
MAPPED B'	FOUND WI	Other	THREATEN	992 PLANT	BLM	########	Mt. Barrow	11	697546
MAPPED 5	OPEN DESERT.		ONLY SOUI	BLM	########	East of Aco	11	686212	
SS ROAD, 7.	ALONG WATER	COURSES WITH OI	MAPPED B/	BLM	########	Quartz Pea	11	707285	
JUST E OF I	SAGUAROS	Developme	OHV, TARG	3 LIVING PI	BLM	########	Laguna Dar	11	734925
SPECIMEN	GROWING IN	A DEEP WASH WITH	1 PLANT OI	BLM	########	Buzzards P	11	709092	
MAPPED A'	GROWING	ORV activit	POSSIBLY T	1 LARGE PL	BLM	########	Mt. Barrow	11	695965
SPECIMEN	GROWING IN	A DESERT PAVEMEN	1 PLANT OI	BLM	########	Palo Verde	11	700267	
SITE MAPP	CREOSOTE	BUSH SCRUB. ON ROCKY	SUBSTRA	BLM	########	Palo Verde	11	707012	
EXACT LOCATION	UNKNOWN.	MAPPED BY CI	ONLY SOUI	BLM	########	In-ko-pah (	11	592422	
EXACT LOCATION	UNKNOWN.	MAPPED BY CI	ONLY SOUI	UNKNOWN	########	Carrizo Mtı	11	592121	
INCLUDES /	SONORAN	DESERT. ASSOCIATED V	UNKNOWN	BLM	########	Carrizo Mtı	11	591194	
EXACT LOC	CREOSOTE	ORV activit	OHV, TARG	SITE BASEI	BLM	########	Painted Go	11	595088
MAPPED A	FAIRLY OPE	Other | Fo	TRAMPLIN	5 PLANTS S	BLM	########	In-ko-pah (	11	585041
MAPPED ALONG	I-8 IN THE	VICINITY OF MOU	APPARENT	DPR-ANZA-	########	In-ko-pah (	11	583784	
EXACT LOC	STEEP ROCKY	HILL.	MAIN SOUI	UNKNOWN	########	In-ko-pah (	11	584322	
SCATTERE	SCRUB OAK	WOODLAND/CHAPAR	MAIN SOUI	UNKNOWN	########	In-ko-pah (	11	584524	

EEC ORIGINAL PKG

MAPPED B' STEEP WALLED CANYON WITH SAI	MENTIONE	BLM	########	Carrizo Mtı	11	591377
ON DIRT ROAD.	ONLY SOUI	UNKNOWN	########	Mount Sigr	11	627488
EXACT LOC GRAVELLY SLOPES ON NORTH BAI	PRIMARY S	DPR-ANZA-	########	In-ko-pah (	11	583784
VOLCANIC FLATS SOUTH OF PINTO WASH. EX	OCCURREN	UNKNOWN	########	Yuha Basin	11	615378
LOPE OF CARRIZO MOUNTAIN.	ONLY SOUI	UNKNOWN	########	Carrizo Mtı	11	592121
MAPPED B' STEEP WALLED CANYON WITH SAI	PLANTS ME	BLM	########	Carrizo Mtı	11	591377
UNABLE TC IN SANDY WASH.	ONLY SOUI	UNKNOWN	########	Carrizo Mtı	11	592495
IRRIGATION DRAIN BETWEEN IMPERIAL STAT	TRAPPING	DFG-IMPEF	########	Niland (331	11	630802
ISOLATED 1 SHORELINE Non-native	NON-NATI\	19,940 FRY	UNKNOWN	########	Palo Verde	11	714155
BACKWATE SUBSTRATE Non-native	SPECIES M/	59,461 FRY	USFWS-IMI	########	Picacho NV	11	715312
MEANDERI DEPTH, 0.2 Non-native	NON-NATI\	94,848 FRY	USFWS-IMI	########	Picacho (33	11	725386
2002 LOCA HABITAT CONSISTS OF CREOSOTE	1 ADULT FE	DPR-OCOTI	########	Kane Spring	11	598659
LOCATIONS STATED AS: MVZ, "COYOTE WELL	MUSEUM (	UNKNOWN	########	Coyote We	11	597024
MAPPED A(CREOSOTE - WHITE BU SOME OFFI	SDNHM #S	PVT	########	Harpers W(	11	598604
FOUND ON SANDY SHOULDER OF HIGHWAY.	MUSEUM S	UNKNOWN	########	Frink (3311	11	618195
SCAT FOUN MOST OF THE HABITAT ALONG TH	ABUNDAN(	BLM	########	Grays Well	11	692376
SCAT FOUN MOST OF THE HABITAT ALONG TH	ABUNDAN(	BLM	########	Grays Well	11	701707
ROCK HILL, HABITAT C(ORV activit THREATEN	ESTIMATEI	USFWS-SOI	########	Niland (331	11	628583
ROCK HILL, HABITAT C(ORV activit THREATEN	ESTIMATEI	USFWS-SOI	########	Niland (331	11	628583
ROCK HILL, HABITAT C(ORV activit THREATEN	ESTIMATEI	USFWS-SOI	########	Niland (331	11	628583
GATED MIN HABITAT C(Mining | O POSSIBLE T	3 BANDED	BLM	########	Hedges (32	11	703297
1990 OBS N HABITAT C(Mining | O RENEWED	14 BANDEI	BLM	########	Hedges (32	11	703890
THE WORK HABITAT SI Landfill | R POSSIBLE D	~125 COUN	DOD-CHOC	########	Blue Moun	11	680957
EXACT LOCATION UNKNOWN. COORDINATES	3 MALE SPI	PVT-SDGE,	########	Palo Verde	11	710433
NORTH OF T HABITAT CONSISTS OF A FLOODEI	4 ADULT M	UNKNOWN	########	Palo Verde	11	710881
	COLLECTIO	UNKNOWN	########	Niland (331	11	638042
	ONE FROG	UNKNOWN	########	Holtville W	11	651477
), BETWEEN EL CENTRO AND HOLTVILLE.	TWO FROG	UNKNOWN	########	Holtville W	11	645375
ES NORTH OF WINTERHAVEN.	TWO FROG	UNKNOWN	########	Araz (3211	11	721284
MAPPED IN THE VICINITY OF WALTERS CAMP	ONE FROG	USFWS-CIB	########	Picacho NV	11	715522
EXACT LOCATION UNKNOWN. MAPPED BY CN	ONLY SOUI	UNKNOWN	########	Calexico (3	11	641015
FREEMAN I SANDY ARROYO WITH DESERT PA\	UNCOMM(	DPR-OCOTI	########	Seventeen	11	586673
EXACT LOCATION UNKNOWN. MAPPED BY CN	ONLY SOUI	UNKNOWN	########	Calexico (3	11	641015
MAPPED BY CNDDB AS BEST GUESS AROUND	TYPE LOCA	UNKNOWN	########	Heber (321	11	637770
"STREETS OF BRAWLEY."	ONLY SOUI	UNKNOWN	########	Brawley (3	11	637820
EXACT LOC OLD BEACH.	ONLY SOUI	UNKNOWN	########	Bonds Corr	11	653162
MAPPED B' MOST CON ORV activit ORV ACTIV	SEEN IN 19	BLM	########	Glamis (32	11	682852
EXACT LOCATION UNKNOWN, MAPPED AS BE	SITE BASEI	UNKNOWN	########	Ogilby (321	11	702138
).	SITE BASEI	UNKNOWN	########	Holtville W	11	645375
EXACT LOC DUNES. GROWING WITH A FEW G	SITE BASEI	BLM	########	Glamis (32	11	677380
MAPPED IN MOST OF SOUTH HALF OF SW1/4	ONLY SOUI	UNKNOWN	########	Tortuga (33	11	656207
EXACT LOCATION UNKNOWN. MAPPED FRON	ONLY SOUI	UNKNOWN	########	Kane Spring	11	609056
EXACT LOCATION UNKNOWN. MAPPED AS BE	ONLY SOUI	UNKNOWN	########	Midway W(	11	685952
EXACT LOCATION UNKNOWN. MAPPED BY CN	ONLY SOUI	UNKNOWN	########	In-ko-pah (	11	583784
LOCALITY S HABITAT C(ORV activit VEHICLES T	29 JUN 20(	UNKNOWN	########	Painted Go	11	599180
4 LIZARDS \ CREOSOTE ORV activit OHV AREA, 1	OBSERVE	BLM	########	Grays Well	11	706421
1.7 MI EAS AGRICULTU Non-native 2001: "...M	10 FOUND	PVT-IMPER	########	Kane Spring	11	614944

EEC ORIGINAL PKG

CAS LOCAL	DESERT SU	ORV activit	OHV ACTIV	24 DETECT	DPR-OCOT	########	Shell Reef (	11	587932
WEST OF C	DESERT ERIOGONUM WASH, W/ A		1 ADULT O	DPR-OCOT	########	Kane Spring	11	594402
D OF SALTON SEA, RIVERSIDE COUNTY.			COLONY A	UNKNOWN	########	Salton (331	11	594849
NIGHT-ROOST.			UNKNOWN	UNKNOWN	########	Palo Verde	11	717794
9 INDIVIDU	HABITAT C	ORV activit	THREATS IN	1 ADULT O	BLM	########	Grays Well	11	708661
72 BELT TR	HABITAT C	ORV activit	THREATEN	1 JUVENILE	BLM	########	Glamis (32	11	676568
B MESA, 1.6	HABITAT C	ORV activit	THREATS C	1 ADULT O	BLM	########	Grays Well	11	708190
END OF SALTON SEA AT MOUTH OF NEW RIV			1954: 1ST I	USFWS-SO	########	Calipatria S	11	621609
NO SPECIFIC LOCATIOI	Developme	THREATEN	8 ADULT O	UNKNOWN	########	Calexico (3	11	648700
BURROW IS LOCATED	Agriculture	THREATEN	1 ADULT AI	UNKNOWN	########	Heber (321	11	633718
BURROW IS	BURROW IS	Agriculture	THREATEN	1 ADULT AI	UNKNOWN	########	Brawley NV	11	623134
BURROW IS	BURROW IS LOCATED ALONG A CA		2 JUVENILE	UNKNOWN	########	Heber (321	11	631973
OF DELIVER	BURROW IS LOCATED		THREATEN	2 ADULTS A	UNKNOWN	########	Heber (321	11	631165
OUTH OF SC	BURROW IS LOCATED		THREATEN	2 ADULTS A	UNKNOWN	########	Calexico (3	11	650436
8 INDIVIDU	HABITAT C	ORV activit	THREATS IN	1 ADULT O	BLM	########	Grays Well	11	707048
6 INDIVIDU	CREOSOTE	ORV activit	PIPELINE C	ONE DEAD	BLM	########	Grays Well	11	704747
SE OF THE JI	CREOSOTE	ORV activit	PIPELINE C	ONE ADUL	BLM	########	Ogilby (321	11	703430
DAVIS ROAD, VICINITY	Other	IN 1987 TH	2 FOUND D	UNKNOWN	########	Wister (331	11	632294
MAPPED AT THE LAT/ LONG COORDINATES G			MVZ EGG S	UNKNOWN	########	El Centro (3	11	630495
ST OF EL CENTRO.			SBCM EGG	UNKNOWN	########	Holtville W	11	646782
NORTHEAST OF WESTMORELAND.			SBCM EGG	UNKNOWN	########	Westmorla	11	632850
BURROW IS	HABITAT SURROUNDIN	POSSIBLE T	1 ADULT O	UNKNOWN	########	Heber (321	11	636564
SITE CONSI	BURROW SITES ARE LOCATED IN A		ON 2 JUN 2	PVT	########	Seeley (321	11	628010
N ROAD AT	BURROW SITES ARE LOCATED IN A		1 ADULT O	UNKNOWN	########	Mount Sigr	11	627507
THE S POLY	BURROW SITES ARE SURROUNDE		8 ADULTS A	PVT	########	Mount Sigr	11	628329
BURROW L	BURROW SITES ARE SURROUNDE		1 ADULT AI	UNKNOWN	########	Heber (321	11	629270
SOUTHERN	SOUTHERN POLYGON: BURROW S		1 ADULT O	UNKNOWN	########	Heber (321	11	629308
BURROWS	BURROW SITES ARE SURROUNDE		4 ADULTS (	PVT	########	El Centro (3	11	629420
BURROWS	BURROW SITES ARE SURROUNDE		8 ADULTS A	PVT	########	El Centro (3	11	630204
BURROW L	BURROW SITES ARE SURROUNDE		2 ADULTS (	PVT	########	El Centro (3	11	629069
OF ALGODO	HABITAT CONSISTS OF PALOVERD		ONE OBSEF	BLM	########	Acolita (33	11	672023
OF ALGODONES DUNES, 0.4 MILE SOUTHWEST			ONE WINTI	BLM	########	Acolita (33	11	671643
OF ALGODONES DUNES, ABOUT 2 MILES SOUT			ONE WINTI	UNKNOWN	########	Acolita (33	11	670272
OF ALGODONES DUNES, ABOUT 1.3 MILES SW			WINTERIN(	UNKNOWN	########	Amos (331	11	663022
ATE ROUTE 115 BETWEEN ORANGE LATERAL D			BIRD OBSE	UNKNOWN	########	Alamorio (3	11	648981
EADOWS UNION SCHOOL, ALONG ACACIA LA			BIRD OBSE	UNKNOWN	########	Holtville W	11	642894
FIELD WITH	RECENTLY BURNED HAYFIELD AFT		2001: 1/21	PVT	########	Westmorla	11	630217
EXACT LOCATION UNKNOWN. MAPPED BY CN			SITE BASEI	DOD-NAVY	########	Superstitio	11	609382
1970'S DAT	DIKED PONDS, MARSHLANDS, ANI		OBSERVED	USFWS-SO	########	Obsidian B	11	627151
MAPPED T(	HABITAT C	Non-native	POSSIBLY T	3 ADULTS (	DPR-ANZA-	########	Carrizo Mtı	11	583041
EXACT LOCATION UNKNOWN, SOURCE LISTS			ONLY SOUI	BLM	########	Glamis NW	11	674697
L, 11 MILES EAST OF NILAND.			ONLY SOUI	DOD-CHOC	########	Lion Head I	11	655367
LOCATION	HABITAT C	Nest parasi	BROWN-HE	2003: AT LE	USFWS-IM	########	Imperial Re	11	733589
LOCATED B	HABITAT C	Nest parasi	COWBIRDS	2 SINGING	USBOR, DP	########	Picacho (33	11	722779
SE 1/4 OF S	HABITAT C	Other	THREATEN	1 ADULT M	USBOR, DP	########	Picacho SW	11	720987
OVE LAGUNA DAM.			2 MALES A	USBOR, BLI	########	Laguna Dar	11	734620
MAPPED LOCATION CENTERED AT SILSBEE SC			MALE COLL	UNKNOWN	########	Seeley (321	11	627562

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LOCATION MAPPED IN THE SENATOR WASH A	FEMALE CC	USBOR	########	Imperial Re	11	734727
LOCATION GIVEN AS "ALAMO DUCK PRESERV	MALE COLL	DFG-IMPEF	########	Niland (331	11	631199
MAPPED ACCORDING TO LAT/LONG GIVEN B'	MVZ #9095	UNKNOWN	########	Wiley Well	11	686567
AREA MAPPED TO INCLUDE PALO VERDE AND	MVZ #2140	UNKNOWN	########	Palo Verde	11	710576
EXACT LOC STONY DESERT SLOPES.	MAIN SOU	UNKNOWN	########	In-ko-pah G	11	584496
MAPPED ACCORDING TO LAT/LONG GIVEN B'	MVZ #1060	UNKNOWN	########	Picacho NV	11	714441
MAPPED ACCORDING TO LAT/LONG GIVEN B'	FEMALE CC	UNKNOWN	########	Wiley Well	11	686563
	UNIVERSIT'	UNKNOWN	########	Calexico (3	11	641015
LOCATION MAPPED JUST SOUTH OF INTERST/	LACM #673	BLM	########	Coyote We	11	602266
LOCALE STATED AS "BARD."	1 COLLECTI	UNKNOWN	########	Bard (3211	11	729107
LOCATION MAPPED IN VICINITY OF WHERE M	2 COLLECTI	UNKNOWN	########	Bard (3211	11	729610
LOCATION MAPPED NW OF THE JUNCTION OI	1 COLLECTI	UNKNOWN	########	Araz (3211	11	719575
V OF GLAMIS.	ORIGINAL I	BLM	########	East of Aco	11	675848
V OF GLAMIS.	ALLOTYPE I	BLM	########	East of Aco	11	675848
V OF GLAMIS.	HOLOTYPE	BLM	########	East of Aco	11	677109
1 MILE WEST OF GLAMIS.	4 MALE PA	BLM	########	Glamis (321	11	679398
EST OF GLAMIS.	259 MALE I	UNKNOWN	########	Glamis (321	11	676732
NW OF GLAMIS.	6 MALE PA	BLM	########	East of Aco	11	675102
WEST OF GLAMIS.	ONE MALE	BLM	########	Amos (331	11	662290
UNTAIN, 21 KM NE OF GLAMIS.	COLLECTIO	BLM	########	Quartz Pea	11	700949
F SMUGGLERS CAVE EAST OF JACUMBA.	ONE MALE	BLM, UNKN	########	In-ko-pah G	11	585106
EXACT LOCATION UNKNOWN. MAPPED BY CN	LOCATION	DPR-PICAC	########	Picacho Pe	11	721330
/ASH, 0.7 R(	IN GRANITIC SANDS OF WASH. AS	MENTIONE	UNKNOWN	########	Quartz Pea	11	708556
MAPPED ACCORDING TO THE FOLLOWING T-	LARGE ARE	BLM	########	Chuckwalla	11	670683
EXACT LOCATIONS NOT GIVEN. MAPPED IN TI	COLLECTED	UNKNOWN	########	Brawley (32	11	637820
EXACT LOCATION UNKNOWN. MAPPED IN TH	ONE FEMA	UNKNOWN	########	Calexico (3	11	641015
EXACT LOCATION NOT GIVEN. MAPPED IN TH	ALL SPECIM	UNKNOWN	########	El Centro (3	11	634594
NON-SPECIFIC LOCALE, THUS MAPPED TO LAT	ONE MALE	UNKNOWN	########	Heber (321	11	637770
MAPPED AT THE LAT-LONG COORDINATES GI	ONE MALE	UNKNOWN	########	El Centro (3	11	630512
EXACT LOCATION UNKNOWN. MAPPED IN TH	ALL MVZ: 1	UNKNOWN	########	Holtville W	11	651477
EXACT LOCATION NOT GIVEN. MAPPED IN TH	2 FEMALE S	UNKNOWN	########	El Centro (3	11	633887
EXACT LOCATION UNKNOWN. MAPPED IN TH	3 MALE SPI	UNKNOWN	########	Westmorla	11	628845
LOCATION NOT SPECIFIC, MAPPED ACCORDIN	ONE MALE	UNKNOWN	########	Picacho NV	11	714441
EXACT LOCATION NOT GIVEN. LOCATION ONL	ONE MALE	UNKNOWN	########	El Centro (3	11	634594
IILES SSW OF POTHOLES ALONG THE COLORAI	1 FEMALE S	UNKNOWN	########	Bard (3211	11	731265
EXACT LOCATION NOT KNOWN. MAPPED IN T	21 F & 24 M	BLM, UNKN	########	In-ko-pah G	11	585106
EXACT LOCATION NOT KNOWN. MAPPED IN T	A:1F 12 MA	DPR-ANZA-	########	In-ko-pah G	11	583784
EXACT LOCATION NOT KNOWN. MAPPED AS I	4 FEMALES	UNKNOWN	########	Wiley Well	11	695997
MVZ LOCATION GIVEN AS "20 MI N PACACHC	NEST PLUS	UNKNOWN	########	Picacho NV	11	715543
LAND.	HISTORICA	UNKNOWN	########	Westmorla	11	628845
V OF GLAMIS.	ONE FEMA	BLM	########	East of Aco	11	675848
MAPPED B'	SPARSE CREOSOTE BUSH SCRUB II	OCCURREN	BLM	########	Painted Go	11	596171
RAINBOW :	CREOSOTE	ORV activit	OHV RECRE	1 OBSERVE	DPR-OCOTI	########	Kane Spring	11	594037
RAINBOW :	CREOSOTE	ORV activit	OHV RECRE	ONE ADUL	DPR-OCOTI	########	Kane Spring	11	595022
AROUND 8	DESERT PAVEMENT/DESERT WASI	1991 LARU	BLM	########	Hedges (32	11	707383
IN THE NW	STRINGER \	ORV activit	THREATEN	10 PLANTS	BLM	########	Hedges (32	11	699726
AIR MILE N	FOUND WI	ORV activit	THREATEN	84 PLANTS	BLM	########	Hedges (32	11	700606

EEC ORIGINAL PKG

IN THE SE 1	OPEN ROCI	ORV activit	THREATEN	91 PLANTS	BLM	########	Hedges (32	11	701986
SOUTH ED(	FOUND WI	ORV activit	THREATEN	2 PLANTS S	BLM	########	Hedges (32	11	701852
NE 1/4 OF	FOUND WI	ORV activit	THREATEN	5 PLANTS S	BLM	########	Hedges (32	11	701643
EAST EDGE	FOUND WI	ORV activit	THREATEN	56 PLANTS	BLM	########	Hedges (32	11	701088
IN THE SE 1	FOUND WI	ORV activit	THREATEN	5 PLANTS C	BLM	########	Hedges (32	11	700188
NW 1/4 OF	FOUND WI	ORV activit	THREATEN	304 PLANT	BLM	########	Hedges (32	11	699895
SE 1/4 OF S	FOUND WI	ORV activit	THREATEN	36 PLANTS	BLM	########	Quartz Pea	11	698540
MAPPED A	WASH WITH SANDY SOIL ON FLAT	SITE BASEC			BLM	########	Ninemile W	11	695822
2 POLYGON	STRINGER \	ORV activit	THREATEN	13 PLANTS	BLM	########	Ninemile W	11	696030
IN THE SW	FOUND WI	ORV activit	THREATEN	22 PLANTS	BLM	########	Ninemile W	11	695844
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	595782
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	597944
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	598754
EAST OF SIDE OF ROAI	ORV activit	THREATEN	<20 PLANT	BLM	########	Ninemile W	11	695707	
SAN FELIPE	HABITAT C(	ORV activit	OHV RECRE	1 ADULT C(	DPR-OCOTI	########	Kane Spring	11	598321
ES ESE OF I	FOUND WI	ORV activit	THREATEN	38 PLANTS	BLM	########	Ninemile W	11	695724
IN THE NE :	FOUND WI	ORV activit	THREATEN	40 PLANTS	BLM	########	Ninemile W	11	695928
EAST SIDE OF ROAD, A	ORV activit	THREATEN	1 PLANT SE	BLM	########	Buzzards P(	11	698148	
MAPPED A	HABITAT C(	ORV activit	OHV RECRE	1 ADULT C/	DPR-OCOTI	########	Kane Spring	11	601278
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	602263
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	601332
IN THE SE 1	STRINGER \	ORV activit	THREATEN	15 PLANTS	BLM	########	Hedges (32	11	699529
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	598112
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	601044
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	602202
EXACT LOC	WASH WOODLAND WITH OLNEYA	1978 LATTI			UNKNOWN	########	Ogilby (321	11	702396
IN WASHES	EDGES OF SMALL WASHES ON RO	180 PLANT	BLM	########	Mt. Barrow	11	695052		
MAPPED IN	OPEN, SANDY, ILL-DEFINED WASH	1999 TAYL(			UNKNOWN	########	Chuckwalla	11	669171
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	602097
MAPPED A	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	600306
LOCATION	CREOSOTE SCRUB, TABULAR SANI	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	595818
LOCATION	HABITAT C(	ORV activit	OHV RECRE	2 ADULTS (	DPR-OCOTI	########	Kane Spring	11	597545
LOCATION	HABITAT IN AREA CON	OHV TRACI		2 ADULTS (	DPR-OCOTI	########	Kane Spring	11	601702
SAN FELIPE	CREOSOTE	ORV activit	OHV RECRE	1 ADULT C/	DPR-OCOTI	########	Kane Spring	11	600640
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	597140
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	596447
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	597612
ALONG FOI	HABITAT CONSISTS OF CREOSOTE	2 ADULTS (			DPR-OCOTI	########	Kane Spring	11	602603
MAPPED T(	2003: CREOSOTE SCRUB ON SUBS	1 MALE AD			DPR-OCOTI	########	Kane Spring	11	595285
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	595053
LOCATION	CREOSOTE SCRUB, AEOLIAN SANI	1 JUVENILE			DPR-OCOTI	########	Kane Spring	11	594031
LOCATION	HABITAT C(	ORV activit	OHV RECRE	8 ADULTS ‡	DPR-OCOTI	########	Kane Spring	11	594071
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR-OCOTI	########	Kane Spring	11	594072
LOCATION	HABITAT C(	ORV activit	OHV RECRE	3 ADULTS (	DPR-OCOTI	########	Kane Spring	11	594686
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR	########	Shell Reef (	11	586791
LOCATION	CREOSOTE	ORV activit	OHV RECRE	1 CAUGHT	DPR-OCOTI	########	Shell Reef (	11	587828
LOCATION	HABITAT CONSISTS OF CREOSOTE	1 ADULT C/			DPR	########	Shell Reef (	11	588996

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ARRAY 16,	2002: MED	ORV activit	OHV RECRE	1	MALE AN	DPR-OCOTI	########	Shell Reef (	11	590126
LOCATION	HABITAT CONSISTS OF	CREOSOTE	1	ADULT C/	DPR	########	Shell Reef (	11	589972	
LOCATION	HABITAT CI	ORV activit	OHV RECRE	1	ADULT C/	DPR-OCOTI	########	Shell Reef (	11	591388
MAPPED A	2002: CREC	ORV activit	VEHICLE CC	1	MALE AD	BLM	########	Shell Reef (	11	592050
LOCATION	HABITAT CONSISTS OF	CREOSOTE	1	ADULT C/	DPR-OCOTI	########	Shell Reef (	11	592289	
RAINBOW '	CREOSOTE	ORV activit	OHV RECRE	1	ADULT C/	DPR-OCOTI	########	Shell Reef (	11	592512
ALONG THI	HABITAT CI	ORV activit	OHV RECRE	1	ADULT FE	DPR-OCOTI	########	Shell Reef (	11	589980
EXACT LOC	MUD HILLS	ORV activit	POSSIBLY T	1	FEMALE (	DPR-OCOTI	########	Shell Reef (	11	592298
LOCATION	HABITAT CONSISTS OF	OHV TRACI	1	ADULT C/	DPR, BLM	########	Shell Reef (	11	592430	
1998 DETE	CREOSOTE SCRUB, LAK	OHV TRACI	4	LIZARDS (	DPR-OCOTI	########	Shell Reef (	11	590546	
LOCATION	HABITAT CONSISTS OF	CREOSOTE	1	ADULT C/	DPR-OCOTI	########	Shell Reef (	11	589896	
PLOT 4 IN 1	CREOSOTE SCRUB AND GRAVEL O	3	FLAT-TAII	DPR-OCOTI	########	Shell Reef (	11	591722		
LOCATION	HABITAT CONSISTS OF	CREOSOTE	1	ADULT C/	DPR-OCOTI	########	Shell Reef (	11	586255	
LOCATION	HABITAT CI	ORV activit	OHV RECRE	3	ADULTS (	DPR-OCOTI	########	Shell Reef (	11	588596
MAPPED BY	CNDDB AS BEST GUESS AROUND	NOTE IN 2(	SDG COUN	########	In-ko-pah (	11	583470			
WHERE Z D	AGRICULTU	Non-native	NON-NATI\	0	FOUND II	PVT-IMPER	########	Wister (33:	11	630185
MOUTH OF	AGRICULTU	Non-native	NON-NATI\	UP TO 5 AI	PVT-IMPER	########	Calipatria S	11	618004	
WHERE TRI	AGRICULTU	Non-native	NON-NATI\	1	ADULT &	PVT-IMPER	########	Calipatria S	11	622021
WHERE O I	AGRICULTU	Non-native	NON-NATI\	1	ADULT &	PVT-IMPER	########	Niland (331	11	631630
MAPPED W/	RESPECT TO 1951 CIBOLA 15-MI	GRINNELL I	UNKNOWN	########	Cibola (331	11	712695			
MAPPED B'	SANDY/SIL	ORV activit	HEAVY OH\	11	PLANTS	BLM	########	Kane Spring	11	595614
IE NEW RIV	OLD DATE I	Developme	SITE PROP(	THIS HAS B	PVT	########	Brawley (3:	11	635130	
WASH SOU	DESERT W/	ORV activit	OFF-ROAD	1	ADULT O	BLM	########	Hedges (32	11	699897
WEEN CHOI	DESERT W/	ORV activit	OFF-ROAD	2	ADULTS (	BLM	########	Ninemile W	11	696606
T OF STATE	DESERT W/	ORV activit	OFF-ROAD	2	ADULTS (	BLM	########	Ninemile W	11	697106
H ABOUT 1.	DESERT W/	ORV activit	OFF-ROAD	1	ADULT O	BLM	########	Thumb Pea	11	708084
/ASH WEST	BRAIDED W	ORV activit	ORV USE A	1	ADULT O	UNKNOWN	########	Buzzards P(	11	698832
DGE OF IMI	MICROPHYLL WOODL/	ORV USE A	1	FEMALE (	BLM	########	Clyde (321:	11	687852	
TOAD FOU	DESERT SCRUB ON HIGH SLOPE RU	1	TOAD FO	BLM	########	Palo Verde	11	709435		
SOME MUSEUM LOCATIONS GIVEN AS "WASI	MVZ #2718	UNKNOWN	########	Harpers W(	11	602064				
MUSEUM I	THIS LOCATION IS WITHIN THE MA	MVZ #2785	UNKNOWN	########	Harpers W(	11	599972			
BOTH ADULTS AND TADPOLES COLLECTED. M	MVZ #4941	BLM	########	Imperial Re	11	736514				
MVZ RECORD GIVES LOCATION AS "1.5 MI W	MVZ #3297	UNKNOWN	########	Wister (33:	11	635958				
MAPPED ACCORDING TO THE LAT-LONG GIVE	MVZ #1058	UNKNOWN	########	Seeley (321	11	624462				
MVZ RECORD GIVES LOCATION AS "20 MI S P/	MVZ #1202	BLM	########	Picacho NV	11	712599				
WEST OF GL	COLLECTED BY SWEEPING FLOWE	IN SPITE OI	UNKNOWN	########	Glamis NW	11	669467			
GENERAL L	25% GOODDING WILLOW, 30% CC	1	RESIDENT	BLM	########	Picacho NV	11	716042		
2004 SURV	40% WILLC	Nest parasi	COWBIRDS	1	RESIDENT	BLM	########	Picacho SW	11	720857
MAPPED T(	DENSE TAN	Nest parasi	COWBIRDS	1	PAIR & 1	BLM	########	Picacho NV	11	715906
				1	MALE SPI	UNKNOWN	########	Calexico (3	11	641015
EXACT LOCATION UNKNOWN. MAPPED ALON	1	MALE SPI	UNKNOWN	########	Picacho NV	11	714692			
EXACT LOCATION UNKNOWN. MAPPED IN TH	1	FEMALE S	BLM	########	Glamis (32:	11	679398			
MAPPED ACCORDING TO LAT/LONG COORDI	1	MALE & 1	UNKNOWN	########	Kane Spring	11	608456			
EXACT LOCATION UNKNOWN. MAPPED IN TH	1	MALE SPI	PVT-SDGE,	########	Palo Verde	11	710433			
EXACT LOCATION UNKNOWN. MAPPED IN TH	1	MALE CO	UNKNOWN	########	Picacho NV	11	716397			
SHAFT & AI	NIGHT ROOST FOR ANTROZOUS P.	6	INDIVIDU	UNKNOWN	########	Hedges (32	11	703327		
SHAFT & AI	MATERNITY COLONY FOR MACRO	45	INDIVID	UNKNOWN	########	Hedges (32	11	703327		

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LOCATION GIVEN AS "TURTLE" MINE IN SECTI	GUANO AN	UNKNOWN	########	Buzzards P	11	708103
SHAFT OMR 13328 IN NW 1/4 OF SECTION 36	1 BAT OBSI	UNKNOWN	########	Hedges (32	11	703316
SMALL, UN NARROW PENINSULA COMPOSED	40-50 GULI	PVT-IMPER	########	Obsidian B	11	626678
, 13 KM EAST OF SIPHON 10 OF COACHELLA C	1 MALE SPI	UNKNOWN	########	Lion Head I	11	655418
	1 MALE SPI	UNKNOWN	########	Calexico (3	11	641015
, 13 KM EAST OF SIPHON 10 OF COACHELLA C	1 MALE SPI	UNKNOWN	########	Lion Head I	11	655418
EXACT LOCATION UNKNOWN. MAPPED AS BE	1 FEMALE S	PVT-SDGE,	########	Palo Verde	11	710433
MAPPED ACCORDING TO T-R-S DATA PROVID	INDIVIDUA	UNKNOWN	########	Hedges (32	11	706316
MAPPED ACCORDING TO T-R-S DATA PROVID	INDIVIDUA	UNKNOWN	########	Hedges (32	11	706316
MOUNTAINS, NORTH OF Recreation CLOSE TO \	OUTFLIGHT	BLM	########	Bard (3211	11	733439
BOY MINE. CARGO MUCHACHO MOUNTAINS	MAINLY W	UNKNOWN	########	Ogilby (321	11	708635
MARY LODE MINE #2, WEST ADIT.	A FEW IND	DOD-CHOC	########	Blue Moun	11	680957
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Iris Wash (3	11	643950
MAPPED ACCORDING TO UTM COORDINATES	ROOST SITI	DOD-CHOC	########	Iris Wash (3	11	643950
MAPPED ACCORDING TO UTM COORDINATES	NIGHT ROC	DOD-CHOC	########	Lion Head I	11	652824
MAPPED ACCORDING TO UTM COORDINATES	ROOST SITI	DOD-CHOC	########	Lion Head I	11	652824
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Lion Head I	11	652824
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Lion Head I	11	652824
MAPPED ACCORDING TO UTM COORDINATES	ROOST SITI	UNKNOWN	########	Ninemile W	11	692695
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Lion Head I	11	661614
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Iris Wash (3	11	640100
MAPPED ACCORDING TO UTM COORDINATES	FORAGING	DOD-CHOC	########	Iris Wash (3	11	640100
EXACT LOCATION UNKNOWN. CANNOT LOCA	ONLY SOUI	UNKNOWN	########	Heber (321	11	631561
MAPPED A DISTURBEI Developme	RESIDENTIA	UNOCCUPI	UNKNOWN	########	El Centro (3	11	634766
MAPPED ACCORDING Agriculture	FURTHER A	BURROW S	UNKNOWN	########	El Centro (3	11	640327
E OF THE AI HABITAT CONSISTS OF ARROW W	2 ADULT M	PVT-IMPER	########	Midway W	11	667688
OF EAST HI HABITAT CONSISTS OF TAMARISK	2 NON-REP	PVT-IMPER	########	Holtville Ea	11	660724
SOUTH OF T HABITAT CONSISTS OF ARROW W	4 NON-REP	PVT-IMPER	########	Midway W	11	670324
MAPPED T HABITAT C Agriculture	THREATS IN	5 NON-BRE	PVT-IMPER	########	Holtville Ea	11	659318
SOUTH OF T HABITAT CONSISTS OF CREOSITE E	1 NON-REP	PVT-IMPER	########	Brawley NV	11	623873
1903 USNM 2007 HABITAT CONSISTED OF DEN	2 MALES &	PVT-IMPER	########	Yuma West	11	714045
MAPPED LOCATION CENTERED AT SILSBEE SC	MVZ #8102	UNKNOWN	########	Seeley (321	11	627562
LOCALE STATED AS "BARD."	4 SPECIME	UNKNOWN	########	Bard (3211	11	729107
MILES SW OF PALO VERDE.	MVZ #3074	BLM, UNKN	########	Palo Verde	11	709193
THE BURRC DEVELOPM Developme	AREA TO TI	A PAIR OF I	PVT	########	El Centro (3	11	635233
THE BURRC DEVELOPM Developme	AREA TO TI	2 PAIRS OF	PVT	########	El Centro (3	11	635408
ON IMPERI DEVELOPM Developme	SITE MAY B	A PAIR OF I	UNKNOWN	########	El Centro (3	11	632412
ON IMPERI DEVELOPM Developme	SITE MAY B	A PAIR OF I	UNKNOWN	########	El Centro (3	11	631628
ER OF THE INTERSECTIC Road/trail (	THREATEN	A BUOW P/	UNKNOWN	########	Calexico (3	11	640613
THE IMPERIAL IRRIGATION DISTRICT MONITO	# OF ACTIV	PVT-IMPER	########	El Centro (3	11	636672
MAPPED A HABITAT DESCRIBED AS DISTURBE	1 OVER-WI	UNKNOWN	########	Iris (331152	11	640388
MAPPED A HABITAT D Over-collec	THREATEN	AT LEAST 3	UNKNOWN	########	Wister (331	11	632520
MAPPED A HABITAT D Over-collec	THREATEN	AT LEAST 3	UNKNOWN	########	Wister (331	11	631688
EXACT LOCATION UNKNOWN, BUT IT SEEMS I	IN JUN 196	BLM	########	Imperial Re	11	736739
EXACT LOC LOW DESERT SCRUB, SANDY SOIL.	ONLY SOUI	BLM	########	Ogilby (321	11	706984
MAPPED B SMALL POPULATION GROWING IN	ONLY SOUI	UNKNOWN	########	In-ko-pah (	11	592268
EXACT LOCATION UNKNOWN. LOCATION DES	ONLY SOUI	UNKNOWN	########	Yuha Basin	11	615378

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MAPPED A	SPARSELY VEGETATED GRAVELLY	MAIN SOU	BLM	########	Hedges (32	11	702274
V OF NILAN	HABITAT C	Developme	THREATEN	ACTIVE BU	UNION PAC	########	Wister (33	11	629122
V OF NILAN	HABITAT C	Developme	THREATEN	ACTIVE BU	UNION PAC	########	Wister (33	11	633164
BLOCK COL	HABITAT C	Developme	THREATEN	ACTIVE BU	PVT	########	Wister (33	11	636188
V OF NILAN	HABITAT C	Developme	THREATEN	ACTIVE BU	UNION PAC	########	Wister (33	11	636881
V OF NILAN	HABITAT C	Developme	THREATEN	ACTIVE BU	UNION PAC	########	Niland (331	11	637402
MI SW OF I	HABITAT CONSISTS OF DESERT SC	3 ADULTS A	UNION PAC	########	Iris (33115	11	640012
OF NILAND	HABITAT CONSISTS OF DESERT SC	3 ACTIVE B	UNION PAC	########	Iris (33115	11	643151
OF NILAND	HABITAT CONSISTS OF DESERT SC	1ACTIVE BU	UNION PAC	########	Iris (33115	11	644701
OF NILAND	HABITAT CONSISTS OF DESERT SC	1ACTIVE BU	UNION PAC	########	Iris (33115	11	645330
OF GLAMIS	HABITAT CONSISTS OF DESERT SC	1ADULT AT	UNION PAC	########	Acolita (33	11	673771
EXACT LOC	SILTY PLAY	ORV activit	OHV, TRAF	PLANTS OB	BLM	########	Coyote We	11	603506
MAPPED B	DRIED, MU	ORV activit	OHV, HEAV	OCCURREN	BLM	########	Coyote We	11	598495
EXACT LOC	DRY, OPEN DESERT.		ONLY SOUI	UNKNOWN	########	Seeley (321	11	622615
EXACT LOCATION UNKNOWN. MAPPED BY CI			ONLY SOUI	UNKNOWN	########	Picacho SW	11	715876
EXACT LOC	GROWING AMONG ROCKS ON A S		ONLY SOUI	BLM	########	Quartz Pea	11	706387
MAPPED W	IN ROCKY GRANITIC SLOUTH FACI	37 PLANTS	BLM	########	Mt. Barrow	11	691305
EXACT LOC	ROCKY MOUNTAIN SLOPE.		ONLY SOUI	UNKNOWN	########	Palo Verde	11	706867
EXACT LOC	BASE OF CONGLOMERATE CUT AL		ONLY SOUI	BLM	########	Palo Verde	11	709213
.	ROCKY STEEP SLOPES.		ONLY SOUI	DOD-CHOC	########	Lion Head I	11	655367
MAPPED T	HABITAT C	Developme	POTENTIAL	3-4 APR 20	BLM	########	Clyde (321	11	698390
MAPPED T	HABITAT C	Developme	POTENTIAL	1 TORTOISI	BLM	########	Ninemile W	11	697034
MAPPED T	HABITAT C	ORV activit	POTENTIAL	11" FEMAL	BLM	########	Ninemile W	11	698243
MAPPED T	HABITAT C	Developme	POTENTIAL	A TORTOIS	BLM	########	Ninemile W	11	696032
OF THE INT	CREOSOTE	ORV activit	ORV'S.	3 FEMALES	BLM	########	Ninemile W	11	697515
MAPPED T	ROLLING H	Developme	POTENTIAL	1 OLD AND	BLM	########	Ninemile W	11	695737
MAPPED T	DESERT WA	Developme	PIPELINE C	1 TORTOISI	PVT-SF PAC	########	Buzzards P	11	699921
MAPPED W	HABITAT C	Developme	POTENTIAL	UP TO 5 TC	BLM, PVT-S	########	Buzzards P	11	698542
STATION 3	CREOSOTE	Developme	PIPELINE C	MALE TOR	BLM	########	Clyde (321	11	697509
STATION 3	CREOSOTE	Developme	PIPELINE C	TORTOISE (	BLM	########	Clyde (321	11	696645
MAPPED T	HABITAT C	ORV activit	POTENTIAL	11 INDIVID	BLM	########	Buzzards P	11	698452
MAPPED T	HABITAT C	ORV activit	POTENTIAL	3 TORTOISI	BLM	########	Buzzards P	11	699309
MAPPED T	HABITAT C	Developme	POTENTIAL	1 TORTOISI	BLM	########	Ninemile W	11	696637
E OF ARRO	IRONWOO	Developme	ORVS AND	1 ADULT O	BLM	########	Pegleg Wel	11	669453
OF INDIAN	DESERT PA	ORV activit	ORVS.	1 JUVENILE	BLM	########	Hedges (32	11	702075
EXACT LOCATION UNKNOWN. MAPPED BY CI			ONLY SOUI	UNKNOWN	########	Cibola (331	11	713262
EXACT LOC	ALKALI SOIL.		MAIN SOU	UNKNOWN	########	Palo Verde	11	710433
T OF PEGLEG MINE, CHOCOLATE MOUNTAIN A			1 ADULT O	DOD-CHOC	########	Pegleg Wel	11	668815
MAPPED TO PROVIDED COORDINATES.			2 TORTOISI	STATE LAN	########	Pegleg Wel	11	667932
SE QUARTE	HABITAT C	ORV activit	POTENTIAL	10 INCH FE	BLM	########	Hedges (32	11	701613
MAPPED T	HABITAT C	ORV activit	POTENTIAL	10" FEMAL	BLM	########	Hedges (32	11	700920
NEAR CENT	HABITAT C	ORV activit	POTENTIAL	1 TORTOISI	BLM	########	Hedges (32	11	700243
OBSERVATI	DESERT WA	ORV activit	ORV TRAFF	30 MAR 20	BLM	########	Buzzards P	11	698247
MAPPED T	HABITAT C	ORV activit	POTENTIAL	1 ADULT M	BLM	########	Buzzards P	11	701039
NE 1/4 OF S	HABITAT C	ORV activit	POTENTIAL	1 MATING	BLM	########	Buzzards P	11	702008
MAPPED T	HABITAT C	ORV activit	POTENTIAL	FEMALE TC	UNKNOWN	########	Palo Verde	11	703489
NEAR CENT	HABITAT C	ORV activit	POTENTIAL	SCAT LESS	BLM	########	Palo Verde	11	704932

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MI NW OF	FLOODED [	Developme	CONTINUE	1 ADULT O	UNION PA(	########	Wister (33:	11	634102
LOCATION	GIVEN AS, "EL CENTRO, IMPERIAL		2 INDIVIDU	UNKNOWN	########	El Centro (3	11	634594
LOCATION	CREOSOTE	SCRUBLAND WITH PAT	1 ADULT O	BLM	########	Mount Sigr	11	617931
LOCATION	CREOSOTE	SCRUBLAND WITH PAT	2 ADULTS (	BLM	########	Yuha Basin	11	609152
1.25 MILES	CREOSOTE	SCRUBLAND WITH PAT	6 ADULTS (	BLM	########	Glamis SE (	11	681354
JUST NORT	CREOSOTE	SCRUBLAND WITH PAT	1 ADULT O	BLM	########	Plaster City	11	604586
SOUTHEAS	CREOSOTE	SCRUBLAND WITH PAT	3 ADULTS (	BLM	########	Plaster City	11	601100
SOUTH OF	CREOSOTE	SCRUBLAND WITH PAT	5 ADULTS (	BLM	########	Plaster City	11	603749
MAPPED T(	OBS IN LOV	Biocides | I	BOTULISM	3 NESTS W,	PVT-IMPER	########	Niland (331	11	629071
MAPPED T(	OBSERVED	Biocides | I	BOTULISM	NEST WITH	PVT-IMPER	########	Niland (331	11	629644
MAPPED T(	OBSERVED	Biocides | I	BOTULISM	5 NESTS OE	PVT-IMPER	########	Obsidian B	11	626655
1978 SPECI	2002: CRE(	Vehicle col	VEHICLE C(	1 DOR OBS	BLM	########	Kane Spring	11	594654
1969-70: N	2000-1: EN	Other | Re	EXCESSIVE	4-6 DETECT	BLM	########	Imperial Re	11	736593
MAPPED T(	CATTAIL	MARSHLAND WITH MAT	1 ADULT DI	USFWS-IM	########	Picacho SW	11	714110
MAPPED T(	STEEP-SIDE	ORV activit	ORV USE A	1 INDIVIDU	BLM	########	Harpers W(	11	600042
2006: ABO	2006: CLRA	Recreation	EXCESSIVE	CALIFORNI,	BLM	########	Imperial Re	11	736255
2000: STAT	LEAST BITT	Recreation	EXCESSIVE	NONE DETI	BLM	########	Imperial Re	11	736410
LOCATION	LEAST BITT	Recreation	EXCESSIVE	1 ADULT HI	BLM	########	Imperial Re	11	736192
MAPPED B'	SAND DUNES. ASSOCIATED WITH		ONLY SOUI	BLM	########	Grays Well	11	689479
MAPPED B'	SPARSE DESERT SCRUB ON LOOSE		SITE BASEC	BLM	########	Ogilby (321	11	702733
MAPPED ACCORDING '	ORV activit	OHV USE.	PLANTS PR	BLM	########	Clyde (321:	11	690287
MAPPED B'	CREOSOTE	BUSH SCRUB ON SAND	UNCOMM(	BLM	########	Tortuga (33	11	653029
1988: "TRIL	EMERGENT	WETLAND VEGETATIO	4 DETECTE	UNKNOWN	########	Frink NW (3	11	621565
TRANSECT	EMERGENT	WETLAND VEGETATIO	NONE DETI	PVT-IMPER	########	Obsidian B	11	627667
MAPPED T(	EMERGENT	WETLAND VEGETATIO	NONE DETI	USFWS-SO	########	Calipatria S	11	620956
1989: EME	EVENS: AREA BULLDOZED BY USA(		13 DETECTI	PVT-IMPER	########	Calipatria S	11	622778
SURVEY ST.	EMERGENT	WETLAND VEGETATIO	6 BLACK RA	UNKNOWN	########	Seeley (321	11	620402
1984 & 19{	EMERGENT	WETLAND VEGETATIO	30-38 DETE	BLM, USBC	########	Midway W(	11	671240
1979: BETV	FRESHWATER	MARSH WITH EMEF	8+ DETECTI	BLM	########	Laguna Dar	11	734619
1969-70: IN	EMERGENT	WETLAND VEGETATIO	4-8 DETECT	BLM	########	Imperial Re	11	735564
2000-9 STU	FRESHWATER	MARSH WITH EMEF	2+ DETECTI	BLM	########	Imperial Re	11	735256
STUDY ARE	EMERGENT	WETLAND VEGETATIO	1 DETECTE	BLM	########	Imperial Re	11	735602
1973-4: "SI	FRESHWATER	MARSH WITH EMEF	1 DETECTE	BLM	########	Imperial Re	11	735718
BADLANDS	SPARSE	CREOSOTE AND SALTBUSH	ONE FEMA	DPR-OCOTI	########	Seventeen	11	588498
ALONG WE	CREOSOTE	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Shell Reef (	11	589134
RAINBOW '	MUDHILL T	ORV activit	OHV RECRE	TWO FEMA	DPR-OCOTI	########	Shell Reef (	11	591803
LOCATED V	SUBSTRATE	ORV activit	OHV RECRE	TWO INDIV	DPR-OCOTI	########	Shell Reef (	11	592452
RAINBOW '	VEGETATIC	ORV activit	OHV RECRE	ONE MALE	DPR-OCOTI	########	Shell Reef (	11	591875
EXACT LOC	2006: CRE(	ORV activit	OHV RECRE	FLAT-TAILE	BLM	########	Shell Reef (	11	592266
PLOT M09.	HEAVY OR(	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Shell Reef (	11	588530
TAB 8 PLOT	HABITAT C(	ORV activit	OHV RECRE	ONE OBSEF	DPR-OCOTI	########	Kane Spring	11	597366
LOCATED V	HABITAT IS	ORV activit	OHV RECRE	ONE OBSEF	DPR-OCOTI	########	Shell Reef (	11	592878
LOCATED V	POGONOMYRMEX	PRESENT ON P	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	593120
TAB 12 PLOT.	LOCATED	BETWEEN MIDDLE FO	ONE FEMA	DPR-OCOTI	########	Kane Spring	11	595485
RAINBOW '	HABITAT C(	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	594007
TAB 16 PLC	HABITAT C(	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	595493
M07 PLOT.	HABITAT C(	ORV activit	OHV RECRE	ONE OBSEF	DPR-OCOTI	########	Kane Spring	11	595369

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VICINITY O	MUDHILL T	ORV activit	OHV RECRE	1 OBSERVE	DPR-OCOTI	########	Kane Spring	11	594791
LOCATED J	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	596920
SAN FELIPE	MUDHILL, S	ORV activit	OHV RECRE	1 FEMALE (	BLM	########	Kane Spring	11	596327
LOCATED N	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	597351
TAB15 PLO	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	597758
SAN FELIPE	HABITAT C	ORV activit	OHV RECRE	ONE OBSEF	DPR-OCOTI	########	Kane Spring	11	596635
VICINITY O	2006: MUD	ORV activit	OHV RECRE	20 CAPTUR	DPR-OCOTI	########	Kane Spring	11	595491
M19 PLOT.	HABITAT C	ORV activit	OHV RECRE	ONE OBSEF	DPR-OCOTI	########	Kane Spring	11	593531
BTW SITE II	2006: HABI	ORV activit	OHV RECRE	12 CAPTUR	BLM	########	Shell Reef (	11	592966
1991: LOCA	MUDHILL T	ORV activit	OHV RECRE	1 DETECTEI	DPR-OCOTI	########	Shell Reef (	11	591013
1991: DETE	GRAVEL FL	ORV activit	OHV RECRE	1 DEAD LIZ	BLM, DPR-(	########	Shell Reef (	11	592738
2004: EXAC	2006: GRA	ORV activit	OHV RECRE	FLAT-TAILE	DPR-OCOTI	########	Shell Reef (	11	592163
2004: EXAC	2006: SANI	ORV activit	OHV RECRE	FLAT-TAILE	DPR-OCOTI	########	Kane Spring	11	594003
SAN FELIPE	MUD FLAT	ORV activit	OHV RECRE	ONE FEMA	DPR-OCOTI	########	Kane Spring	11	601727
SAN FELIPE	14 PLOT. L	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	602598
SAN FELIPE	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	605256
SAN FELIPE	11 PLOT. ABOUT 0.7 MILE SSW OF			ONE FEMA	DPR-OCOTI	########	Kane Spring	11	602186
ON NORTH	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	UNKNOWN	########	Kane Spring	11	603513
SAN FELIPE	HABITAT C	ORV activit	OHV RECRE	ONE ADULT	DPR-OCOTI	########	Kane Spring	11	602890
BADLANDS	15 PLOT. 0.7 MILE SSE OF VABM 2			ONE ADULT	DPR-OCOTI	########	Seventeen	11	590905
PLOT 10.	LOCATED 0.3 MILE WNW OF CAHUI			ONE INDIV	DPR-OCOTI	########	Shell Reef (	11	589107
SAND DUNES	EAST OF POLE LINE ROAD, ALON			2 MALES C/	DPR-OCOTI	########	Kane Spring	11	596410
SURVEY SIT	MARSH BY THE COLORADO RIVER			1 ADULT HI	DPR-PICAC	########	Picacho (33	11	722998
LOCATED	ON THE NORTH SIDE OF SAN FELIPE			ONE MALE	DPR-OCOTI	########	Shell Reef (	11	588117
MAPPED	ACCORDING TO PROVIDED UTM CO			ONE MALE	DPR-OCOTI	########	Kane Spring	11	599568
0.3 MILE	SOUTH OF BENCHMARK 17/STATE R			ONE FEMA	DPR-OCOTI	########	Kane Spring	11	602455
1 MILE	NORTH OF MCCAIN SPRING. MAPPED			1 FEMALE (	UNKNOWN	########	Kane Spring	11	595595
MAPPED T(	EMERGENT	Altered flo	CLEARING (	1 PAIR DET	PVT	########	Frink (3311	11	622451
SENATOR V	VEGETATIC	Recreation	EXCESSIVE	NONE SEEN	BLM	########	Imperial Re	11	737088
SET POINTS	VEGETATIC	Recreation	EXCESSIVE	NONE SEEN	BLM	########	Imperial Re	11	736473
CA SIDE OF	VEGETATIC	Recreation	EXCESSIVE	NONE SEEN	BLM	########	Imperial Re	11	736064
CA SIDE OF	VEGETATIC	Recreation	EXCESSIVE	NONE SEEN	BLM	########	Imperial Re	11	735492
SOUTH OF	EMERGENT	WETLAND	VEGETATIO	1 DETECTEI	BLM	########	Imperial Re	11	735306
1991: STOF	EMERGENT	WETLAND	VEGETATIO	TWO RAILS	BIA-FORT Y	########	Bard (3211	11	730070
1987-2005	EMERGENT	WETLAND	VEGETATIO	THE AREA \	USFWS-SOI	########	Calipatria S	11	620385
1987-2005	EMERGENT	WETLAND	VEGETATIO	THE AREA \	USFWS-SOI	########	Niland (331	11	628181
1987-2005	EMERGENT	WETLANDS	VEGETATI	THE AREA \	USFWS-SOI	########	Niland (331	11	629016
JUST WEST	EMERGENT	WETLAND	VEGETATIO	184 TOTAL	DFG-IMPEF	########	Niland (331	11	631544
JUST SOUT	EMERGENT	WETLAND	VEGETATIO	16 DETECTI	DFG-IMPEF	########	Niland (331	11	632126
POINTS MK	EMERGENT	WETLAND	VEGETATIO	8 CLRA RES	PVT-IMP IR	########	Obsidian B	11	627653
2007: OBSE	2007: SON	ORV activit	2011: TRAF	1 FOUND D	BLM	########	Yuha Basin	11	613790
"WESTMORELAND"; "CA WESTMORELAND."				SDNHM CC	UNKNOWN	########	Westmorla	11	628845
LOCATION STATED AS "COYOTE MOUNTAINS.				SDNHM CA	UNKNOWN	########	Carrizo Mtı	11	590518
MAPPED BY CNDDB ACCORDING TO LOCALITY				COLLECTEC	BLM	########	Grays Well	11	696547
LOCALITY GIVEN AS "OCOTILLO; CA 1.5 MI W				SDNHM CA	STATE, BLM	########	In-ko-pah (	11	590957
MAPPED B'	ALKALINE WASH.			ONLY SOUI	DPR-ANZA-	########	Carrizo Mtı	11	589089
EXACT LOCATION UNKNOWN. MAPPED BY CN				ONLY SOUI	DPR-ANZA-	########	Borrego M(	11	582769

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TRANSECT ADJACENT TO CANAL. WASH WITH	ONLY SOUI	UNKNOWN	########	Wister (33:	11	635753
1996 DETE(1996: A GE Vehicle col VEHICLE CC	DETECTED	BLM, UNKN	########	Kane Spring	11	606593
MAPPED B' IN SAND.	OCCURREN	UNKNOWN	########	In-ko-pah C	11	583784
CAS LOCALITY STATES "VIC. W. WINTERHAVEI	CALIFORNI	UNKNOWN	########	Yuma West	11	722293
LOCALITY STATES "OCOTILLO, 7.6 MILES NW (	ROYAL ONT	DPR-ANZA-	########	Carrizo Mtı	11	583535
SPECIMEN #13899: LOCALITY STATED AS "OC(	ROYAL ONT	BLM, UNKN	########	Carrizo Mtı	11	593437
MAPPED B' SANDY SOIL WITH LARREA AND CF	ONLY SOUI	UNKNOWN	########	Grays Well	11	710370
MAPPED B' AT MARGIN	ORV activit SLOPES SE\	SEVERAL TI	STATE LAN	########	Seventeen	11	587722
MAPPED IN	SANDY WA ORV activit	ILLICIT OFF	>100 INDIV	DPR-OCOTI	########	Seventeen	11	589140
JUST SOUT WASH ON S	ORV activit	ILLEGAL OF	SEVERAL H	DPR-OCOTI	########	Seventeen	11	591098
EXACT LOC IN ARROYO BOTTOM AND SURRO	MENTIONE	UNKNOWN	########	Seventeen	11	590263
MAPPED B' ARROYO BOTTOM AND SURROUN	MENTIONE	DPR, STATE	########	Seventeen	11	586776
MAPPED B' ROCKY WASH BOUNDED BY MUDS	MENTIONE	STATE LAN	########	Seventeen	11	585990
EXACT LOC SAND DUNES.	ONLY SOUI	BLM	########	Grays Well	11	689951
LOCATION 2002: BADLANDS HABITAT, COMP	3 MALES AI	DPR-OCOTI	########	Shell Reef (	11	588935
JUST EAST OF POLE LINE ROAD. LOCATION GI'	MVZ SPECI	DPR-OCOTI	########	Kane Spring	11	595397
EXACT LOCATION UNK Agriculture MOST OF T	ONLY SOUI	UNKNOWN	########	Holtville Ea	11	661124
NEAR "GAT SANDY SOI Agriculture AGRICULTU	ONLY SOUI	UNKNOWN	########	Holtville NE	11	659710
E OF THE EAST HIGHLINE. MAPPED BY CNDDB	ONLY SOUI	UNKNOWN	########	Glamis NW	11	665618
2004: EXAC 2006: CREC ORV activit OHV RECRE	FLAT-TAILE	DPR-OCOTI	########	Kane Spring	11	593321
NORTH OF STATE ROAD 111 WHERE IT CURVE	ONLY SOUI	PVT, BLM, S	########	Frink (3311	11	616924
SPRING, N IN WASH.	ONLY SOUI	DOD-CHOC	########	Frink NW (3	11	626847
MAPPED B' ALONG WASH IN DESERT WASH S(	MAIN SOUI	BLM	########	Picacho Pe:	11	720526
MAPPED B' IN SANDY WASH IN CREOSOTE BU	ONLY SOUI	UNKNOWN	########	Iris (33115)	11	649410
ON NORTH AMONG ROCKS.	UNKNOWN	UNKNOWN	########	Little Picac	11	729633
MAPPED B' IN OPEN, SANDY, ILL-DEFINED WA	ONLY SOUI	UNKNOWN	########	Chuckwalla	11	669171
MAPPED TO THE COORDINATES G OHVS. THE	TWO COLLI	BLM	########	Glamis (32:	11	680356
LOCATION GIVEN AS "5 MI. S. GLA OHVS. THE	THREE BEE'	BLM	########	Glamis (32:	11	682095
MAPPED W ROCKY GRANITIC S-FACING SLOPE	56 PLANTS	BLM	########	Mt. Barrow	11	691343
EXACT LOCATION UNKNOWN. MAPPED BY CN	ONLY SOUI	USFWS-CIB	########	Cibola (331	11	713401
WESTBOUI BOULDER (GRANITE) SLOPE.	ONLY SOUI	BLM	########	In-ko-pah C	11	585576
GROWING SANDY WA Foot traffic	TRAMPLIN(	3 PLANTS C	DPR-PICAC	########	Picacho (33	11	722048
EXACT LOC HIGH, ROCKY SLOPE.	ONLY SOUI	UNKNOWN	########	Picacho SW	11	711410
FREEMAN I SANDY WASH.	ONE SET O	DPR-OCOTI	########	Seventeen	11	590279
JUST NORTH OF CONFLUENCE OF NORTH ANI	TWO MALE	DPR-ANZA-	########	Seventeen	11	586293
1.7 MILES WNW OF CLAY POINT, JUST OUTSI	ONE ADULT	STATE LAN	########	Seventeen	11	591686
EXACT LOCATION UNKNOWN. MAPPED BY CN	ONLY SOUI	UNKNOWN	########	In-ko-pah C	11	583980
WHERE TRI NOT MUCH Non-native	NON-NATIV	2 ADULTS &	PVT, USFW	########	Calipatria S	11	621229
U DRAIN LE SURROUNI Non-native	NON-NATIV	1 ADULT AI	BLM	########	Niland (331	11	631321
MAPPED A GRANITIC SUBSTRATE WITH FOUC	NE POLYGC	BLM, PVT	########	In-ko-pah C	11	584321
T DRAIN LE SURROUNI Non-native	NON-NATIV	0 FOUND, 1	UNKNOWN	########	Niland (331	11	631808
FISH FOUN NOT MUCH Non-native	NON-NATIV	FOUR JUVE	PVT-IMPER	########	Obsidian Bı	11	625948
WHERE NIL FISH FOUN Non-native	NON-NATIV	1 ADULT TI	DFG, IMPEI	########	Wister (33:	11	629492
AT UNION SHALLOW S Altered flo	CHANGES I	20 ADULTS	PVT	########	Frink (3311	11	622436
S CAVE ARE CHAPARRAL AND DESERT SCRUB I	ONLY SOUI	BLM	########	In-ko-pah C	11	585191
EXACT LOCATION UNKNOWN. MAPPED BY CN	SITE BASEC	UNKNOWN	########	Coyote We	11	594207
MAPPED B' GRAVELLY SILT EDGE OF WASH.	ONLY SOUI	BLM	########	Carrizo Mtı	11	589812

EEC ORIGINAL PKG

MAPPED B'	WASH WITH OLNEYA AND ENCELI	ONLY SOUI	UNKNOWN	########	Seventeen	11	585546
MAPPED B'	ALONG A WASH WITH ENCELIA FA	SITE BASEC	UNKNOWN	########	Seventeen	11	587445
FREEMAN I	IN ROCKY ARROYO AND SURROUN	SITE BASEC	DPR-OCOTI	########	Seventeen	11	587536
FREEMAN I	IN ROCKY ARROYO AND SURROUN	SITE BASEC	STATE LAN	########	Seventeen	11	589553
FREEMAN I	IN SANDY ARROYO AND SURROUN	~5 PLANTS	DPR-OCOTI	########	Seventeen	11	590305
FREEMAN I	IN ARROYO BOTTOM AND SURRO	SITE BASEC	DPR, STATE	########	Seventeen	11	586931
FREEMAN I	IN ARROYO BOTTOM AND SURRO	SITE BASEC	DPR-OCOTI	########	Seventeen	11	589700
FREEMAN I	IN SANDY ARROYO AND SURROUN	SITE BASEC	STATE LAN	########	Seventeen	11	591241
FREEMAN I	IN ARROYO BOTTOM AND SURRO	SITE BASEC	STATE LAN	########	Seventeen	11	586757
FREEMAN I	ON DRIED MUD AND SANDY SUBS	SITE BASEC	DPR-OCOTI	########	Seventeen	11	590233
FREEMAN I	SANDY LOAM IN WASH OF MESA ,	SITE BASEC	STATE LAN	########	Seventeen	11	592144
I TRIBUTAR'	DESERT W/	ORV activit	OFF-HIGHV	>20 PLANT	DPR-OCOTI	########	Seventeen	11	589856
FREEMAN I	MUD AND COBBLE SUBSTRATES. (	SITE BASEC	DPR-OCOTI	########	Seventeen	11	587224
MAPPED A	ROADSIDE	Road/trail (	ILLEGAL DU	6 PLANTS S	DPR-OCOTI	########	Seventeen	11	589894
FREEMAN I	DESERT PAVEMENT AND MUD/CC	SITE BASEC	STATE LAN	########	Seventeen	11	592588
FREEMAN I	SANDY WASHES AND COBBLY MU	SITE BASEC	STATE LAN	########	Seventeen	11	591016
MAPPED B'	BARREN SLOPES OF UPLIFTED SED	SITE BASEC	DPR-OCOTI	########	Seventeen	11	586172
MAPPED BY	CNDDB AS BEST GUESS CENTERE	ONLY SOUI	UNKNOWN	########	Bard (3211	11	729107
EXACT LOC	SANDY SPOTS ON ROCKY SLOPES.	SITE BASEC	UNKNOWN	########	In-ko-pah (	11	583784
EXACT LOC	CREOSOTE BUSH SCRUB.	SITE BASEC	UNKNOWN	########	In-ko-pah (	11	592183
MAPPED B'	VOLCANIC SUBSTRATES WITH LAR	ONLY SOUI	BLM	########	Hedges (32	11	703112
ATELY 0.9 A	ALLUVIAL SLOPE. NARROW WASH	VERY LOCA	BLM	########	Clyde (321	11	695158
MAPPED B'	IN WASHES AND ARROYOS GROW	ONLY SOUI	BLM	########	Quartz Pea	11	699949
EXACT LOCATION UNKNOWN. MAPPED BY CI		ONLY SOUI	UNKNOWN	########	Buzzards P	11	699226
MAPPED BY	CNDDB AC	Mining	MINING AC	SITE BASEC	PVT	########	Ninemile W	11	689418
MAPPED B'	SANDY SOIL WITH LARREA, AMBR	ONLY SOUI	UNKNOWN	########	Bard (3211	11	722953
EXACT LOC	IN SHALLOW, SANDY WASH WITH	ONLY SOUI	UNKNOWN	########	Araz (3211	11	716629
MAPPED A	GRANITIC E	ORV activit	AREA DISTU	UNKNOWN	BLM	########	In-ko-pah (	11	585352
APPROXIM	IN THE BOULDERS. CHAPARRAL W	ONLY SOUI	SDG COUN	########	In-ko-pah (	11	583666
BLOCK COI	UPLAND ELEVATION SUBREGION.	3 BREEDIN	UNKNOWN	########	Bonds Corr	11	652652
BLOCK COI	UPLAND ELEVATION SUBREGION.	1 ADULT O	UNKNOWN	########	Bonds Corr	11	653884
ALONG WE	UPLAND ELEVATION SUBREGION.	1 ADULT E/	UNKNOWN	########	Bonds Corr	11	653366
N OF MT SI	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	UNKNOWN	########	Mount Sigr	11	625122
ALONG W S	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	UNKNOWN	########	Heber (321	11	629214
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	UNKNOWN	########	Heber (321	11	629858
ALONG WA	OWLS FOUND AT DRAIN DITCH. AI	1 BREEDIN	PVT-IMPER	########	Holtville Ea	11	660553
ON WARRE	CANTALOUPE FIELD AND DRAIN D	1 ADULT O	PVT-IMPER	########	Holtville Ea	11	660075
N OF EAST	ALFALFA AGRICULTURE AND DRAI	1 ADULT O	PVT-IMPER	########	Holtville Ea	11	660197
N OF EAST	ALFALFA AGRICULTURE AND DRAI	1 ADULT O	PVT-IMPER	########	Holtville Ea	11	660045
BLOCK COI	ALFALFA AGRICULTURE AND DRAI	1 BREEDIN	PVT-IMPER	########	El Centro (3	11	636056
BETWEEN I	ALFALFA AGRICULTURE AND DRAI	1 BREEDIN	PVT-IMPER	########	El Centro (3	11	636438
BLOCK COI	ALFALFA AGRICULTURE, DRAIN DI	1 BREEDIN	PVT-IMPER	########	El Centro (3	11	635269
BLOCK COI	ALFALFA AGRICULTURE AND DRAI	1 BREEDIN	PVT-IMPER	########	El Centro (3	11	638328
BLOCK COI	ALFALFA AGRICULTURE AND DRAI	1 BREEDIN	PVT-IMPER	########	El Centro (3	11	638041
ALONG OH	ALFALFA AGRICULTURE IN AREA. I	2 BREEDIN	PVT	########	Holtville NE	11	652090
ALONG OH	ALFALFA AGRICULTURE IN AREA. I	1 BREEDIN	PVT	########	Holtville NE	11	652941
ALONG OH	ALFALFA AGRICULTURE IN AREA. I	3 JUVENILE	PVT	########	Holtville NE	11	654196

EEC ORIGINAL PKG

BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	JUVENILE	PVT	########	Holtville NE	11	654767
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	655370
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	657485
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	658200
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	658706
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	658218
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	657291
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	656635
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	656164
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	BREEDIN(	UNKNOWN	########	Holtville NE	11	655324
BLOCK COI	ALFALFA AGRICULTURE IN AREA. I	15	JUL 200	PVT	########	Holtville NE	11	654715
ALONG OLI	AREA SURROUNDED BY AGRICULT	2	JUVENILE	PVT	########	Holtville NE	11	654275
ALONG OLI	ALFALFA AGRICULTURE IN AREA. I	3	JUVENILE	PVT	########	Holtville NE	11	653524
ALONG OLI	TILLED FIELD IN AREA. LOWLAND	1	ADULT O	PVT	########	Holtville NE	11	652585
ALONG OR	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	UNKNOWN	########	Holtville NE	11	656911
ALONG OR	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	UNKNOWN	########	Holtville NE	11	657360
ALONG OR	LOWLAND ELEVATION SUBREGIOI	2	ADULTS (	UNKNOWN	########	Holtville NE	11	657832
ALONG OR	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	UNKNOWN	########	Holtville NE	11	658649
ALONG OR	LOWLAND ELEVATION SUBREGIOI	2	JUVENILE	PVT	########	Holtville NE	11	654759
ALONG OR	ALFALFA AGRICULTURE IN AREA. I	1	ADULT O	PVT	########	Holtville NE	11	653293
ALONG OX	TILLED FIELD AT 18 AND ALFALFA	1	ADULT O	PVT	########	Holtville NE	11	652248
ALONG OX	ALFALFA AGRICULTURE IN AREA. I	1	ADULT O	PVT	########	Holtville NE	11	653055
JUST NORT	SLIGHTLY S Developme	THREATEN	IN 2010, 24	BLM	########	Painted Go	11	600663
JUST NORT	SLIGHTLY S Developme	THREATEN	7 PLANTS V	BLM	########	Painted Go	11	601555
BETWEEN (	SLIGHTLY S Developme	THREATEN	3 PLANTS V	BLM	########	Painted Go	11	604806
MUNYON I	HABITAT TYPE IS AN IRRIGATION (	1	BREEDIN(	PVT	########	Amos (331	11	655314
ALONG MY	HABITAT TYPE IS AN IRRIGATION (	1	ADULT O	PVT	########	Amos (331	11	655578
BLOCK COI	HABITAT TYPE IS LISTED AS IRRIGA	1	ADULT O	PVT	########	Amos (331	11	655870
ALONG MA	LOWLAND ELEVATION SUBREGIOI	2	BREEDIN(	UNKNOWN	########	Wiest (331	11	649433
ALONG MA	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	UNKNOWN	########	Wiest (331	11	647828
ALONG MA	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Wiest (331	11	645969
ALONG ME	HABITAT TYPE IS LISTED AS FIELD (	1	BREEDIN(	PVT	########	Wiest (331	11	646665
ALONG ME	HABITAT TYPE IS LISTED AS FIELD (	1	BREEDIN(	PVT	########	Wiest (331	11	648117
ALONG ME	HABITAT TYPE IS LISTED AS FIELD (	4	ADULTS (	PVT	########	Wiest (331	11	649021
ALONG ME	HABITAT TYPE IS LISTED AS FIELD (	2	ADULTS (	PVT	########	Wiest (331	11	649720
ALONG MA	HABITAT TYPE IS LISTED AS FIELD /	2	ADULTS (	PVT	########	Wiest (331	11	648125
ALONG MA	HABITAT TYPE IS LISTED AS FIELD /	1	BREEDIN(	PVT	########	Wiest (331	11	646196
ALONG MA	HABITAT TYPE IS LISTED AS FIELD (	1	BREEDIN(	PVT	########	Wiest (331	11	645012
ALONG ML	HABITAT TYPE IS LISTED AS FIELD (	1	ADULT O	PVT	########	Wiest (331	11	645142
BLOCK COI	HABITAT TYPE IS LISTED AS IDLE O	1	PAIR OBS	PVT	########	Westmorla	11	628544
BLOCK COI	HABITAT TYPE IS LISTED AS GRAIN	1	ADULT O	PVT	########	Calipatria S	11	624689
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Calipatria S	11	624681
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Calipatria S	11	624676
ALONG TRI	LOWLAND ELEVATION SUBREGIOI	10	OWLS C	PVT	########	Calipatria S	11	624830
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Calipatria S	11	624557
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Calipatria S	11	624491
BLOCK COI	UPLAND ELEVATION SUBREGION.	1	ADULT O	PVT	########	Bonds Corr	11	653918

EEC ORIGINAL PKG

E OF VAIL E	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Calipatria S	11	626118
BLOCK COI	HABITAT TYPE LISTED AS GRAIN O	2 ADULTS (	PVT	########	Calipatria S	11	623840
BLOCK COI	HABITAT TYPE LISTED AS DISKED I	2 ADULTS (	PVT	########	Calipatria S	11	623732
BLOCK COI	HABITAT TYPE LISTED AS DISKED F	1 PERCHED	PVT	########	Calipatria S	11	623858
BLOCK COI	HABITAT TYPE LISTED AS GRAIN O	1 ADULT O	PVT	########	Calipatria S	11	623862
BLOCK COI	HABITAT TYPE LISTED AS DISKED I	1 ADULT O	PVT	########	Calipatria S	11	623882
BLOCK COI	HABITAT TYPE LISTED AS DISKED I	1 ADULT O	PVT	########	Calipatria S	11	623880
BLOCK COI	HABITAT TYPE LISTED AS GRAIN O	1 ADULT O	PVT	########	Calipatria S	11	623685
BLOCK COI	HABITAT TYPE LISTED AS GRAIN O	1 BREEDIN(	PVT	########	Calipatria S	11	622923
BLOCK 365	HABITAT TYPE LISTED AS GRAIN O	10 UNIQUE	PVT	########	Calipatria S	11	623110
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Calipatria S	11	623056
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Calipatria S	11	623071
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Calipatria S	11	623087
ALONG TRI	LOWLAND ELEVATION SUBREGIOI	4 ADULTS (	PVT	########	Calipatria S	11	622858
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	PVT	########	Calipatria S	11	622045
BLOCK COI	LOWLAND ELEVATION SUBREGIOI	1 BREEDIN(	PVT	########	Calipatria S	11	622274
ARTIFICIAL	HABITAT TYPE LISTED AS IDLE OR I	14 DIFFERE	PVT, USFW	########	Calipatria S	11	621281
BLOCK COI	HABITAT TYPE LISTED AS FIELD CR	1 ADULT O	PVT, USFW	########	Calipatria S	11	621074
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Obsidian B	11	626093
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	2 ADULTS (	PVT	########	Obsidian B	11	626896
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	2 ADULTS (	PVT	########	Obsidian B	11	627702
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Obsidian B	11	627713
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Obsidian B	11	627721
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Niland (331	11	629327
ALONG D D	HABITAT TYPE LISTED AS DRAIN D	2 ADULTS (	PVT	########	Iris (33115	11	648988
ALONG D D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	645679
ALONG E D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	645061
ALONG E D	HABITAT TYPE LISTED AS DRAIN D	2 ADULTS A	PVT	########	Iris (33115	11	646392
ALONG E D	HABITAT TYPE LISTED AS DRAIN D	2 ADULTS (	PVT	########	Iris (33115	11	647270
ALONG E D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT AI	PVT	########	Iris (33115	11	647922
EXACT LOCATION UNK	Surface wa BLUE LAKE	ONLY SOUI	UNKNOWN	########	Seeley (321	11	622790
ALONG F D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	647861
ALONG F D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	646566
ALONG F D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	645257
ALONG G D	HABITAT TYPE LISTED AS DRAIN D	1 ADULT O	PVT	########	Iris (33115	11	646000
ALONG NIL	HABITAT TYPE LISTED AS IRRIGATI	1 ADULT O	PVT	########	Wister (331	11	636126
JUST NORT	HABITAT TYPE LISTED AS NATURA	2 ADULTS (	PVT	########	Wister (331	11	636725
ALONG Y L	HABITAT TYPE LISTED AS IRRIGATI	2 ADULTS (	PVT	########	Wister (331	11	636218
ALONG W I	HABITAT TYPE LISTED AS IRRIGATI	1 ADULT O	PVT	########	Wister (331	11	637619
BLOCK COI	HABITAT TYPE LISTED AS CEMENT	1 ADULT O	PVT	########	Wister (331	11	637127
BLOCK COI	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT O	PVT	########	Wister (331	11	637549
EXACT LOC SURROUNI	Surface wa LAKE HAS E	ONLY SOUI	UNKNOWN	########	Plaster City	11	614925
0.1 MI NW	HABITAT TYPE LISTED AS IDLE OR I	1 ADULT AI	PVT	########	Truckhaver	11	597579
EXACT LOCATION UNKNOWN. MAPPED BY CI		ONLY SOUI	DPR-ANZA-	########	Oasis (3311	11	583884
ALONG RO	TRANSITION BETWEEN DESERT AI	ONLY SOUI	UNKNOWN	########	In-ko-pah C	11	583539
MAPPED A	CATTAIL MARSH WITH MATURE P	UP TO 4 BI	USFWS-IMI	########	Picacho SW	11	714079
MAPPED A	BACKWATER CHANNELS LINED WI	1 DETECTE	USFWS-CIB	########	Cibola (331	11	715209

EEC ORIGINAL PKG

LOCATION	DISTURBED DESERT SCRUB & DESI	ADULTS SE	BLM	########	Iris (33115	11	649443
ALONG MI	HABITAT CONSISTS OF TAMARISK	PAIR OBSEI	USFWS-CIB	########	Cibola (331	11	711156
MAPPED A	HABITAT CONSISTS OF MESQUITE	TWO BREEI	PVT	########	Palo Verde	11	709346
ALONG MA	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	UNKNOWN	########	Wiest (331	11	650045
ALONG MA	LOWLAND ELEVATION SUBREGIOI	2 ADULTS (	UNKNOWN	########	Wiest (331	11	650849
ALONG ML	LOWLAND ELEVATION SUBREGIOI	1 ADULT O	UNKNOWN	########	Wiest (331	11	651693
ALONG MA	HABITAT CONSISTS OF GRASS FIEL	2 ADULTS (	UNKNOWN	########	Wiest (331	11	650640
ALONG MA	LOWLAND ELEVATION SUBREGIOI	2 ADULTS (	UNKNOWN	########	Wiest (331	11	651168
ALONG ME	HABITAT CONSISTS OF FIELD CROI	2 ADULTS (	UNKNOWN	########	Amos (331	11	652041
ALONG MA	HABITAT CONSISTS OF GRASS FIEL	2 ADULTS (	UNKNOWN	########	Amos (331	11	651861
NEAR BANI	HABITAT CONSISTS OF IDLE OR FA	1 MALE AD	PVT	########	Niland (331	11	629257
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT &	PVT-IMPER	########	Mount Sigr	11	622985
MAPPED T(	HABITAT C(Waterway	THREATS IN	2 ADULTS I	PVT-IMPER	########	Seeley (321	11	618277
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT O	PVT-IMPER	########	Seeley (321	11	618081
MAPPED T(	HABITAT C(Waterway	THREATS IN	3 ADULTS (	PVT-IMPER	########	Plaster City	11	616613
MAPPED T(	HABITAT C(Waterway	THREATS IN	3 ADULTS (	PVT-IMPER	########	Wister (33	11	635524
MAPPED T(	HABITAT C(Waterway	THREATS IN	4 ADULTS &	PVT-IMPER	########	Calipatria S	11	619798
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT O	PVT-IMPER	########	Calipatria S	11	624426
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT O	DFG-IMPEF	########	Niland (331	11	631609
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT O	PVT-IMPER	########	El Centro (3	11	638736
MAPPED T(	HABITAT C(Waterway	THREATS IN	1 ADULT M	PVT-IMPER	########	Amos (331	11	654925
MAPPED T(	HABITAT C(Altered flo(	THREATS IN	1 NON REP	BLM	########	Laguna Dar	11	736057
MAPPED TO PROVIDED COORDINATES.			THE FOLLO	UNKNOWN	########	Seeley (321	11	617605
			2 FEMALES	UNKNOWN	########	Ogilby (321	11	702138
EXACT LOC	EDGE OF WASH.		SITE BASEI	UNKNOWN	########	Borrego M	11	584700
COLORADC	STATIONS 106 (NW FEATURE) & 1	1 ADULT HI	BLM	########	Imperial Re	11	736257
ALONG E SI	VACANT R(Vehicle col	POSSIBLY T	2 OWLS OE	UNKNOWN	########	El Centro (3	11	638721
ALONG ALI	VACANT R(Vehicle col	POSSIBLY T	14 ACTIVE	UNKNOWN	########	El Centro (3	11	638680
ALONG ALI	VACANT R(Vehicle col	POSSIBLY T	2 OWLS OE	UNKNOWN	########	El Centro (3	11	638673
ABOUT 15(	VACANT R(Vehicle col	POSSIBLY T	OWLS OBSI	UNKNOWN	########	El Centro (3	11	638583
NEAR THE I	VACANT R(Vehicle col	POSSIBLY T	3 EAST-FAC	UNKNOWN	########	El Centro (3	11	638607
ALONG RO	VACANT R(Vehicle col	POSSIBLY T	20 BURROV	UNKNOWN	########	El Centro (3	11	639419
"183 FEET I	VACANT R(Vehicle col	POSSIBLY T	3 OWLS OE	UNKNOWN	########	Brawley (32	11	639259
NORTH OF	VACANT R(Vehicle col	POSSIBLY T	10 BURROV	UNKNOWN	########	Brawley (32	11	639310
ALONG THI	VACANT R(Vehicle col	POSSIBLY T	1 NORTH-F	UNKNOWN	########	Brawley (32	11	639340
ALONG THI	VACANT R(Vehicle col	POSSIBLY T	4 ACTIVE B	UNKNOWN	########	Brawley (32	11	639318
E OF BEST (	VACANT R(Vehicle col	POSSIBLY T	EAST-FACI	UNKNOWN	########	Westmorla	11	639260
ALONG BES	VACANT R(Vehicle col	POSSIBLY T	5 ACTIVE B	UNKNOWN	########	Westmorla	11	639185
MAPPED T(	VACANT R(Vehicle col	POSSIBLY T	6 BURROW	UNKNOWN	########	Westmorla	11	638972
1 BURROW	VACANT R(Vehicle col	POSSIBLY T	2 ACTIVE B	UNKNOWN	########	Westmorla	11	639169
MAPPED T(	SONORAN	Developme	THREATEN	1 ADULT O	UNKNOWN	########	Plaster City	11	613035
MAPPED T(	SONORAN	Developme	BURROW S	1 DECEASE	BLM	########	Yuha Basin	11	613850
MAPPED TO PROVIDEI	Developme	THREATEN	BURROWIN	UNKNOWN	########	Plaster City	11	609328
MAPPED TO PROVIDEI	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	610679
MAPPED TO PROVIDEI	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	611587
MAPPED TO PROVIDEI	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	605760
MAPPED TO PROVIDEI	Developme	THREATEN	BURROW V	BLM	########	Yuha Basin	11	612471

EEC ORIGINAL PKG

MAPPED TO PROVIDE	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	609861
MAPPED TO PROVIDE	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	610363
MAPPED TO PROVIDE	Developme	THREATEN	BURROW V	BLM	########	Plaster City	11	606291
ALONG OX	HABITAT DESCRIBED AS ALFALFA/	2	JUVENILE	PVT	########	Holtville NE	11	654182
ALONG OX	LOWLAND ELEVATION SUBREGION	1	ADULT O	PVT	########	Holtville NE	11	655012
ALONG OX	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Holtville NE	11	656418
ALONG OX	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Holtville NE	11	658564
ALONG OLI	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Holtville NE	11	658376
ALONG OLI	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Holtville NE	11	655655
ALONG OLI	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Holtville NE	11	654306
ALONG OR	HABITAT DESCRIBED AS ALFALFA/	1	ADULT O	PVT	########	Holtville NE	11	654025
ALONG OR	HABITAT DESCRIBED AS ALFALFA /	1	JUVENILE	PVT	########	Holtville NE	11	652467
ALONG OR	HABITAT DESCRIBED AS TILLED FIE	1	ADULT O	PVT	########	Holtville NE	11	651945
ALONG MC	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645329
ALONG MC	LOWLAND ELEVATION SUBREGION	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	646934
ALONG MC	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	647742
ALONG MC	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	648871
ALONG MC	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	650574
ALONG OA	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	651185
ALONG OA	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	649756
ALONG OA	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	647835
ALONG OA	LOWLAND ELEVATION SUBREGION	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	647019
ALONG OA	LOWLAND ELEVATION SUBREGION	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	646122
ALONG OA	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645603
ALONG OS	LOWLAND ELEVATION SUBREGION	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	648426
ALONG OS	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	649739
OSAGE DR	LOWLAND ELEVATION SUBREGION	1	ADULT O	UNKNOWN	########	Alamorio (3	11	650990
JUST SSE O	SAILFIN MC	Non-native	NON-NATI	13	SPECIM	BLM, OTHE	########	Kane Spring	11	609239
ALONG OR	HABITAT DESCRIBED AS CANAL W	1	ADULT O	PVT	########	Alamorio (3	11	650100
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	2	JUVENILE	PVT	########	Alamorio (3	11	649607
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	645801
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	645974
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647075
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647957
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	649576
ALONG OLI	HABITAT DESCRIBED AS ALFALFA /	1	JUVENILE	PVT	########	Alamorio (3	11	650410
ALONG OLI	HABITAT DESCRIBED AS ALFALFA /	1	ADULT O	PVT	########	Alamorio (3	11	651782
ALONG OH	HABITAT DESCRIBED AS TILLED FIE	1	JUVENILE	PVT	########	Alamorio (3	11	650867
ALONG OH	HABITAT DESCRIBED AS AN IRRIGA	3	JUVENILE	PVT	########	Alamorio (3	11	649509
ALONG OH	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	648855
ALONG OH	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	648015
ALONG OH	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647386
ALONG OH	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	645038
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	645501
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT AI	PVT	########	Alamorio (3	11	646545
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647136
ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	2	JUVENILE	PVT	########	Alamorio (3	11	648365

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ALONG OR	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	649622
ALONG OR	HABITAT DESCRIBED AS BERMUDA	1	JUVENILE	PVT	########	Alamorio (3	11	651442
ALONG OX	HABITAT DESCRIBED AS ALFALFA A	1	JUVENILE	PVT	########	Alamorio (3	11	650711
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	2	JUVENILE	PVT	########	Alamorio (3	11	649506
MAPPED GENERALLY TO THE ENTRANCE TO S	USNM SPE	UNKNOWN	########	Yuma East	11	723447
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT AI	PVT	########	Alamorio (3	11	648657
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647817
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	647342
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	1	JUVENILE	PVT	########	Alamorio (3	11	646789
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	3	JUVENILE	PVT	########	Alamorio (3	11	646269
MAPPED T	HABITAT C	Agriculture	THREATS I	2	ADULT M	PVT-IMPER	########	Bard (3211	11	732083
ALONG OX	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	645825
LOCATED B	HABITAT DESCRIBED AS CLOVER A	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	645036
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT &	PVT	########	Alamorio (3	11	646154
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	648391
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	2	ADULTS (	PVT	########	Alamorio (3	11	649307
ALONG OLI	HABITAT DESCRIBED AS IRRIGATIC	1	ADULT O	PVT	########	Alamorio (3	11	649948
ALONG OC	HABITAT DESCRIBED AS AGRICULT	1	ADULT O	UNKNOWN	########	Alamorio (3	11	647227
ALONG OC	HABITAT DESCRIBED AS AGRICULT	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645625
ALONG OR	HABITAT DESCRIBED AS ALFALFA A	2	ADULTS (	PVT	########	Alamorio (3	11	645146
ALONG OR	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	PVT	########	Alamorio (3	11	645718
ALONG OR	HABITAT DESCRIBED AS ALFALFA A	1	ADULT O	UNKNOWN	########	Alamorio (3	11	646950
ALONG OR	HABITAT DESCRIBED AS ALFALFA A	1	ADULT O	UNKNOWN	########	Alamorio (3	11	648160
ALONG OA	HABITAT DESCRIBED AS ALFALFA A	1	ADULT O	UNKNOWN	########	Alamorio (3	11	648297
ALONG OA	HABITAT DESCRIBED AS HARVESTI	1	ADULT O	PVT	########	Alamorio (3	11	646257
ALONG OA	LOWLAND ELEVATION SUBREGIOI	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645626
ALONG AN	HABITAT DESCRIBED AS A FALLOW	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645070
ALONG OA	HABITAT DESCRIBED AS SUGAR BE	1	ADULT O	UNKNOWN	########	Alamorio (3	11	645560
ALONG OA	HABITAT DESCRIBED AS A CORN F	2	ADULTS (	UNKNOWN	########	Alamorio (3	11	646436
ALONG OA	HABITAT DESCRIBED AS ALFALFA F	1	ADULT O	UNKNOWN	########	Alamorio (3	11	647935
ALONG OA	HABITAT DESCRIBED AS FALLOW F	1	ADULT O	UNKNOWN	########	Alamorio (3	11	648745
ALONG OA	HABITAT DESCRIBED AS ALFALFA F	1	ADULT O	UNKNOWN	########	Alamorio (3	11	650182
ALONG TO	HABITAT DESCRIBED AS ALFALFA F	1	ADULT O	PVT	########	Alamorio (3	11	651184
ALONG TO	HABITAT DESCRIBED AS ALFALFA F	1	ADULT O	UNKNOWN	########	Alamorio (3	11	647943
TYPE LOCALITY GIVEN	Developme	CALEXICO F	TYPE SPECI	UNKNOWN	########	Calexico (3	11	641015
MSU SPECIMEN LOCATION STATED AS "5 MI.	BERNARD E	BLM, STATI	########	Bard (3211	11	728713
ALONG OSAGE DRAIN. BLOCK CODE 3650-65(	1	ADULT O	UNKNOWN	########	Holtville NE	11	652385
ALONG OSAGE DRAIN. BLOCK CODE 3650-65(	1	ADULT O	UNKNOWN	########	Holtville NE	11	653101
ALONG OSAGE DRAIN. BLOCK CODE 3650-65(	1	ADULT O	UNKNOWN	########	Holtville NE	11	654178
ALONG OSAGE DRAIN. BLOCK CODE 3650-65(	2	ADULTS (	UNKNOWN	########	Holtville NE	11	655216
ALONG OSAGE DRAIN. BLOCK CODE 3650-65(	1	ADULT O	UNKNOWN	########	Holtville NE	11	657163
ALONG TO	HABITAT DESCRIBED AS ALFALFA F	1	ADULT O	UNKNOWN	########	Alamorio (3	11	646415
MAPPED T	HABITAT C	Mining	POSSIBLY T	1	ADULT M	BLM, PVT-E	########	Ogilby (321	11	707119
ON THE NC	GENERALL	Developme	PROPOSED	ABOUT 30	BLM	########	Chuckwalla	11	667889
ARTIFICIAL BURROW #38 (EAST), 39 (CENTER)	7	DIFFEREN	UNKNOWN	########	Calipatria S	11	621588
ARTIFICIAL BURROW #10 (WEST) AND 50 (EA	3	OWLS CA	PVT, USFW	########	Obsidian B	11	628078
ARTIFICIAL BURROW #07. MAPPED TO PROVI	2	OWLS CA	PVT, USFW	########	Niland (331	11	629024

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ARTIFICIAL BURROW #12. MAPPED TO PROVI	2 OWLS CA	DFG-IMPEF	########	Niland (331	11	631790
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Mt. Barrow	11	690192
MAPPED B' IN A CREOSOTE BUSH SCRUB COM	MAIN SOUI	DOD-CHOC	########	Mammoth	11	670622
1.4 MI STRI SURROUNI Agriculture AGRICULTU	1998: TWO	UNKNOWN	########	Bonds Corr	11	652801
STOP NO. 1: S END OF HAUGHTELIN LAKE IN 1	2 RAILS SIG	UNKNOWN	########	Bard (3211	11	725877
MAPPED TO 2001 COORDINATES. 1982 DATA	BURROW A	STATE LAN	########	Mt. Barrow	11	688475
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Mt. Barrow	11	689688
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Mt. Barrow	11	689736
MAPPED TO PROVIDED COORDINATES.	FEMALE (2	DOD-CHOC	########	Mt. Barrow	11	690530
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Mt. Barrow	11	689642
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Mt. Barrow	11	690026
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Mt. Barrow	11	689868
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Mt. Barrow	11	690237
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Mt. Barrow	11	691394
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Mt. Barrow	11	691642
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Mt. Barrow	11	691305
ABOUT 1 MILE NNW OF PAYMASTER MINE. M	MALE TOR	BLM	########	Mt. Barrow	11	694302
ABOUT 1.5 MILES NW OF PAYMASTER MINE.	MALE TOR	UNKNOWN	########	Mt. Barrow	11	693762
MAPPED TO PROVIDED COORDINATES.	1 MALE (27	BLM	########	Mt. Barrow	11	694259
2004 & 2008 DATA MAPPED TO PROVIDED C(	1 BURROW	BLM	########	Mt. Barrow	11	693116
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	West of Pa	11	688798
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	West of Pa	11	690111
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM, UNKN	########	West of Pa	11	690503
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	UNKNOWN	########	West of Pa	11	691889
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	West of Pa	11	694937
SMOKETREE VALLEY. MAPPED TO PROVIDED	CARCASS O	BLM	########	West of Pa	11	691959
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	West of Pa	11	695015
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	West of Pa	11	695753
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Mt. Barrow	11	697601
MAPPED TO PROVIDED COORDINATES.	1 FEMALE (	BLM	########	West of Pa	11	695440
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Buzzards P(	11	704515
MAPPED TO PROVIDED COORDINATES.	1 FEMALE '	BLM	########	Buzzards P(	11	699957
MAPPED T(HABITAT C(ORV activit THREATS I	USEABLE L(	BLM	########	Buzzards P(	11	701352
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Buzzards P(	11	700817
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Palo Verde	11	706266
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Palo Verde	11	698779
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Palo Verde	11	700053
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Palo Verde	11	701791
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Palo Verde	11	702727
MAPPED TO PROVIDED COORDINATES.	INTACT CA	BLM	########	Palo Verde	11	702314
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Palo Verde	11	703108
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Palo Verde	11	698663
EAST CENTER OF SECTION 33 AND WEST CEN	1 FEMALE /	BLM	########	Palo Verde	11	698857
SW QUARTER OF SECTION 26 AND SE QUARTI	MALE CAR(	BLM	########	Palo Verde	11	700637
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Palo Verde	11	701786
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Palo Verde	11	702715
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Palo Verde	11	699452

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MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Palo Verde	11	700024
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Palo Verde	11	700640
MAPPED T(HABITAT C(ORV activit THREATS IN	RECENTLY I	BLM	########	Palo Verde	11	704337
MAPPED T(HABITAT C(ORV activit THREATS IN	CARCASS O	BLM	########	Palo Verde	11	707082
MAPPED T(HABITAT C(ORV activit THREATS IN	CARCASS O	BLM	########	Palo Verde	11	705758
MAPPED T(HABITAT C(ORV activit POTENTIAL	2 BURROW	BLM	########	Hedges (32	11	701447
MAPPED T(HABITAT C(ORV activit POTENTIAL	A 9" LONG	BLM	########	Hedges (32	11	699938
MAPPED T(HABITAT C(ORV activit POTENTIAL	BURROW V	BLM	########	Hedges (32	11	700475
MAPPED T(HABITAT C(ORV activit POTENTIAL	ABOUT 1 Y	BLM	########	Clyde (321	11	696468
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Clyde (321	11	694525
MAPPED TO PROVIDED COORDINATES. ON SE	1 MALE CA	BLM	########	Clyde (321	11	693301
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Clyde (321	11	691293
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Clyde (321	11	691279
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Quartz Pea	11	699615
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Quartz Pea	11	699074
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Quartz Pea	11	699060
MAPPED T(HABITAT C(ORV activit POTENTIAL	BURROW C	BLM	########	Ninemile W	11	697618
MAPPED T(HABITAT C(ORV activit POTENTIAL	3 TORTOISI	BLM	########	Ninemile W	11	697400
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Ninemile W	11	694485
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Ninemile W	11	693341
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Ninemile W	11	692681
MAPPED TO PROVIDED COORDINATES.	FEMALE IN	BLM	########	Ninemile W	11	691813
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Quartz Pea	11	698353
NEAR CENTER OF SECTION 30. MAPPED TO PI	TORTOISE (	BLM	########	Ninemile W	11	694988
MAPPED TO PROVIDED COORDINATES.	MALE TOR	STATE LAN	########	Quartz Pea	11	698575
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Ninemile W	11	696667
MAPPED TO PROVIDED COORDINATES.	INTACT FEI	BLM	########	Ninemile W	11	694975
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Ninemile W	11	694294
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Buzzards P(	11	699933
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Mt. Barrow	11	696577
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Mt. Barrow	11	695489
MAPPED TO PROVIDED COORDINATES.	INTACT MA	BLM	########	Mt. Barrow	11	695405
NEARLY CENTER OF SECTION 7. MAPPED TO P	INTACT MA	BLM	########	Mt. Barrow	11	694975
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Mt. Barrow	11	694053
MAPPED T(HABITAT C(ORV activit POTENTIAL	DEEP, RECE	BLM	########	Mt. Barrow	11	697864
MAPPED TO PROVIDED COORDINATES.	INTACT MA	BLM	########	Mt. Barrow	11	696181
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	BLM	########	Mt. Barrow	11	695714
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Mt. Barrow	11	694045
MAPPED T(HABITAT C(ORV activit POTENTIAL	11 INCH FE	BLM	########	Mt. Barrow	11	697915
MAPPED TO PROVIDED COORDINATES.	UNKNOWN	BLM	########	Mt. Barrow	11	696585
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Mt. Barrow	11	695925
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Mt. Barrow	11	694822
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Mt. Barrow	11	694147
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Buzzards P(	11	699969
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Buzzards P(	11	698973
MAPPED T(HABITAT C(ORV activit POTENTIAL	FRESH SCA	BLM	########	Buzzards P(	11	698706
MAPPED TO PROVIDED COORDINATES.	2 FEMALE	BLM	########	Mt. Barrow	11	697469

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MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Mt. Barrow	11	697205
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Mt. Barrow	11	696574
MAPPED TO PROVIDED COORDINATES.	HEALTHY A	BLM	########	Mt. Barrow	11	695561
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Mt. Barrow	11	694528
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	STATE LAN	########	Mt. Barrow	11	693627
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	Mt. Barrow	11	693672
MAPPED T(HABITAT CI	ORV activit	POTENTIAL	1 USEABLE	BLM	########	Buzzards P(	11	699629
MAPPED T(HABITAT CI	ORV activit	POTENTIAL	4 OBSERVA	BLM	########	Buzzards P(	11	698817
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Palo Verde	11	698326
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	West of Pa	11	696418
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM, UNKN	########	West of Pa	11	690228
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	West of Pa	11	690016
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	West of Pa	11	689747
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	West of Pa	11	695675
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	West of Pa	11	694963
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM, UNKN	########	West of Pa	11	693497
ON THE SECTION LINE OF SE SEC 35 AND NE S	TORTOISE (	BLM, UNKN	########	West of Pa	11	691512
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	West of Pa	11	695267
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	UNKNOWN	########	West of Pa	11	692832
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	West of Pa	11	692811
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	West of Pa	11	689360
NEAR CENTER OF SECTION 9. MAPPED TO PR(	MALE CAR(	UNKNOWN	########	Wiley Well	11	687498
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Wiley Well	11	688624
MAPPED T(HABITAT CI	ORV activit	THREATS IN	ON 7 DEC 1	BLM, UNKN	########	Pegleg Wel	11	673539
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Little Mule	11	675018
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	Chuckwalla	11	673856
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM, UNKN	########	Little Chucl	11	674713
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Little Chucl	11	675198
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	BLM	########	Chuckwalla	11	672182
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Chuckwalla	11	673296
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Chuckwalla	11	673904
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Chuckwalla	11	673875
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM, UNKN	########	Chuckwalla	11	670178
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Chuckwalla	11	671018
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Chuckwalla	11	670562
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Chuckwalla	11	671157
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Chuckwalla	11	671279
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	UNKNOWN	########	Little Chucl	11	679743
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Little Chucl	11	680349
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Little Chucl	11	677339
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	BLM	########	Little Chucl	11	679677
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Chuckwalla	11	668887
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Chuckwalla	11	667950
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Chuckwalla	11	666717
MAPPED TO PROVIDED COORDINATES.	2 FEMALE (	BLM	########	Chuckwalla	11	663849
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Chuckwalla	11	663384
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Chuckwalla	11	663276

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MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Augustine I	11	662252
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	661568
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Augustine I	11	661047
MAPPED T(	HABITAT CONSISTED C	POTENTIAL	BETWEEN :	BLM	########	Yuma West	11	711502
IMPERIAL DIVISION SECTION I.	1969-70: ISLAI	MARSH AR	USFWS-IMI	########	Picacho (33	11	731743
SOUTHERN	1990: WITH	Altered flo(	1984: FLOC	MARSH AR	UNKNOWN	########	Bard (3211	11	731613
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Blue Moun	11	684903
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	685127
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Blue Moun	11	684879
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Blue Moun	11	686133
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Mt. Barrow	11	686917
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	West of Pa	11	686683
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Blue Moun	11	686090
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Little Mule	11	685411
CENTER EAST OF SECTION 31. MAPPED TO PR	CARCASS O	DOD-CHOC	########	Little Mule	11	684885
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Little Mule	11	684807
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Blue Moun	11	679985
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	680553
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Blue Moun	11	681197
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Blue Moun	11	681380
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Blue Moun	11	681572
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Blue Moun	11	681611
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Blue Moun	11	682726
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Blue Moun	11	683592
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	682442
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	683269
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	STATE LAN	########	Blue Moun	11	678560
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	679418
MAPPED TO PROVIDED COORDINATES.	4 CARCASS	DOD-CHOC	########	Little Mule	11	680882
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	Little Mule	11	685795
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	UNKNOWN	########	West of Pa	11	687308
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Little Mule	11	685783
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Little Mule	11	684918
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	Little Mule	11	685790
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Little Mule	11	681448
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Little Mule	11	680679
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Little Mule	11	679425
NEAR CENTER OF SEC 27. MAPPED TO PROVI	2 MALE CA	DOD-CHOC	########	Little Mule	11	679739
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Little Mule	11	680210
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	Little Mule	11	680954
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	STATE LAN	########	Little Mule	11	677427
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	UNKNOWN	########	Little Mule	11	681559
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM, UNKN	########	Little Mule	11	678785
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Little Mule	11	678543
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	UNKNOWN	########	Little Mule	11	676668
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	UNKNOWN	########	Little Mule	11	676421
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	Little Mule	11	680402

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MAPPED TO PROVIDED COORDINATES.	MALE CAR(	UNKNOWN	########	Little Mule	11	682339
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	Little Mule	11	682813
MAPPED TO PROVIDED COORDINATES.	THREE CAR	UNKNOWN	########	Little Mule	11	682975
MAPPED TO PROVIDED COORDINATES.	INTACT CA	UNKNOWN	########	Little Mule	11	683395
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Little Mule	11	682999
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	UNKNOWN	########	Little Mule	11	683998
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	BLM, UNK	########	Little Mule	11	684309
MVZ SPECIMENS "ALA Other DECLINE DI	7 COLLECTI	PVT-IMPER	########	Niland (331	11	630050
2000: FIG LAGOON. 2007: SITE NAME PS-33 E	ONE DETEC	UNKNOWN	########	Seeley (321	11	620749
"HOLTVILLE - COACHELLA." MAPPED TO THE	EIGHT DETI	UNKNOWN	########	Holtville W	11	651477
MAPPED T(HEAVY CO\ Developme	LIBERTY EN	THREE PAIF	UNKNOWN	########	Wister (33	11	635499
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Blue Moun	11	676311
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Blue Moun	11	676318
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Blue Moun	11	677242
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Blue Moun	11	676437
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Blue Moun	11	678739
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Blue Moun	11	678324
MAPPED TO PROVIDED COORDINATES.	UNKNOWN	DOD-CHOC	########	Little Mule	11	677277
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Little Mule	11	678533
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Little Mule	11	678955
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Little Mule	11	677688
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Little Mule	11	677301
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Little Mule	11	676435
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Little Mule	11	676279
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Mammoth	11	670947
MAPPED TO PROVIDED COORDINATES.	2 TORTOISI	DOD-CHOC	########	Mammoth	11	669523
ON SECTION LINE BETWEEN SEC 8 AND SEC 9	FEMALE TC	DOD-CHOC	########	Mammoth	11	667279
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Mammoth	11	667943
MAPPED TO PROVIDED COORDINATES.	MALE (260	DOD-CHOC	########	Mammoth	11	666674
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	665229
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	664451
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Mammoth	11	668843
MAPPED TO PROVIDED COORDINATES.	2 TORTOISI	DOD-CHOC	########	Pegleg Wel	11	667745
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	666273
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	665823
MAPPED TO PROVIDED COORDINATES.	2 TORTOISI	DOD-CHOC	########	Pegleg Wel	11	664834
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	664378
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	663811
MAPPED TO PROVIDED COORDINATES.	1 TORTOISI	DOD-CHOC	########	Pegleg Wel	11	668455
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	668581
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	668167
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	667685
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	667216
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	665711
MAPPED TO PROVIDED COORDINATES. ALMC	MALE CAR(	STATE LAN	########	Pegleg Wel	11	672849
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	670439
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	668550

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MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	665816
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	665740
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	666699
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	666588
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	667441
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	667271
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	668825
MAPPED TO PROVIDED COORDINATES.	3 FEMALE (	DOD-CHOC	########	Pegleg Wel	11	665810
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	666484
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	666579
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	667932
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	672077
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	672580
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	672775
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Pegleg Wel	11	672755
MAPPED TO PROVIDED COORDINATES. SE QU	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	673456
MAPPED TO PROVIDED COORDINATES. ON SE	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	674089
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Little Mule	11	675084
MAPPED TO PROVIDED COORDINATES. NEAR	MALE TOR	DOD-CHOC	########	Little Mule	11	676244
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	670755
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	671272
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	672108
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	673120
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	672170
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	673755
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	670484
MAPPED TO PROVIDED COORDINATES. VICIN	1 MALE OB	DOD-CHOC	########	Pegleg Wel	11	670092
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	669323
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	669326
MAPPED TO PROVIDED COORDINATES.	5 CARCASS	DOD-CHOC	########	Pegleg Wel	11	669976
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	669676
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	669829
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	670573
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	670632
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	670486
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	670055
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Lion Head I	11	659411
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	671456
MAPPED TO PROVIDED COORDINATES.	4 CARCASS	DOD-CHOC	########	Pegleg Wel	11	672097
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	673033
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	673051
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	673714
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	674423
NEAR ARROYO SECO IN THE LITTLE MULE MO	MALE CAR(	DOD-CHOC	########	Little Mule	11	674775
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Lion Head I	11	662548
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	661655
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Lion Head I	11	661144

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MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Lion Head I	11	660368
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	660440
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Lion Head I	11	659645
MAPPED TO PROVIDED COORDINATES. NEAR	TORTOISE (	DOD-CHOC	########	Lion Head I	11	659518
SPECIMEN DICKEY'S ORIGINAL SPECIES DESCI	THREE ADU	UNKNOWN	########	Bard (3211	11	729107
LOCATION STATED AS "BOMBAY BEACH MAR	THREE DET	USBOR, BLI	########	Frink (3311	11	621074
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	663998
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	663407
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Lion Head I	11	662821
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	662759
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	663412
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	662903
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Lion Head I	11	662033
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Lion Head I	11	661251
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	665085
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	664605
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	664824
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	665517
MAPPED TO PROVIDED COORDINATES.	CARCASS F	DOD-CHOC	########	Lion Head I	11	662443
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	663690
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	663122
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	661339
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Lion Head I	11	662231
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Lion Head I	11	661554
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Lion Head I	11	662215
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Pegleg Wel	11	668804
MAPPED TO PROVIDED COORDINATES. ONE (	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	667966
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	667314
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	666418
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	665812
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	665005
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Pegleg Wel	11	664851
4 MI NW OF ARROYO SECCO IN THE LITTLE M	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	671025
ABOUT 4 MI WNW OF ARROYO SECCO IN THE	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	671294
ABOUT 4 MI WNW OF ARROYO SECCO IN THE	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	670892
ABOUT 4 MILES WNW OF ARROYO SECCO IN	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	670854
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	671802
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	671285
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	670795
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	669765
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	669387
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	669211
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	668712
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	667641
MAPPED TO PROVIDED COORDINATES.	3 CARCASS	DOD-CHOC	########	Pegleg Wel	11	668215
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	BLM	########	Pegleg Wel	11	668703
NEAR ARROYO SECCO. MAPPED TO PROVIDE	MALE CAR(	BLM	########	Chuckwalla	11	668861

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MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	666310
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	666969
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	666323
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	664833
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	665788
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Pegleg Wel	11	666068
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	665005
MAPPED TO PROVIDED COORDINATES. SW, B	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	666194
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	665664
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	BLM	########	Pegleg Wel	11	666195
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Chuckwalla	11	666709
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Pegleg Wel	11	663967
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Pegleg Wel	11	663454
MAPPED TO PROVIDED COORDINATES.	3 LIVE TOR	DOD-CHOC	########	Pegleg Wel	11	663681
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Pegleg Wel	11	662993
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Pegleg Wel	11	663848
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	UNKNOWN	########	Pegleg Wel	11	664627
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	UNKNOWN	########	Chuckwalla	11	664891
MAPPED TO PROVIDED COORDINATES.	MALE TOR	UNKNOWN	########	Chuckwalla	11	664570
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Lion Head I	11	658133
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	661637
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Pegleg Wel	11	663063
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Augustine I	11	661574
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Augustine I	11	661589
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Augustine I	11	662456
MAPPED TO PROVIDED COORDINATES. NW C	FEMALE CA	DOD-CHOC	########	Augustine I	11	661279
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Augustine I	11	659567
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Lion Head I	11	656878
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	DOD-CHOC	########	Lion Head I	11	656983
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Lion Head I	11	655708
MAPPED TO PROVIDED COORDINATES.	1 MALE TO	DOD-CHOC	########	Lion Head I	11	655980
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Lion Head I	11	657373
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Lion Head I	11	657384
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Lion Head I	11	657621
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Lion Head I	11	661357
EXACT LOC IN ROCKS APPROXIMATELY 40-60	SINGLE PLA	DPR-ANZA-	########	Carrizo Mtı	11	583190
EXACT LOC HILLSIDE WASH.	ONLY SOUI	BLM	########	Painted Go	11	593598
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	657166
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Augustine I	11	656598
MAPPED TO PROVIDED COORDINATES.	1 TORTOISI	DOD-CHOC	########	Augustine I	11	656523
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	658373
MAPPED TO PROVIDED COORDINATES.	FEMALE CA	DOD-CHOC	########	Augustine I	11	658338
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	657298
MAPPED TO PROVIDED COORDINATES.	2 MALE CA	DOD-CHOC	########	Augustine I	11	656789
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	DOD-CHOC	########	Augustine I	11	656131
MAPPED TO PROVIDED COORDINATES. ALMC	TORTOISE (	DOD-CHOC	########	Augustine I	11	656925
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	BLM	########	Chuckwalla	11	667680

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NEAR CENTER OF SECTION 16. MAPPED TO PI	FEMALE CA	BLM	########	Chuckwalla	11	667694
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Chuckwalla	11	666258
MAPPED TO PROVIDED COORDINATES.	TORTOISE (	BLM	########	Chuckwalla	11	663630
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	UNKNOWN	########	Chuckwalla	11	664832
MAPPED TO PROVIDED COORDINATES.	CARCASS O	BLM	########	Chuckwalla	11	663009
MAPPED TO PROVIDED COORDINATES.	CARCASS O	UNKNOWN	########	Chuckwalla	11	663076
MAPPED TO PROVIDED COORDINATES.	2 CARCASS	BLM	########	Augustine I	11	661576
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Augustine I	11	662407
MAPPED TO PROVIDED COORDINATES.	MALE TOR	BLM	########	Augustine I	11	661589
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	661572
MAPPED TO PROVIDED COORDINATES.	MALE CAR(	DOD-CHOC	########	Augustine I	11	660191
MAPPED TO PROVIDED COORDINATES.	3 CARCASS	DOD-CHOC	########	Augustine I	11	659675
NEAR CENTER OF SEC 3. MAPPED TO PROVIDI	1 MALE (25	DOD-CHOC	########	Augustine I	11	659411
MAPPED TO PROVIDED COORDINATES.	CARCASS O	DOD-CHOC	########	Augustine I	11	658230
NE QUARTER OF SEC 4 AND NW QUARTER OF	TORTOISE (	DOD-CHOC	########	Augustine I	11	658398
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	DOD-CHOC	########	Augustine I	11	657703
MAPPED TO PROVIDED COORDINATES.	MALE TOR	DOD-CHOC	########	Augustine I	11	657298
ALONG COUNTY LINE. MAPPED TO PROVIDED	FEMALE TC	DOD-CHOC	########	Augustine I	11	656900
MAPPED T(HABITAT C(Developme	POTENTIAL	3 TORTOISI	BLM	########	Ogilby (321	11	702200
MAPPED T(HABITAT C(Developme	POTENTIAL	4 PIECES O	BLM	########	Ogilby (321	11	702226
MAPPED T(HABITAT C(ORV activit	POTENTIAL	CARCASS O	BLM	########	Hedges (32	11	701289
NEAR CENT HABITAT C(Developme	POTENTIAL	TORTOISE I	BLM	########	Clyde (321	11	697209
MAPPED T(HABITAT C(Developme	POTENTIAL	3 TORTOISI	BLM	########	Clyde (321	11	696777
MAPPED T(HABITAT C(Developme	POTENTIAL	3 TORTOISI	BLM	########	Clyde (321	11	696781
MAPPED T(HABITAT C(Developme	POTENTIAL	2 OLD BUR	BLM	########	Clyde (321	11	696503
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE I	BLM	########	Clyde (321	11	696236
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE I	BLM	########	Buzzards P(	11	699128
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE S	BLM	########	Buzzards P(	11	699443
MAPPED T(HABITAT C(Developme	POTENTIAL	2 TORTOISI	BLM	########	Buzzards P(	11	700093
MAPPED T(HABITAT C(Developme	POTENTIAL	2 TORTOISI	BLM	########	Buzzards P(	11	703313
MAPPED TO PROVIDED COORDINATES.	FEMALE TC	STATE LAN	########	Ninemile W	11	693530
MAPPED T(HABITAT C(Developme	POTENTIAL	MALE TOR	BLM	########	Buzzards P(	11	700826
MAPPED T(HABITAT C(ORV activit	POTENTIAL	4 PIECES O	BLM	########	Cibola (331	11	711595
MAPPED T(HABITAT CONSISTED OF OPEN SP/	TORTOISE (	BLM	########	Cibola (331	11	710951
MAPPED T(HABITAT C(ORV activit	POTENTIAL	TORTOISE (	BLM	########	Cibola (331	11	710448
MAPPED A IN SMALL ROCKY WASHES OFF RO	80+ PLANT	BLM	########	Mt. Barrow	11	695965
PLANTS FO GRANITIC SOIL GROWING WITH O	20+ PLANT	BLM	########	Mt. Barrow	11	691274
MAPPED T(HABITAT C(ORV activit	POTENTIAL	FRESH SCA	BLM	########	Clyde (321	11	697657
MAPPED T(HABITAT CONSISTED C	POTENTIAL	TORTOISE I	BLM	########	Ninemile W	11	695567
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE (	BLM	########	Ninemile W	11	697015
MAPPED T(THOUGHT Other	POTENTIAL	TORTOISE (	BLM	########	In-ko-pah (	11	587357
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE (	BLM	########	Ninemile W	11	694861
EAST SIDE (HABITAT C(Developme	POTENTIAL	3 TORTOISI	BLM	########	Ninemile W	11	695534
MAPPED T(HABITAT C(Developme	POTENTIAL	TORTOISE,	BLM	########	Ninemile W	11	696542
MAPPED T(HABITAT C(Developme	POTENTIAL	3 TORTOISI	BLM, STATI	########	Ninemile W	11	697434
MAPPED T(HABITAT C(Developme	POTENTIAL	9 LIVE, 5 DI	BLM	########	Mt. Barrow	11	697812
MAPPED T(HABITAT C(ORV activit	POTENTIAL	3 TORTOISI	BLM	########	Buzzards P(	11	700259

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MAPPED T(	HABITAT C(	ORV activit	POTENTIAL	FRESH SCA	BLM	########	Ogilby (321	11	702069
MAPPED T(	HABITAT C(	Developme	POTENTIAL	TORTOISE (	BLM	########	Chuckwalla	11	667889
NE SIDE OF	HERBACEO	ORV activit	SITE DISTU	~12 PLANT	BLM	########	Grays Well	11	700950
ABOUT 60	GROWING	Developme	NEAR OHV	2 MATURE	BLM?	########	Plaster City	11	612182
BETWEEN	TRANSMISSION POLES 8191 AND 8		ONLY SOUI		BLM	########	Grays Well	11	692862
MAPPED IN	SONORAN	Developme	THREATEN	2 PLANTS C	BLM	########	Coyote We	11	600809
MAPPED IN	GROWING IN ROCKY SOIL ON A LC		ONLY SOUI		BLM	########	Coyote We	11	594770
NORTH OF	SONORAN	Developme	THREATEN	1 PLANT OI	BLM	########	Plaster City	11	607763
MAPPED IN	SONORAN	Developme	THREATEN	2 PLANTS C	BLM	########	Plaster City	11	609725
NORTH OF	SONORAN	Developme	THREATEN	2 PLANTS C	BLM	########	Plaster City	11	610797
MAPPED IN	CREOSOTE	Developme	THREATEN	2 DEAD PL/	BLM	########	Plaster City	11	614589
MAPPED IN	SONORAN	Developme	THREATEN	3 PLANTS C	BLM	########	Painted Go	11	601698
MAPPED A(	GROWING IN ROCKY SOIL ON THE		ONLY SOUI		BLM	########	In-ko-pah (	11	593103
DIRECTION	SILTY, BROWN SOIL (MUDLANDS).		ONLY SOUI		BLM	########	Carrizo Mtı	11	586601
MAPPED IN	ROCKY FLA	Non-native	SOME WEE	100+ PLAN	BLM	########	Carrizo Mtı	11	589739
MAPPED IN	SANDY GRAVELLY WASH AREA IN		12 PLANTS		BLM	########	Carrizo Mtı	11	592384
EXACT LOCATION UNKNOWN. MAPPED AS BE			ONLY SOUI		BLM	########	Glamis NW	11	669467
EXACT LOCATION UNKNOWN. MAPPED BY CN			ONLY SOUI		UNKNOWN	########	Calexico (3	11	641015
LOCALITY (	DRY DESERT WASHES.		ONLY SOUI		BLM	########	Yuha Basin	11	616750
LOCATIONS	GROWING IN SANDY SOIL.		ONLY SOUI		UNKNOWN	########	Kane Spring	11	606854
NEAR 33 DI	FLATS AND STABILIZED DUNES, GE		ONLY SOUI		UNKNOWN	########	Harpers W(	11	599031
EXACT LOCATION UNKNOWN. MAPPED BY CN			ONLY SOUI		UNKNOWN	########	Niland (331	11	638042
MAPPED T(	LOW SANDY EW TRENDING RIDGE		UNKNOWN		DOD-NAVY	########	Glamis NW	11	664431
EXACT LOCATION UNKNOWN. MAPPED AS BE			ONLY SOUI		BLM	########	In-ko-pah (	11	592980
MAPPED O	IN ROCKY (	Non-native	THREATEN	10+ PLANT	BLM	########	In-ko-pah (	11	585949
MAPPED T(	HABITAT CONSISTED OF "BACKW/		2 INDIVIDU		USFWS-CIB	########	Cibola (331	11	714886
MAPPED T(	HABITAT CONSISTED OF "TAMARI		SINGING M		USFWS-IMI	########	Picacho NV	11	716349
EBIRD OBS	MOUNTAIN PLOVERS LIKELY USE I		50 REPORT		PVT	########	Niland (331	11	635746
MAPPED TO EBIRD COORDINATES & LOCATIO			15 DETECTI		UNKNOWN	########	Seeley (321	11	621565
MAPPED TO PROVIDED COORDINATES AND L(			ABOUT 80		PVT	########	Mount Sigr	11	622215
MAPPED TO PROVIDED COORDINATES AND L(			320 REPOR		PVT	########	Brawley NV	11	623912
MAPPED TO PROVIDED COORDINATES AND L(			16 DETECTI		PVT	########	Alamorio (3	11	642012
MAPPED TO PROVIDED COORDINATES AND L(			3 DETECTEI		DFG-IMPEF	########	Westmorla	11	639763
MAPPED TO PROVIDED COORDINATES AND L(			A GROUP C		PVT	########	Westmorla	11	635097
EXACT LOCATION UNKNOWN. MAPPED TO PI			2 DETECTEI		PVT	########	Westmorla	11	628845
MAPPED TO PROVIDED COORDINATES AND L(			3 DETECTEI		PVT	########	Calipatria S	11	626113
MAPPED TO PROVIDED COORDINATES AND L(			ONE OR M(		PVT	########	Calipatria S	11	626311
EXACT LOC	STONY HILLS.		ONLY SOUI		UNKNOWN	########	In-ko-pah (	11	583784
EAST OF UI	DESERT W/	Developme	POSSIBLY T	4 PLANTS C	BLM	########	Mount Sigr	11	623448
SOUTH OF	CREOSOTE	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Mount Sigr	11	621097
MAPPED B'	DESERT W/	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Mount Sigr	11	622200
MAPPED B'	DESERT W/	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Yuha Basin	11	615064
JUST SOUT	DESERT W/	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Yuha Basin	11	613983
JUST NORT	CREOSOTE	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Plaster City	11	613270
NORTH OF	CREOSOTE	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Plaster City	11	613603
NORTH OF	CREOSOTE	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Plaster City	11	614447
MAPPED B'	CREOSOTE	Developme	POSSIBLY T	1 PLANT OI	BLM	########	Plaster City	11	612304

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EXACT LOC	SANDY DESERT.	ONLY SOUI	BLM	########	Plaster City	11	608697
LOCATION	STATED AS "BOWLES AND LACK." I	ABOUT 20(	PVT	########	Calipatria S	11	626685
MAPPED T(	EXACT LOCATIONS NOT KNOWN A	903 DETEC	PVT	########	Wiest (331	11	644704
MAPPED T(	MOUNTAIN PLOVERS LIKELY USE I	449 REPOR	PVT	########	Wiest (331	11	648818
MAPPED TO	PROVIDED COORDINATES AND L	88 DETECTI	PVT	########	Niland (331	11	629018
MAPPED T(	MOUNTAIN PLOVERS LIKELY USE I	84 REPORT	PVT	########	Niland (331	11	631473
SEVERAL EI	MOUNTAIN PLOVERS LIKELY USE I	46 OBSERV	PVT	########	Iris (33115	11	641357
3 POLYGON	LARGE, OPI Developme	PROPOSED	FEWER TH/	BLM	########	In-ko-pah (	11	584369
EBIRD DETI	MOUNTAIN PLOVERS LIKELY USE I	AT LEAST 1	PVT	########	Niland (331	11	635616
MAPPED T(	MOUNTAIN PLOVERS MORE THAN	AT LEAST C	PVT	########	Niland (331	11	638555
MAPPED T(	MOUNTAIN PLOVERS LIKELY USE I	ONE OR M(	PVT	########	Niland (331	11	638080
MAPPED TO	PROVIDED COORDINATES AND L	SINGLE DE	BLM	########	Kane Spring	11	606253
EXACT LOC	ATION UNKNOWN. MAPPED TO PI	30 DETECTI	DPR-SALTC	########	Durmid (33	11	609786
MAPPED T(	HABITAT D Developme	POTENTIAL	1 ADULT O	BLM	########	In-ko-pah (	11	587518
NEAR CENT	WASH WIT Vehicle col	POSSIBLE C	1 ADULT O	BLM	########	In-ko-pah (	11	588747
STATED LO	43 ACRES OF RESTORED RIPARIAN	SPECIMENS	UNKNOWN	########	Yuma West	11	720744
MAPPED A	1910: MATURE WILLOWS, COTTO	UNKNOWN	USFWS, PV	########	Picacho (33	11	733380
MUSEUM SP	ECIMEN LOCALITY PROVIDED AS	1 MALE AN	UNKNOWN	########	Westmorla	11	628845
EXACT COL	LECTION LOCATIONS FOR MUSEUI	STAGER CC	UNKNOWN	########	Brawley (3	11	637820
MAPPED T(	DESCRIBED AS RIVER BOTTOM WI	AT LEAST 1	UNKNOWN	########	Bard (3211	11	726046
NO EXACT	LOCATIONS GIVEN; MUSEUM SPEC	4 COLLECTI	BLM, UNKN	########	Laguna Dar	11	734306
1977 SURV	EY BY BOAT FROM IMPERIAL TO LA	1 BIRD DET	BLM	########	Laguna Dar	11	735256
EXACT LOC	ATION OF MUSEUM SPECIMENS U	WILDER CC	UNKNOWN	########	Palo Verde	11	710433
EXACT LOC	ATION UNKNOWN; MAPPED TO BE	1 MALE AN	UNKNOWN	########	Palo Verde	11	713695
EXACT LOC	ATION UNKNOWN; MAPPED TO B(	1 MALE CO	UNKNOWN	########	Yuma West	11	713904
MAPPED TO	"20 MI. ABOVE PICACHO" PER GI	GRINNELL I	USFWS	########	Picacho NV	11	715769
MAPPED TO	PROVIDED MAP & LOCATION DE	ON 8 MAY	BLM	########	Yuma West	11	713904
EXACT LOC	ATION UNKNOWN, MAPPED TO BE	1 TAKEN B\	UNKNOWN	########	Cibola (331	11	711587
MAPPED T(	GRINNELL (1910) NOTED MANY SA	1 NEST FOU	BLM, UNKN	########	Imperial Re	11	737081
MAPPED T(	PENINSULA IN LOOP OF RIVER WI	GRINNELL (	BLM, UNKN	########	Palo Verde	11	720535
MAPPED A	LARGE WASH WITH HEAVY GROW	GRINNELL I	USFWS	########	Picacho NV	11	716848
DETECTION	HABITAT CONSISTED OF DENSE W	3 PRESUMI	DPR-PICAC	########	Picacho (33	11	724328
MAPPED T(	HABITAT "OF MARGINAL QUALITY	TWO CALIF	DFG-IMPEF	########	Wister (331	11	631105
MAPPED G	CONWAY (2007): "HAE "LAKE IS BU	UP TO 7 HE	DFG-IMPEF	########	Wiest (331	11	640028
MAPPED T(	GENERALLY DESCRIBED AS A SEEP	1-4 DETECT	BLM	########	Frink NW (3	11	623969
MAPPED T(	AREA IS CURRENTLY DEVELOPED A	2 SETS OF 5	UNKNOWN	########	Bard (3211	11	729107
MAPPED	APPROXIMATELY TO LOCATIONS DE	4 MALES &	UNKNOWN	########	Bard (3211	11	729610
MAPPED TO	LOCATIONS DESCRIBED AS "FOR"	1 FEMALE (	UNKNOWN	########	Yuma East	11	723447
MAPPED T(	HABITAT CONSISTED OF A BELT OI	NEST OBSE	UNKNOWN	########	Imperial Re	11	736636
1903: SAGI	1903, 1910 Over-collec	EXCESSIVE	2 NESTING	BLM, UNKN	########	Imperial Re	11	736636
EXACT LOC	ATION UNKNOWN. MAPPED BY CN	ONLY SOUI	UNKNOWN	########	Bard (3211	11	729107
EXACT LOC	NORTH-FACING SLOPES. ASSOCIA	ONLY SOUI	BLM?	########	Palo Verde	11	701929
HILLS ON S	NORTH-FACING ROCKY SLOPE.	ONLY SOUI	BLM	########	Picacho Pe	11	717408
MAPPED T(	TWO ELF O Agriculture	DESTRUCTI	TWO BIRDS	UNKNOWN	########	Bard (3211	11	729107
MAPPED T(	HABITAT CONSISTED OF MARSHLA	1 INDIVIDU	USFWS	########	Picacho SW	11	714056
MAPPED T(	HABITAT CONSISTED OF "BACKWA	1 INDIVIDU	USFWS	########	Cibola (331	11	715258
MAPPED G	1997 DETE Improper b	DISTRUBAN	0 ON 2 SUF	USBOR, DP	########	Picacho (33	11	722779

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MCKERNAI	1997 DETECTION IN MIXED SALT (	0 ON 2 SUF	USBOR, DP	########	Picacho SW	11	720678
NO SPECIFIC LOCATION GIVEN FOR MUSEUM		1 FEMALE (	UNKNOWN	########	Niland (331	11	628405
MAPPED TO "WESTMORLAND, 5 MI NW"; EX/		1 MALE CO	UNKNOWN	########	Calipatria S	11	622022
MAPPED TO COORDINATES GIVEN IN 2003 RE		1 MALE CA	DPR-OCOTI	########	Shell Reef (	11	586893
AT OR NEA MEDIUM LEVELS OF OHV USE. SIT		3 ADULT M	DPR-OCOTI	########	Shell Reef (	11	592711
1991 LOCA AREA DESCRIBED AS HAVING MEI		1 LIZARD D	DPR-OCOTI	########	Shell Reef (	11	592672
MAPPED TO PROVIDED COORDINATES.		1 FEMALE /	BLM	########	Shell Reef (	11	587531
ARRAY 14, TRANSECT 6 IN 2002 SURVEY. MAI		1 ADULT O	DPR-OCOTI	########	Shell Reef (	11	587006
SITE BTW II	DESCRIBED IN 2003 REPORT AS BA	1 ADULT M	DPR-OCOTI	########	Kane Spring	11	593891
MAPPED TO COORDINATES PROVIDED IN 200		1 ADULT M	BLM	########	Kane Spring	11	595367
GRINNELL S	ACCORDING TO GRINNELL'S FIELD	A MALE AN	USFWS	########	Picacho (33	11	733380
MAPPED TO PROVIDED COORDINATES.		1 FEMALE (	BLM, DPR-(	########	Kane Spring	11	595249
EXACT LOC 2002: CREOSOTE SCRUB ON LAKE		1 FLAT-TAII	BLM, UNKN	########	Kane Spring	11	596847
JUST NORT NEST FOUND "3.5 FEET UP, ON HC		DURING GI	UNKNOWN	########	Imperial Re	11	737081
EXACT DETECTION LOCATIONS NOT GIVEN; F(		1 FLAT-TAII	BLM	########	Plaster City	11	601389
MAPPED T(	HABITAT C(Developme	POTENTIAL	2007: 5 GR	UNKNOWN	########	Wister (33:	11	635689
EXACT LOC	DOMINANT PERENNIAL IS BURSA(	3 LIZARDS I	DPR-OCOTI	########	Shell Reef (	11	585326
MAPPED A	HABITAT CONSISTED OF A DREDG	2010: 3 INI	USFWS-CIB	########	Cibola (331	11	715209
MAPPED T(	HABITAT CONSISTED OF GOODDIN	2010: 2 INI	BLM	########	Laguna Dar	11	734965
DETECTION	LIZARD FO(Vehicle col	VEHICLE C(	1 FOUND D	BLM	########	Painted Go	11	596726
MAPPED T(	SONORAN Vehicle col	VEHICLE TR	1 ADULT FE	BLM	########	Painted Go	11	604671
1930 SPECI	SONORAN ORV activit	CONSTRUC	COLLECTED	BLM	########	Plaster City	11	607012
MAPPED T(	SPARSE VE(ORV activit	CONSTRUC	1 ADULT FE	UNKNOWN	########	Plaster City	11	608645
MAPPED T(	SPARSE CR Developme	VEHICLE TR	1 OBSERVE	BLM	########	Yuha Basin	11	615561
MAPPED A	SPARSELY \ ORV activit	TRAFFIC FR	1 ADULT AI	BLM	########	Plaster City	11	612430
MAPPED A	2010: FALL Developme	SOLAR PRC	1 FOUND C	BLM, PVT	########	Plaster City	11	613827
MAPPED A	IN 2010 TH Developme	SOLAR PRC	1 LIZARD D	PVT	########	Plaster City	11	613178
MAPPED T(	TAMARIX AND ATRIPLEX ON HARI	1 MALE OB	BLM, UNKN	########	Harpers W(	11	604319
MAPPED T(	HABITAT CONSISTED OF GOODDIN	1 INDIVIDU	USFWS-IMI	########	Picacho SW	11	714079
SPECIMENS WITH LOC	ORV activit	BETWEEN :	COLLECTED	BLM	########	Yuha Basin	11	616530
1978-2002	SUBSTRATE IS ROSITAS COARSE/L(	37 DETECTI	BLM	########	Yuha Basin	11	614208
DETECTED	2008: SONORAN CREOSOTE BUSH	1 FLAT-TAII	BLM	########	Plaster City	11	608701
DETECTED	2008: SONORAN CREOSOTE BUSH	1 ADULT SE	BLM	########	Plaster City	11	610527
MAPPED U	CREOSOTE BUSH - WHITE BURSAG	1 FLAT-TAII	BLM	########	Mount Sigr	11	620813
EXACT LOC	2011: CRE(Vehicle col	CONSTRUC	1 FLAT-TAII	BLM	########	Mount Sigr	11	619852
MAPPED T(	CREOSOTE Vehicle col	CONSTRUC	1 ADULT FE	BLM	########	Mount Sigr	11	618564
MAPPED T(	CREOSOTE Vehicle col	CONSTRUC	1 FLAT-TAII	BLM	########	Mount Sigr	11	617112
MAPPED T(	CREOSOTE ORV activit	OHV USE.	1 FLAT-TAII	BLM	########	Mount Sigr	11	619195
MAPPED U	CREOSOTE BUSH - WHITE BURSAG	1 FTHL DET	BLM	########	Mount Sigr	11	622994
MAPPED U	CREOSOTE BUSH - WHITE BURSAG	1 FTHL DET	BLM	########	Mount Sigr	11	623480
MAPPED T(	VEHICLE TRACK DENSITY ASSESSEI	LSU #1556:	BLM	########	Glamis SW	11	664274
LOCATION	WETLAND FIELD ACTIV	POSSIBLE P	1 DETECTEI	PVT-IMPER	########	Wister (33:	11	629969
MAPPED T(	FURTHER R Biocides | I	BOTULISM	BROWN PE	PVT-IMPER	########	Truckhaver	11	598539
LOCATION	WETLAND FIELD ACTIV	POSSIBLE P	1 DETECTEI	DFG-IMPEF	########	Wister (33:	11	632599
MAPPED TO POINT RE'	Biocides | I	BOTULISM	BROWN PE	PVT-IMPER	########	Kane Spring	11	615086
MAPPED TO POINT RE'	Biocides | I	BOTULISM	BROWN PE	PVT-IMPER	########	Wister (33:	11	630460
SPECIMEN	CARDIFF (1978) NOTED THAT THE	HUEY AND	UNKNOWN	########	Bard (3211	11	733478

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SURVEY DA	OPEN, GEN	Other | Po	POTENTIAL	EGG SETS (	PVT-IMPER	########	Truckhaver	11	598539
SURVEY DA	OPEN, GEN	Other | Po	POTENTIAL	EGG SETS (	UNKNOWN	########	Wister (33	11	628252
MAPPED B'	GROWING	IN A SMALL	ROCKY CAI	50 PLANTS	BLM	########	Coyote We	11	599031
MAPPED B'	GROWING	Foot traffic	FOOT TRAF	FEWER TH/	BLM	########	Coyote We	11	599535
EAST OF PC	IN CLAY AN	ORV activit	OFF-ROAD	GREATER T	UNKNOWN	########	Harpers W	11	595531
720 METEF	CLAY SOIL I	ORV activit	OFF-ROAD	GREATER T	DFG-SAN F	########	Harpers W	11	601664
MAPPED A	ASSOCIATED	WITH ASCLEPIAS ALE	ONLY SOUI	UNKNOWN	########	Hedges (32	11	704203
EXACT LOCATION UNKNOWN. MAPPED IN TH			MAIN SOU	BLM	########	East of Aco	11	676690
MAPPED A	GROWING	IN SMALL	ROCKY DRAI	60 PLANTS	BLM	########	Buzzards P	11	698766
MAPPED A	SCATTERED	IN ROCKY/GRAVELLY \	FEWER TH/	BLM	########	Carrizo Mtı	11	588575
ON STEEP (	ROCKY	CANYON WITH LARREA TR	OVER 50 PI	BLM	########	Carrizo Mtı	11	588575
COLLECTION LABEL SAYS "...AT CA			HIGHWAY	ONLY SOUI	UNKNOWN	########	In-ko-pah (	11	592183
IN THE SW	ROCKY, GR	Developme	THREATEN	3 PLANTS (	BLM	########	In-ko-pah (	11	584396
MAPPED A	LARGE, OP	Developme	THREATEN	8 PLANTS S	BLM	########	In-ko-pah (	11	584396
MAPPED A	NARROW,	ORV activit	AREA DIST	35-45 PLAI	BLM	########	In-ko-pah (	11	588299
MAPPED A	ROCKY SLO	ORV activit	AREA DIST	100+ PLAN	BLM	########	In-ko-pah (	11	585352
IN WASH A	BOULDERY	Foot traffic	AREA DIST	35+ PLANT	UNKNOWN	########	In-ko-pah (	11	586567
MAPPED A	NARROW,	ORV activit	THREATEN	25+ PLANT	BLM	########	In-ko-pah (	11	585578
IN THE NW	ROCKY SLO	Foot traffic	AREA DIST	24 PLANTS	UNKNOWN	########	In-ko-pah (	11	586567
MAPPED A	BOULDERY	ORV activit	THREATEN	50+ PLANT	BLM	########	In-ko-pah (	11	584647
IN THE NE :	GRAVELLY	ORV activit	THREATEN	12 PLANTS	BLM	########	In-ko-pah (	11	585578
IN THE NE :	BOULDERY	ORV activit	THREATEN	AROUND 5	BLM	########	In-ko-pah (	11	584647
MAPPED A	SANDY SOIL, SONORAN DESERT SC		ONLY SOUI	UNKNOWN	########	In-ko-pah (	11	583825
MAPPED A	NARROW,	ORV activit	AREA DIST	UNKNOWN	BLM	########	In-ko-pah (	11	588299
MAPPED A	BOULDERY	Foot traffic	AREA DIST	6 PLANTS (	UNKNOWN	########	In-ko-pah (	11	586567
MAPPED A	BOULDERY	ORV activit	THREATEN	30-40 PLAI	BLM	########	In-ko-pah (	11	584647
MAPPED A	NARROW,	ORV activit	AREA DIST	3 PLANTS I	BLM	########	In-ko-pah (	11	588299
ON THE WI	PRIMARILY	Non-native	CYNODON	OVER 1000	BLM	########	Cibola (331	11	711860
NEAR ABAI	LARGE, OP	Developme	AREA DIST	TYPE LOCA	BLM	########	In-ko-pah (	11	585382
MAPPED B'	IN LARGE D	ORV activit	IN MAMM(	HUNDREDS	BLM	########	Amos (331	11	660794
MAPPED B'	IN BROAD I	ORV activit	IN MAMM(	HUNDREDS	BLM	########	Tortuga (3	11	660409
NORTH SID	IN A POND	Non-native	INVADED B	230 PLANT	BLM	########	Kane Spring	11	593511
NORTH SID	IN DISTURE	ORV activit	POSSIBLY T	25 PLANTS	BLM	########	Shell Reef (	11	586733
ON THE NC	IN SMALL S	ORV activit	POSSIBLY T	17 PLANTS	DPR-OCOT	########	Shell Reef (	11	589072
MAPPED T(	ROCK OUTCROP.		NEST DETE	BLM, UNKN	########	Carrizo Mtı	11	592687
IN GRAVEL	NARROW,	ORV activit	THREATEN	7 PLANTS (	BLM	########	In-ko-pah (	11	585578
PLANTS SEI	BOULDERY	ORV activit	THREATEN	APPROXIM	BLM	########	In-ko-pah (	11	584647
MAPPED A	NARROW,	ORV activit	AREA DIST	6-10 PLAN	BLM	########	In-ko-pah (	11	588299
MAPPED TO PROVIDED COORDINATES. COOR			BREEDING	BLM	########	Buzzards P	11	699980
EXACT LOCATION UNKNOWN. MAPPED AS BE			ONLY SOUI	BLM?	########	Palo Verde	11	701929
MAPPED T(	HABITAT	DESCRIBED AS DESERT R	1 ADULT AI	USFWS, DF	########	Picacho SW	11	713820
LOCATION	BONYTAILS	Non-native	POTENTIAL	POND USEI	USFWS-CIB	########	Cibola (331	11	713879
MAPPED W	HABITAT C	Altered flo	THREATEN	GRINNELL (	USFWS-CIB	########	Cibola (331	11	712545
LOCATION	DOMINATED	BY DENSI	POTENTIAL	POND USEI	USFWS-CIB	########	Cibola (331	11	713879
ALL FISH W	GALLEANO	RESERVOIR IS A COMP	3 CAPTURE	UNKNOWN	########	Wister (33	11	637354
MAPPED TO ENTIRETY OF RAMER LAKE.			1 RAZORBA	DFG-IMPEF	########	Westmorla	11	638930
MAPPED TO AREA NEAR "BOMBAY BEACH" A			1 RAZORBA	DPR-SALTC	########	Frink (3311	11	619775

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MAPPED TO LOCATION DESCRIBED AS "NEAR	1	RAZORBA	PVT-IMPER	########	Niland (331	11	631473
MARCH COLLECTION LOCATION WAS "0.125-(	24	RAZORB	BLM, UNKN	########	Bard (3211	11	733944
COLLECTION LOCATION WAS "TRAVERTINE R(	1	RAZORBA	UNKNOWN	########	Oasis (3311	11	587908
COLLECTION LOCATION WAS "ALAMO RIVER,	1	RAZORBA	PVT	########	Westmorla	11	634093
MAPPED T(GENERAL AREA DESCRIBED AS "C(	2	CRISSAL T	BLM, PVT-S	########	Thumb Pea	11	705021
MAPPED T(GENERAL A Developme	THIS AREA	1	LE CONTE	PVT-SDGE,	########	Thumb Pea	11	706718
MAPPED B' DRY, CRACKED, SILTY DEPRESSION	OVER 40 PI	BLM	########	Amos (331	11	660866
MAPPED T(HABITAT D ORV activit	OFF HIGHV	SCUTE "LES	UNKNOWN	########	Thumb Pea	11	708529
MAPPED T(TOPOGRAPHY: FLAT. SOIL TYPE: P.	1	MALE DE	BLM	########	Thumb Pea	11	705045
MAPPED T(DESERT W/ ORV activit	POTENTIAL	2	ADULT LE	BLM, UNKN	########	Thumb Pea	11	708122
PLEASE CO GEOMORPHOLOGY: DOME. SUPPORTING	STRUCTURE: S(	########	Thumb Pea	0	
MAPPED B' ROCKY PLACES IN A GRANITIC BO(	12	PLANTS	BLM	########	In-ko-pah (	11	588641
EXACT LOC SANDBAR. OPEN SANDY SOIL.	MAIN SOU	UNKNOWN	########	Yuma West	11	721786
EXACT LOC EAST MARGIN OF DUNES.	ONLY SOUI	BLM	########	Clyde (321	11	686928
EXACT LOC SILTY DEPRESSIONS IN MICROPHY	FEWER TH/	BLM	########	Amos (331	11	659888
2 POLYGON GRANITIC, BOULDERY CANYON W	40+	PLANT	BLM	########	In-ko-pah (	11	588641
LOCALITY S ACCORDING TO JENNINGS (1983),	1	COLLECTI	UNKNOWN	########	Bard (3211	11	729107
LOCALITY I! ACCORDING TO JENNINGS (1983),	1	COLLECTI	UNKNOWN	########	Bonds Corr	11	660029
LOCALITY I! ACCORDING TO JENNINGS (1983),	1	COLLECTI	UNKNOWN	########	Palo Verde	11	710433
EXACT LOCATION UNKNOWN. MAPPED IN TH	ONLY SOUI	BLM	########	East of Aco	11	676690
PLANTS WI ROCKY/BOULDERY CANYON WITH	APPROXIM	BLM	########	In-ko-pah (	11	586504
SPECIMEN ACCORDING TO JENNINGS (1983),	VAN DENBI	UNKNOWN	########	Yuma West	11	721786
SPECIMEN ACCORDING TO JENNINGS (1983),	ONE ADULT	UNKNOWN	########	Laguna Dar	11	734306
MAPPED ACCORDING TO COORDINATES PRO'	UNKNOWN	BLM	########	Glamis NW	11	670676
MAPPED APPROXIMATELY TO LOCALITY STAT	1	COLLECTI	UNKNOWN	########	Little Picac	11	733257
MAPPED TO LOCALITY STATED AS "TUMCO M	1	MALE CO	UNKNOWN	########	Hedges (32	11	704351
MAPPED GENERALLY TO THE ENTRANCE TO S	1	COLLECTI	UNKNOWN	########	Yuma East	11	723447
MAPPED A SHALLOW DUNES AND SANDY SOI	ONLY SOUI	UNKNOWN	########	Ogilby (321	11	701564
MAPPED A SMALL DRA ORV activit	OHV, GARE	20	PLANTS	BLM	########	Ninemile W	11	694739
MAPPED A SMALL DRA ORV activit	OHV, GARE	30-40	PLAN	BLM	########	Ninemile W	11	694701
MAPPED AS BEST GUESS BY CNDDB ALONG TI	ONLY SOUI	UNKNOWN	########	Mammoth	11	663393
LOCALITY (ALLUVIAL SLOPE NEAR LOW VOLC	ONE SOLIT/	BLM	########	Chuckwalla	11	669152
SCATTERED SILTY PLAY/ ORV activit	OHV, TRAF	25-30	PLAN	BLM	########	Coyote We	11	603965
SCATTERED LARGE, SIL ORV activit	OHV, HEAV	GREATER T	BLM	########	Coyote We	11	598226
ON SANDY, OPEN, ROC ORV activit	OHV, HIGH	6	LARGE IN	BLM	########	Picacho Pe	11	721532
ON ROCKY ROCKY CAN ORV activit	OHV, HIGH	1	LARGE, R	BLM	########	Picacho Pe	11	721487
MAPPED B' ON ROCKY ORV activit	OHV, HEAV	5	SHRUBS S	BLM	########	Coyote We	11	599602
MAPPED B' GROWING ON ROCKY OUTCROPPI	TWO SHRU	BLM	########	In-ko-pah (	11	584396
EXACT LOC ASSOCIATES INCLUDE HILARIA SP. 'COMMON	BLM	########	Wiley Well	11	694871
MAPPED B' RUGGED R(ORV activit	OHV, MINI	OVER 50 IN	BLM	########	Painted Go	11	594453
OPEN FLAT A LARGE SI ORV activit	OHV, HEAV	APPROXIM	BLM	########	Coyote We	11	598226
NORTHWE! SONORAN DESERT SCRUB ON GRA	ONLY SOUI	BLM	########	In-ko-pah (	11	588226
MAPPED A! ON LOOSE ORV activit	OHV.	WEST POLY	BLM, DOD	########	Amos (331	11	658611
MAPPED B' DENSE RIPARIAN WILLOW GROVE	10	CUCKOO	USFWS-IMI	########	Picacho NV	11	716440
MAPPED T(CREOSOTE- ORV activit	OVERUSE E	1	ADULT O	BLM	########	Borrego M	11	587561
LOCATION HABITAT DESCRIBED AS CREOSOT	1	JUVENILE	UNKNOWN	########	Borrego M	11	589411
LOCATION HABITAT DESCRIBED AS SANDY DE	1	YEARLIN(	UNKNOWN	########	Borrego M	11	588854

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MAPPED T(	HABITAT DESCRIBED AS "SAND DL	1	ADULT O	BLM	########	Coyote We	11	599972
MAPPED T(	LIZARD DE1	ORV activit	OHV USE.	1	LIZARD A	BLM	########	Yuha Basin	11	615415
DETECTED	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Yuha Basin	11	616389
ALONG AC(	ROCKY ANI	ORV activit	SURVEYOR	1	ADULT F(	BLM	########	Mount Sigr	11	619033
MAPPED TO INCLUDE SPECIFIC LOCATION GI\				1	LIZARD F(	BLM	########	Mount Sigr	11	621912
WITHIN A (	CREOSOTE SCRUB WITH SUBSTRA			1	ADULT FE	DOD	########	Amos (331	11	660250
MAPPED T(	CREOSOTE SCRUB WITH SUBSTRA			1	ADULT M	UNKNOWN	########	Glamis NW	11	664003
MAPPED T(	CREOSOTE SCRUB WITH SUBSTRA			2	ADULT M	UNKNOWN	########	Glamis NW	11	665739
MAPPED T(	MUD HILLS, SAND/GRAVEL FLATS,			1	ADULT O	DPR-SALTC	########	Durmid (33	11	613944
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Yuha Basin	11	615158
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Glamis SW	11	673349
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Glamis SE (	11	677721
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Glamis SE (	11	677793
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	3	BLM	########	Glamis SE (	11	677238
MAPPED GENERALLY TO LOCALITY GIVEN FOF				1	COLLECTI	UNKNOWN	########	Midway W(	11	670237
1979 & 19{	1979 AND 1986 SURVEYORS ASSU			1	LIZARD A	BLM	########	Midway W(	11	670392
1993 DETE(	2001: VEHICLE TRACK DENSITY AS			1	LIZARD D	BLM	########	Glamis SW	11	670710
MAPPED T(	VEHICLE TRACK DENSITY ASSESSEI			AT LEAST	1	BLM	########	Glamis SW	11	670822
MAPPED T(	ACCESS RO	Road/trail (	VEHICLE C(	1	OLD CAR(	BOR	########	Midway W(	11	667359
MAPPED T(	ACCESS RO	Road/trail (	VEHICLE C(	1	CARCASS	BOR	########	Midway W(	11	666931
MAPPED T(	SANDY CRE	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Midway W(	11	672906
MAPPED TO COORDINATES GIVEN FOR 2010				1	COLLECTI	BLM	########	Midway W(	11	677856
1936 SPECI	1984 SURVEYORS ASSUMED THE S			1	FLAT-TAII	BLM, USBC	########	Midway W(	11	679641
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	AT LEAST	1	BLM	########	Glamis SE (	11	677075
MAPPED T(	VEHICLE TF	ORV activit	OHV IMPA(	1	LIZARD F(	BLM	########	Midway W(	11	682017
DETECTION	SURVEYORS PRESUMED THE SCAT			1	LIZARD A	BLM	########	Midway W(	11	684415
A 1984 SUF	1984 SURVEYORS ASSUMED THE S			1	ADULT O	USBOR	########	Midway W(	11	683753
MAPPED TO PROVIDED COORDINATES.				6	CAUGHT	BLM	########	Yuha Basin	11	612986
MAPPED T(	FLAT, SANDY AREA NEAR ALLUVIA			MARK AND		BLM	########	Mount Sigr	11	618226
LOCATION GIVEN ONLY AS T16.5S R12E SEC 2				1	LIZARD D	BLM, UNKN	########	Mount Sigr	11	621525
LOCATION GIVEN ONLY AS T17S R13E SECTIO				1	LIZARD D	BLM	########	Mount Sigr	11	623319
MAPPED T(	LOWER PINTO WASH. SANDY, SEE			MARK AND		BLM	########	Mount Sigr	11	617866
1993 DETE(	2002 PLOT WAS IN FEEDER WASH			1	LIZARD D	BLM	########	Yuha Basin	11	612832
MAPPED T(	SOUTHERN SHOULDER OF PINTO \			MARK AND		BLM	########	Yuha Basin	11	613786
2002: MAP	2002: FLAT	Other	BORDER PA	MARK AND		BLM	########	Yuha Basin	11	610455
MAPPED T(	FLAT, GRAVEL HARDPAN BETWEEI			MARK AND		BLM	########	Yuha Basin	11	614280
MAPPED T(	ROCKY GROUND WITH FEW PERE(			MARK AND		BLM	########	Yuha Basin	11	608012
LOCATION GIVEN AS T17S, R11E, SECTION 6. I				1	LIZARD D	BLM	########	Coyote We	11	603660
MAPPED T(	FINE GRAVEL BEDS AND GRAVEL I			1	FLAT-TAII	BLM	########	Yuha Basin	11	606079
MAPPED T(	SPARSELY \	ORV activit	OHVS, BOR	1	FLAT-TAII	BLM	########	Yuha Basin	11	615493
MAPPED T(	SPARSELY \	Developme	DEVELOPM	2	ADULTS A	BLM	########	Painted Go	11	596180
MAPPED T(	FOUND ON	Military op	MILITARY A	2	LIZARDS I	DOD	########	Plaster City	11	607606
MAPPED T(	FOUND ON	Military op	MILITARY A	1	FEMALE (	DOD	########	Plaster City	11	608899
1978 SPECIMEN FROM		Military op	MILITARY A	1	COLLECTI	DOD	########	Superstitio	11	610172
MAPPED TO GIVEN COORDINATES.				1	LIZARD C.	BLM	########	Superstitio	11	611380
MAPPED TO GIVEN COORDINATES.				1	LIZARD C.	BLM	########	Superstitio	11	610536
LOCATION ONLY GIVEN AS T14S, R11E, SECTI(				1	LIZARD D	BLM	########	Superstitio	11	605225

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MAPPED TO LOCATION GIVEN FOR PLOT WM		11 ADULTS	BLM	########	Superstitio	11	606290
1987 LOCATION GIVEN ONLY AS T14S, R10E, S		1 FLAT-TAI	BLM	########	Plaster City	11	603697
MAPPED A	FOUND ON PAVED ROAD.	4 LIZARDS I	DOD	########	Superstitio	11	611440
1990 TO 19	MAINLY HARDPAN SUBSTRATE, TH	284 CAUGH	DOD-NAVY	########	Superstitio	11	616477
DETECTED IN T14S, R1	Vehicle col TRAFFIC OI	2 LIZARDS /	DOD	########	Brawley NV	11	620267
LOCATION GIVEN AS T14S, R11E, SECTION 24.		1 LIZARD A	BLM, DOD	########	Superstitio	11	613315
LOCATIONS GIVEN AS T13S, R11E, SECTIONS 1		2 LIZARDS	BLM	########	Kane Spring	11	610056
LOCATION GIVEN AS T13S, R11E, SECTION 32.		1 LIZARD D	BLM	########	Superstitio	11	606772
LOCATION GIVEN AS T14S, R10E, SECTION 21.		1 LIZARD D	BLM	########	Plaster City	11	598781
LOCATION GIVEN AS T14S, R10E, SECTION 32.		1 LIZARD D	BLM	########	Plaster City	11	597226
DETECTION	FOUND ON ROAD THROUGH A LO	1 JUVENILE	UNKNOWN	########	Kane Spring	11	607388
MAPPED TO PROVIDED COORDINATES.		1 ADULT FE	DPR-OCOTI	########	Kane Spring	11	593715
1991 DETECTION WITH LOCATION GIVEN ONI		1 LIZARD D	BLM	########	Shell Reef (	11	592918
MAPPED TO GIVEN COORDINATES FROM 199		1 DETECTEI	DPR-OCOTI	########	Shell Reef (	11	586140
MAPPED TO GIVEN COORDINATES.		3 LIZARDS I	DPR-OCOTI	########	Shell Reef (	11	586845
MAPPED TO PROVIDED COORDINATES.		1 MALE LIZ	DPR-OCOTI	########	Shell Reef (	11	585714
MAPPED TO GIVEN COORDINATES FROM 199		1 LIZARD D	UNKNOWN	########	Shell Reef (	11	586293
LOCATION	SCAT FOUND WAS PRESUMED TO	1 LIZARD A	DOD	########	Plaster City	11	607028
MAPPED T(	RELEASE SI Developme	SOLAR PRC	1 HEALTHY	BLM	########	Plaster City	11	611958
MAPPED T(	FOUND ON Developme	SOLAR PRC	1 INJURED	PVT	########	Plaster City	11	614625
MAPPED T(	FOUND UN Developme	SOLAR PRC	1 MALE AD	PVT	########	Plaster City	11	613593
MAPPED A	CAUGHT AT ACTIVE SC SOLAR PRC	1 ADULT LI	PVT-SEVILL	########	Harpers W	11	593738
MAPPED T(	RELOCATION SITE CHARACTERIZEI	1 ADULT LI	BLM	########	Borrego M	11	591267
MAPPED GENERALLY TO GIVEN LOCALITY, "H(		COLLECTEI	UNKNOWN	########	Glamis SW	11	667188
MAPPED T(	OLD AGRIC Developme	CONSTRUC	1 ADULT C/	BLM, PVT	########	Shell Reef (	11	593183
MAPPED T(	LIZARDS FC Developme	CONSTRUC	1 LIZARD C	PVT	########	Borrego M	11	592836
MAPPED T(	LIZARD CAUGHT ON CONSTRUCTI	1 LIZARD C	BLM	########	Borrego M	11	591256
MAPPED T(	LIZARD CAUGHT IN CONSTRUCTIO	1 LIZARD C	PVT	########	Borrego M	11	592418
MAPPED T(	LIZARD CAUGHT IN CONSTRUCTIO	1 LIZARD C	PVT	########	Borrego M	11	592874
LOCATION GIVEN AS T15S, R17E, SECTION 14.		1 FLAT-TAI	BLM	########	Glamis SW	11	669693
EXACT LOCATION UNKNOWN. MAPPED BY CI		COLLECTIO	UNKNOWN	########	Brawley (32	11	637820
EXACT LOCATION UNKNOWN. THE LOCALITY		COLLECTEI	BLM	########	Glamis (321	11	679398
MAPPED T(	DESERT SIN	Vehicle col TRAFFIC AL	1 ADULT O	UNKNOWN	########	Truckhaver	11	602450
STEPHENS DESCRIBES THIS SITE WELL IN HIS F		TYPE SPECI	DPR-ANZA-	########	Carrizo Mtı	11	583812
ELLS.		1 COLLECTI	UNKNOWN	########	Coyote We	11	597024
LOCATION	BROAD, FLAT VALLEY ONCE A LAR	1 FEMALE /	DFG, BLM	########	Harpers W	11	601408
EXACT LOCATION UNKNOWN. MAPPED IN TH		5 COLLECTI	UNKNOWN	########	Palo Verde	11	710433
MAPPED GENERALLY TO HISTORIC SILSBEE SC		1 FEMALE (	UNKNOWN	########	Seeley (321	11	627562
EXACT LOCATION UNKNOWN. MAPPED BASE		ONE COLLE	UNKNOWN	########	Bard (3211	11	726046
MAPPED TO PROVIDED COORDINATES.		1 CAUGHT	DPR-OCOTI	########	Shell Reef (	11	590142
MAPPED TO PROVIDED COORDINATES.		1 CAUGHT	DPR-OCOTI	########	Seventeen	11	587833
MAPPED TO PROVIDED COORDINATES.		1 CAUGHT	BLM	########	Painted Go	11	594632
MAPPED T(	SURROUNI	Other	PONDS WE	POND #3: (	IMPERIAL I	########	Niland (331	11	632025
MAPPED T(	AGRICULTURAL DRAIN TO THE SAI	1 JUVENILE	IMPERIAL I	########	Niland (331	11	631875
MAPPED T(	AGRICULTURAL DRAIN TO THE SAI	NONE FOU	DFG-IMPEF	########	Wister (33:	11	631004
MAPPED T(	AGRICULTU	Non-native	NON-NATI\	NONE FOU	IMPERIAL I	########	Calipatria S	11	622693
PLEASE CO	THIS AREA IS NOW PART OF BLM'S JACUMBA WILDERNES				########	Coyote We	0	

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MAPPED T(	DETECTION ON TRAIL IN DESERT S	1 ADULT O	USFWS-SOI	########	Niland (331	11	628753
PLEASE CO	SOME OF THE LAND IN THIS AREA	IS MANAGED BY BLM,		########	In-ko-pah (	0	
ACCORDIN	HABITAT WAS ROCKY DESERT MO	2 COLLECTI	UNKNOWN	########	In-ko-pah (	11	583857
NITY OF OL	ACCORDING TO KLAUBER (1946) \	SPECIMENS	UNKNOWN	########	In-ko-pah (	11	583905
MAPPED T(	THE SMALL Non-native	TAMARISK	6-10 DETE(	DPR-ANZA-	########	Carrizo Mtı	11	583665
A, IMPERIAI	THOUGH IT IS NOT ENTIRELY CLEA	W. M. GAB	UNKNOWN	########	Yuma East	11	723447
LOCATIONS	JANUARY COLLECTION WAS FOUN	THOUGH L(	DFG, USFW	########	Niland (331	11	632188
MAPPED G	MUCH OF THE LANDSCAPE WAS D	ONE WAS (	BLM	########	Quartz Pea	11	701990
EXACT LOC	WITH LARREA AND AMBROSIA.	ONLY SOUI	UNKNOWN	########	Yuma West	11	715730
EXACT LOC	WASTE DISTURBED PLACES.	ONLY SOUI	UNKNOWN	########	Laguna Dar	11	734306
EXACT LOC	ROCKY SLOPE, WITH ENCELIA FAR	ONLY SOUI	BLM?	########	Picacho Pe	11	721225
EXACT LOC	STEEP-WALLED CANYON WITH SA	ONLY SOUI	BLM	########	Carrizo Mtı	11	591377
EXACT LOCATION UNKNOWN. MAPPED AS BE		ONLY SOUI	UNKNOWN	########	Frink NW (3	11	622746
CLOSE TO SUMMIT OF BARREN GYPSUM MOI		ABOUT 5 P	PVT	########	Carrizo Mtı	11	584544
MAPPED T(	THE MANAGED MARSH COMPLEX	ONE WAS [	IMPERIAL I	########	Niland (331	11	637397
MAPPED T(	RIGHT-OF-WAY AND AGRICULTUR	2 ADULTS /	UNKNOWN	########	Bonds Corr	11	660307
MAPPED A(	GROWING IN BOULDER CRACKS B	15-30 PLAN	BLM	########	In-ko-pah (	11	585041
MAPPED A(	ON COMPACT SANDY SLOPES.	SITE BASEC	BLM	########	In-ko-pah (	11	591989
MAPPED A(	SANDY DR/	ORV activit	OHV, TRAN	70+ PLANT	BLM	########	In-ko-pah (	11	588595
MAPPED A:	POPULATIONS OF CYLINDROPUNT	ABOUT 10(	BLM	########	In-ko-pah (	11	586010
MAPPED A(	POPULATIONS OF CYLINDROPUNT	15 PLANTS	BLM	########	In-ko-pah (	11	586819
MAPPED A:	CREOSOTE	ORV activit	MINOR THI	DURING 20	BLM	########	In-ko-pah (	11	589057
MAPPED A(	CREOSOTE	ORV activit	MINOR THI	75 PLANTS	BLM	########	Carrizo Mtı	11	588006
MAPPED	ACCORDING TO 2017 MORSE COOR	UNKNOWN	DPR-ANZA-	########	Borrego M(	11	584218
MAPPED A(	IN AMONGST BOULDERS. BOULDE	3 SPRAWLI	BLM	########	In-ko-pah (	11	585041
MAPPED	ACCORDING TO 2017 MORSE COOR	UNKNOWN	UNKNOWN	########	Borrego M(	11	589699
MAPPED A(	ON THE EDGE OF CREOSOTE SCRU	1 PLANT OI	BLM	########	Acolita (33	11	667204
MAPPED A(	DESERT WASH WOODLAND. 5% SI	1 PLANT OI	BLM	########	Tortuga (33	11	661035
MAPPED A:	PRIMARILY DESERT W/	NONE.	48 PLANTS	BLM	########	Little Mule	11	682564
MAPPED B'	DESERT UNICORN PLANTS ALSO A	OBSERVED	UNKNOWN	########	Chuckwalla	11	674212
MAPPED T(	SPARSE CREOSOTE, SALTBUSH AN	3 ADULT FE	UNKNOWN	########	Kane Spring	11	606413
MAPPED T(	DESERT HARDPAN WITH SPARSE (	1 ADULT W	UNKNOWN	########	Kane Spring	11	605274
MAPPED A:	WASTE GROUND.	ONLY SOUI	BLM?	########	Imperial Re	11	736636
LLEY NEAR I	DESERT WASH. THIS AREA IS ABOU	INTACT, FR	BLM	########	In-ko-pah (	11	593664
MAPPED T(	PRIMARILY ORV activit	OHV USE, F	1 JUVENILE	BLM	########	Glamis NW	11	671386
MAPPED T(	CREOSOTE	ORV activit	OHV USE.	40 DETECT	BLM	########	Superstitio	11	606280
MAPPED T(	CREOSOTE SCRUB ON SANDY SUB	2 ADULTS (	BLM	########	Glamis SW	11	666296
MAPPED T(	ROAD THROUGH CREOSOTE SCRU	1 ADULT O	DOD-NAVY	########	Superstitio	11	616594
MAPPED T(	CREOSOTE SCRUB WITH A FEW PA	15 ADULTS	BLM	########	Yuha Basin	11	614473
MAPPED T(	OPEN CRE(	Military op	MILITARY L	24 ADULTS	DOD-NAVY	########	Brawley NV	11	616843
MAPPED T(	PAVED PUE	Vehicle col	VEHICLE ST	1 ADULT M	DOD-NAVY	########	Brawley NV	11	621626
FORT YUM/	ROADSIDES.	ONLY SOUI	BIA-FORT Y	########	Yuma West	11	721345
MAPPED	TO PROVIDED COORDINATES.	1 ADULT &	BLM	########	Tortuga (33	11	655337
MAPPED	TO PROVIDED COORDINATES.	1 ADULT M	BLM	########	Frink NW (3	11	616972
MAPPED A(	ROOTED BELOW OUTC	NONE APP/	SINGLE PLA	BLM	########	Palo Verde	11	703288
MAPPED T(	DETECTED	Vehicle col	VEHICLE ST	1 ADULT O	BLM	########	In-ko-pah (	11	589728
MAPPED N	FOUND ON ITS LARVAL HOST PLAI	COLLECTIO	BLM	########	Glamis (32:	11	678720

EEC ORIGINAL PKG

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MAPPED NON-SPECIFICALLY ACROSS THE EXT	COLLECTIO	BLM	########	Glamis (32	11	681857
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EEC ORIGINAL PKG

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EEC ORIGINAL PKG

Scientific_Name	Common_Name	Element_Code	Occ_Number	MAPNDX
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	43	6251
Setophaga petechia	yellow warbler	ABPBX03010	32	6328
Athene cunicularia	burrowing owl	ABNSB10010	107	17289
Mentzelia hirsutissima	hairy stickleaf	PDLOA030K0	1	37025
Incilius alvarius	Sonoran desert toad	AAABB01010	3	43447
Abronia villosa var. aurita	chaparral sand-verbena	PDNYC010P1	1	6328
Euphorbia abramsiana	Abrams' spurge	PDEUP0D010	3	45965
Euphorbia abramsiana	Abrams' spurge	PDEUP0D010	1	6328
Pholisma sonorae	sand food	PDLNN02020	26	43447
Athene cunicularia	burrowing owl	ABNSB10010	523	49108
Athene cunicularia	burrowing owl	ABNSB10010	526	49116
Athene cunicularia	burrowing owl	ABNSB10010	533	49169
Athene cunicularia	burrowing owl	ABNSB10010	534	49174
Athene cunicularia	burrowing owl	ABNSB10010	535	49175
Athene cunicularia	burrowing owl	ABNSB10010	568	51255
Athene cunicularia	burrowing owl	ABNSB10010	576	51268
Athene cunicularia	burrowing owl	ABNSB10010	583	51277
Athene cunicularia	burrowing owl	ABNSB10010	595	51578
Athene cunicularia	burrowing owl	ABNSB10010	596	51584
Athene cunicularia	burrowing owl	ABNSB10010	598	51610
Buteo regalis	ferruginous hawk	ABNKC19120	8	52945
Taxidea taxus	American badger	AMAJF04010	139	56801
Taxidea taxus	American badger	AMAJF04010	258	6328
Lasiurus xanthinus	western yellow bat	AMACC05070	3	58808
Lasiurus xanthinus	western yellow bat	AMACC05070	5	58812
Lasiurus xanthinus	western yellow bat	AMACC05070	7	58819
Lasiurus xanthinus	western yellow bat	AMACC05070	2	6328
Lasiurus xanthinus	western yellow bat	AMACC05070	4	45965
Nyctinomops macrotis	big free-tailed bat	AMACD04020	2	58808
Eumops perotis californicus	western mastiff bat	AMACD02011	49	6328
Nyctinomops femorosaccus	pocketed free-tailed bat	AMACD04010	13	6328
Imperata brevifolia	California satintail	PMPOA3D020	1	69048
Athene cunicularia	burrowing owl	ABNSB10010	922	69261
Athene cunicularia	burrowing owl	ABNSB10010	925	69263
Pyrocephalus rubinus	vermilion flycatcher	ABPAE36010	33	56801
Athene cunicularia	burrowing owl	ABNSB10010	1005	70860
Athene cunicularia	burrowing owl	ABNSB10010	1006	70863
Athene cunicularia	burrowing owl	ABNSB10010	1007	70865
Athene cunicularia	burrowing owl	ABNSB10010	1008	70867
Athene cunicularia	burrowing owl	ABNSB10010	1009	70876
Abronia villosa var. aurita	chaparral sand-verbena	PDNYC010P1	43	72386
Lithobates pipiens	northern leopard frog	AAABH01170	8	58808
Malperia tenuis	brown turbans	PDAST67010	2	37037
Calliandra eriophylla	pink fairy-duster	PDFAB0N040	37	37037
Athene cunicularia	burrowing owl	ABNSB10010	1285	79608
Athene cunicularia	burrowing owl	ABNSB10010	1289	79615

EEC ORIGINAL PKG

Athene cunicularia	burrowing owl	ABNSB10010	1290	79616
Athene cunicularia	burrowing owl	ABNSB10010	599	51611
Athene cunicularia	burrowing owl	ABNSB10010	1288	79614
Athene cunicularia	burrowing owl	ABNSB10010	597	51609
Athene cunicularia	burrowing owl	ABNSB10010	1004	70858
Athene cunicularia	burrowing owl	ABNSB10010	1301	79730
Athene cunicularia	burrowing owl	ABNSB10010	1302	79732
Athene cunicularia	burrowing owl	ABNSB10010	1303	79733
Athene cunicularia	burrowing owl	ABNSB10010	1304	79734
Athene cunicularia	burrowing owl	ABNSB10010	1305	79736
Nama stenocarpa	mud nama	PDHYD0A0H0	18	80341
Euphorbia abramsiana	Abrams' spurge	PDEUP0D010	6	80483
Sigmodon hispidus eremicus	Yuma hispid cotton rat	AMAFF07013	9	81266
Sigmodon hispidus eremicus	Yuma hispid cotton rat	AMAFF07013	17	81274
Athene cunicularia	burrowing owl	ABNSB10010	1642	81565
Athene cunicularia	burrowing owl	ABNSB10010	1643	81566
Athene cunicularia	burrowing owl	ABNSB10010	1644	81567
Athene cunicularia	burrowing owl	ABNSB10010	1645	81568
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	218	6328
Athene cunicularia	burrowing owl	ABNSB10010	1647	81571
Rallus obsoletus yumanensis	Yuma Ridgway's rail	ABNME0501A	48	82675
Astragalus sabulonum	gravel milk-vetch	PDFAB0F7R0	1	6328
Charadrius montanus	mountain plover	ABNNB03100	69	84816
Charadrius montanus	mountain plover	ABNNB03100	70	84817
Lycium parishii	Parish's desert-thorn	PDSOL0G0D0	6	84963
Lycium parishii	Parish's desert-thorn	PDSOL0G0D0	8	84965
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	279	86259
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	280	86260
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	314	96587
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	315	96589
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	1	6154
Phrynosoma mcallii	flat-tailed horned lizard	ARACF12040	289	96453
Neotoma albigula venusta	Colorado Valley woodrat	AMAFF08031	20	56801

EEC ORIGINAL PKG

EONDX	Key_Quad_Code	Key_Quad_Name	Key_County_Code	Accuracy
27928	3211566	Mount Signal	IMP	1 mile
24911	3211564	Calexico	IMP	1 mile
12220	3211575	El Centro	IMP	1/5 mile
32022	3211566	Mount Signal	IMP	1 mile
43447	3211574	Holtville West	IMP	1 mile
45033	3211564	Calexico	IMP	1 mile
45965	3211565	Heber	IMP	3/5 mile
45963	3211564	Calexico	IMP	1 mile
46503	3211574	Holtville West	IMP	1 mile
49108	3211564	Calexico	IMP	nonspecific area
49116	3211565	Heber	IMP	2/5 mile
49169	3211565	Heber	IMP	1/5 mile
49174	3211565	Heber	IMP	1/5 mile
49175	3211564	Calexico	IMP	1/10 mile
51255	3211575	El Centro	IMP	1/5 mile
51268	3211574	Holtville West	IMP	1 mile
51277	3211565	Heber	IMP	1/10 mile
51578	3211576	Seeley	IMP	specific area
51584	3211566	Mount Signal	IMP	80 meters
51610	3211565	Heber	IMP	80 meters
52945	3211574	Holtville West	IMP	80 meters
56817	3211576	Seeley	IMP	1 mile
57376	3211564	Calexico	IMP	1 mile
58844	3211575	El Centro	IMP	1 mile
58848	3211575	El Centro	IMP	1 mile
58855	3211575	El Centro	IMP	1 mile
58841	3211564	Calexico	IMP	1 mile
58845	3211565	Heber	IMP	3/5 mile
59560	3211575	El Centro	IMP	1 mile
66376	3211564	Calexico	IMP	1 mile
68714	3211564	Calexico	IMP	1 mile
69816	3211565	Heber	IMP	1 mile
70041	3211575	El Centro	IMP	80 meters
70043	3211575	El Centro	IMP	specific area
71631	3211576	Seeley	IMP	1 mile
71842	3211575	El Centro	IMP	specific area
71843	3211575	El Centro	IMP	80 meters
71846	3211575	El Centro	IMP	80 meters
71847	3211564	Calexico	IMP	80 meters
71854	3211575	El Centro	IMP	nonspecific area
73348	3211576	Seeley	IMP	1 mile
74659	3211575	El Centro	IMP	1 mile
32034	3211567	Yuha Basin	IMP	5 miles
73125	3211567	Yuha Basin	IMP	5 miles
80595	3211563	Bonds Corner	IMP	specific area
80602	3211565	Heber	IMP	80 meters

EEC ORIGINAL PKG

80604	3211565	Heber	IMP	80 meters
51611	3211565	Heber	IMP	specific area
80601	3211566	Mount Signal	IMP	80 meters
51609	3211566	Mount Signal	IMP	specific area
71840	3211575	El Centro	IMP	specific area
80725	3211575	El Centro	IMP	80 meters
80727	3211575	El Centro	IMP	specific area
80728	3211575	El Centro	IMP	80 meters
80729	3211575	El Centro	IMP	specific area
80730	3211575	El Centro	IMP	specific area
81316	3211576	Seeley	IMP	1 mile
45968	3211563	Bonds Corner	IMP	1 mile
82245	3211566	Mount Signal	IMP	80 meters
82253	3211575	El Centro	IMP	80 meters
82532	3211575	El Centro	IMP	80 meters
82533	3211575	El Centro	IMP	specific area
82534	3211575	El Centro	IMP	80 meters
82535	3211575	El Centro	IMP	80 meters
82788	3211564	Calexico	IMP	1 mile
82538	3211575	El Centro	IMP	specific area
83677	3211563	Bonds Corner	IMP	specific area
85298	3211564	Calexico	IMP	1 mile
85848	3211576	Seeley	IMP	3/5 mile
85849	3211566	Mount Signal	IMP	nonspecific area
85999	3211566	Mount Signal	IMP	specific area
86001	3211566	Mount Signal	IMP	specific area
87303	3211566	Mount Signal	IMP	specific area
87304	3211566	Mount Signal	IMP	80 meters
97765	3211566	Mount Signal	IMP	nonspecific area
97767	3211566	Mount Signal	IMP	nonspecific area
14781	3211566	Mount Signal	IMP	nonspecific area
97635	3211566	Mount Signal	IMP	nonspecific area
101662	3211576	Seeley	IMP	1 mile

EEC ORIGINAL PKG

Presence	Occ_Type	Occ_Rank	Sensitive	Site_Date
Possibly Extirpated	Natural/Native occurrence	None	N	19331130
Presumed Extant	Natural/Native occurrence	Unknown	N	19210508
Presumed Extant	Natural/Native occurrence	Fair	N	19901211
Presumed Extant	Natural/Native occurrence	Unknown	N	19610304
Possibly Extirpated	Natural/Native occurrence	None	N	19120618
Presumed Extant	Natural/Native occurrence	Unknown	N	19121019
Presumed Extant	Natural/Native occurrence	Unknown	N	190406XX
Presumed Extant	Natural/Native occurrence	Unknown	N	19030725
Presumed Extant	Natural/Native occurrence	Unknown	N	1915XXXX
Presumed Extant	Natural/Native occurrence	Unknown	N	1994XXXX
Presumed Extant	Natural/Native occurrence	Excellent	N	19910401
Presumed Extant	Natural/Native occurrence	Excellent	N	19910401
Presumed Extant	Natural/Native occurrence	Excellent	N	19910401
Presumed Extant	Natural/Native occurrence	Excellent	N	19910419
Presumed Extant	Natural/Native occurrence	Unknown	N	19090405
Presumed Extant	Natural/Native occurrence	Unknown	N	19340530
Presumed Extant	Natural/Native occurrence	Excellent	N	19910419
Presumed Extant	Natural/Native occurrence	Excellent	N	20030602
Presumed Extant	Natural/Native occurrence	Excellent	N	20030602
Presumed Extant	Natural/Native occurrence	Excellent	N	20030603
Presumed Extant	Natural/Native occurrence	Unknown	N	20030122
Presumed Extant	Natural/Native occurrence	Unknown	N	19110405
Presumed Extant	Natural/Native occurrence	Unknown	N	19220814
Presumed Extant	Natural/Native occurrence	Unknown	N	19990825
Presumed Extant	Natural/Native occurrence	Unknown	N	19770425
Presumed Extant	Natural/Native occurrence	Unknown	N	19920723
Presumed Extant	Natural/Native occurrence	Unknown	N	19770812
Presumed Extant	Natural/Native occurrence	Unknown	N	19850617
Presumed Extant	Natural/Native occurrence	Unknown	N	19870331
Presumed Extant	Natural/Native occurrence	Unknown	N	19961007
Presumed Extant	Natural/Native occurrence	Unknown	N	19951003
Presumed Extant	Natural/Native occurrence	Unknown	N	19630605
Presumed Extant	Natural/Native occurrence	Poor	N	20070104
Presumed Extant	Natural/Native occurrence	Good	N	20061121
Presumed Extant	Natural/Native occurrence	Unknown	N	19090406
Presumed Extant	Natural/Native occurrence	Excellent	N	20051102
Presumed Extant	Natural/Native occurrence	Excellent	N	20051102
Presumed Extant	Natural/Native occurrence	Excellent	N	20051102
Presumed Extant	Natural/Native occurrence	Poor	N	20070123
Presumed Extant	Natural/Native occurrence	Unknown	N	19941123
Presumed Extant	Natural/Native occurrence	Unknown	N	19490317
Presumed Extant	Transplant Outside of Native Hab./Range	Unknown	N	19290415
Presumed Extant	Natural/Native occurrence	Unknown	N	19920308
Presumed Extant	Natural/Native occurrence	Unknown	N	19700301
Presumed Extant	Natural/Native occurrence	Unknown	N	20070626
Presumed Extant	Natural/Native occurrence	Unknown	N	20070627

EEC ORIGINAL PKG

Presumed Extant	Natural/Native occurrence	Unknown	N	20070627
Presumed Extant	Natural/Native occurrence	Excellent	N	20070627
Presumed Extant	Natural/Native occurrence	Unknown	N	20070627
Presumed Extant	Natural/Native occurrence	Excellent	N	20070627
Presumed Extant	Natural/Native occurrence	Excellent	N	20060620
Presumed Extant	Natural/Native occurrence	Unknown	N	20060620
Presumed Extant	Natural/Native occurrence	Unknown	N	20060620
Presumed Extant	Natural/Native occurrence	Unknown	N	20060621
Presumed Extant	Natural/Native occurrence	Unknown	N	20060621
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Possibly Extirpated	Natural/Native occurrence	None	N	19030401
Presumed Extant	Natural/Native occurrence	Unknown	N	19121019
Presumed Extant	Natural/Native occurrence	Unknown	N	20081007
Presumed Extant	Natural/Native occurrence	Unknown	N	20081006
Presumed Extant	Natural/Native occurrence	Fair	N	20090310
Presumed Extant	Natural/Native occurrence	Fair	N	20090310
Presumed Extant	Natural/Native occurrence	Fair	N	20090310
Presumed Extant	Natural/Native occurrence	Fair	N	20090310
Possibly Extirpated	Natural/Native occurrence	None	N	196905XX
Presumed Extant	Natural/Native occurrence	Fair	N	20090310
Presumed Extant	Natural/Native occurrence	Fair	N	19980518
Presumed Extant	Natural/Native occurrence	Unknown	N	19020113
Presumed Extant	Natural/Native occurrence	Unknown	N	20100116
Presumed Extant	Natural/Native occurrence	Unknown	N	20080218
Presumed Extant	Natural/Native occurrence	Fair	N	20100511
Presumed Extant	Natural/Native occurrence	Poor	N	20101118
Presumed Extant	Natural/Native occurrence	Unknown	N	20100617
Presumed Extant	Natural/Native occurrence	Unknown	N	20101110
Presumed Extant	Natural/Native occurrence	Unknown	N	19930805
Presumed Extant	Natural/Native occurrence	Unknown	N	19930806
Presumed Extant	Natural/Native occurrence	Good	N	20130620
Presumed Extant	Natural/Native occurrence	Unknown	N	1985XXXX
Presumed Extant	Natural/Native occurrence	Unknown	N	19090410

EEC ORIGINAL PKG

Elm_Date	Owner_Management	Federal_Status	State_Status	Global_Rank	State_Rank
19331130	UNKNOWN	None	None	G3	S2
19210508	UNKNOWN	None	None	G5	S3S4
19901211	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
19610304	UNKNOWN	None	None	G4?	S3
19120618	UNKNOWN	None	None	G5	SH
19121019	UNKNOWN	None	None	G5T2?	S2
190406XX	UNKNOWN	None	None	G4	S2
19030725	UNKNOWN	None	None	G4	S2
1915XXXX	UNKNOWN	None	None	G2	S2
1994XXXX	UNKNOWN	None	None	G4	S3
19910401	UNKNOWN	None	None	G4	S3
19910401	UNKNOWN	None	None	G4	S3
19910401	UNKNOWN	None	None	G4	S3
19910419	UNKNOWN	None	None	G4	S3
19090405	UNKNOWN	None	None	G4	S3
19340530	UNKNOWN	None	None	G4	S3
19910419	UNKNOWN	None	None	G4	S3
20030602	PVT	None	None	G4	S3
20030602	UNKNOWN	None	None	G4	S3
20030603	UNKNOWN	None	None	G4	S3
20030122	UNKNOWN	None	None	G4	S3S4
19110405	UNKNOWN	None	None	G5	S3
19220814	UNKNOWN	None	None	G5	S3
19990825	UNKNOWN	None	None	G5	S3
19770425	UNKNOWN	None	None	G5	S3
19920723	UNKNOWN	None	None	G5	S3
19770812	UNKNOWN	None	None	G5	S3
19850617	UNKNOWN	None	None	G5	S3
19870331	UNKNOWN	None	None	G5	S3
19961007	UNKNOWN	None	None	G5T4	S3S4
19951003	UNKNOWN	None	None	G4	S3
19630605	UNKNOWN	None	None	G4	S3
20070104	UNKNOWN	None	None	G4	S3
20061121	UNKNOWN	None	None	G4	S3
19090406	UNKNOWN	None	None	G5	S2S3
20051102	PVT	None	None	G4	S3
20051102	UNKNOWN	None	None	G4	S3
20051102	UNKNOWN	None	None	G4	S3
20070123	UNKNOWN	None	None	G4	S3
19941123	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
19490317	UNKNOWN	None	None	G5T2?	S2
19290415	UNKNOWN	None	None	G5	S2
19920308	UNKNOWN	None	None	G4?	S2?
19700301	UNKNOWN	None	None	G5	S3
20070626	UNKNOWN	None	None	G4	S3
20070627	UNKNOWN	None	None	G4	S3

EEC ORIGINAL PKG

20070627	UNKNOWN	None	None	G4	S3
20070627	UNKNOWN	None	None	G4	S3
20070627	UNKNOWN	None	None	G4	S3
20070627	PVT	None	None	G4	S3
20060620	PVT	None	None	G4	S3
20060620	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
20060620	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
20060621	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
20060621	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
20060621	PVT-IMPERIAL IRRIGATION DIST	None	None	G4	S3
19030401	UNKNOWN	None	None	G4G5	S1S2
19121019	UNKNOWN	None	None	G4	S2
20081007	PVT-IMPERIAL IRRIGATION DIST	None	None	G5T2T3	S2
20081006	PVT-IMPERIAL IRRIGATION DIST	None	None	G5T2T3	S2
20090310	UNKNOWN	None	None	G4	S3
20090310	UNKNOWN	None	None	G4	S3
20090310	UNKNOWN	None	None	G4	S3
20090310	UNKNOWN	None	None	G4	S3
196905XX	UNKNOWN	None	None	G3	S2
20090310	UNKNOWN	None	None	G4	S3
19980518	UNKNOWN	Endangered	Threatened	G5T3	S1S2
19020113	UNKNOWN	None	None	G4G5	S2
20100116	UNKNOWN	None	None	G3	S2S3
20080218	PVT	None	None	G3	S2S3
20100511	BLM	None	None	G4	S1
20101118	BLM	None	None	G4	S1
20100617	BLM	None	None	G3	S2
20101110	BLM	None	None	G3	S2
19930805	BLM; UNKNOWN	None	None	G3	S2
19930806	BLM	None	None	G3	S2
20130620	BLM	None	None	G3	S2
1985XXXX	BLM	None	None	G3	S2
19090410	UNKNOWN	None	None	G5T3T4	S1S2

EEC ORIGINAL PKG

Rare_Plant_Rank	CDFW_Status	Other_Status	Symbology
	SSC	BLM_S; IUCN_NT	204
	SSC	USFWS_BCC	804
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
2B.3		SB_RSABG; SB_USDA	104
	SSC	IUCN_LC	804
1B.1		BLM_S; SB_RSABG; USFS_S	804
2B.2		SB_RSABG	804
2B.2		SB_RSABG	804
1B.2		BLM_S; SB_RSABG	804
	SSC	BLM_S; IUCN_LC; USFWS_BCC	203
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	204
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	WL	IUCN_LC; USFWS_BCC	201
	SSC	IUCN_LC	804
	SSC	IUCN_LC	804
	SSC	IUCN_LC; WBWG_H	804
	SSC	IUCN_LC; WBWG_H	204
	SSC	IUCN_LC; WBWG_H	204
	SSC	IUCN_LC; WBWG_H	804
	SSC	IUCN_LC; WBWG_H	804
	SSC	IUCN_LC; WBWG_MH	804
	SSC	BLM_S; WBWG_H	804
	SSC	IUCN_LC; WBWG_M	804
2B.1		SB_RSABG; SB_SBBG; USFS_S	104
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	IUCN_LC	804
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	203
1B.1		BLM_S; SB_RSABG; USFS_S	104
	SSC	IUCN_LC	804
2B.3		SB_RSABG; SB_USDA	804
2B.3		SB_RSABG	804
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201

EEC ORIGINAL PKG

	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
2B.2			104
2B.2		SB_RSABG	104
	SSC		201
	SSC		201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_LC; USFWS_BCC	201
	SSC	BLM_S; IUCN_NT	804
	SSC	BLM_S; IUCN_LC; USFWS_BCC	202
	FP	NABCI_RWL	202
2B.2			804
	SSC	BLM_S; IUCN_NT; NABCI_RWL; USFWS_BCC	204
	SSC	BLM_S; IUCN_NT; NABCI_RWL; USFWS_BCC	203
2B.3			102
2B.3			102
	SSC	BLM_S; IUCN_NT	202
	SSC	BLM_S; IUCN_NT	201
	SSC	BLM_S; IUCN_NT	203
	SSC	BLM_S; IUCN_NT	203
	SSC	BLM_S; IUCN_NT	203
	SSC	BLM_S; IUCN_NT	203
			804

EEC ORIGINAL PKG

Taxon_Group
Reptiles
Birds
Birds
Dicots
Amphibians
Dicots
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EEC ORIGINAL PKG

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Reptiles
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Dicots
Dicots
Reptiles
Reptiles
Reptiles
Reptiles
Reptiles
Reptiles
Mammals

EEC ORIGINAL PKG

CALIFORNIA DEPARTMENT OF FISH and WILDLIFE **RareFind**

Query Summary:
County IS (Imperial)

Print Close

CNDDB Element Query Results

Scientific Name	Common Name	Taxonomic Group	Element Code	Total Occs	Returned Occs	Federal Status	State Status	Global Rank	State Rank	CA Rare Plant Rank	Other Status	Habitats
Abronia villosa var. aurita	chaparral sand-verbena	Dicots	PDNYC010P1	98	2	None	None	G5T2?	S2	1B.1	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden, USFS_S-Sensitive	Chaparral, Coastal scrub, Desert dunes
Accipiter cooperii	Cooper's hawk	Birds	ABNKC12040	118	3	None	None	G5	S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	Cismontane woodland, Riparian forest, Riparian woodland, Upper montane coniferous forest
Acmispon haydonii	pygmy lotus	Dicots	PDFAB2A0H0	32	13	None	None	G3	S3	1B.3	SB_USDA-US Dept of Agriculture	Pinon & juniper woodlands, Sonoran desert scrub
Active Desert Dunes	Active Desert Dunes	Dune	CTT22100CA	4	1	None	None	G4	S2.2	null	null	Desert dunes
Agrilus harenus	Harenus jewel beetle	Insects	IICOLV0060	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Anomala carlsoni	Carlson's dune beetle	Insects	IICOL30050	24	23	None	None	G1	S1	null	null	Desert dunes, Sonoran desert scrub
Anomala hardyorum	Hardy's dune beetle	Insects	IICOL30060	17	17	None	None	G1	S1	null	null	Desert dunes, Sonoran desert scrub
Antrozous pallidus	pallid bat	Mammals	AMACC10010	420	10	None	None	G5	S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, USFS_S-Sensitive, WBWG_H-High Priority	Chaparral, Coastal scrub, Desert wash, Great Basin grassland, Great Basin scrub, Mojavean desert scrub, Riparian woodland, Sonoran desert scrub, Upper montane coniferous forest, Valley & foothill grassland
Apiocera warneri	Glamis sand fly	Insects	IIDIP54020	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Aquila chrysaetos	golden eagle	Birds	ABNKC22010	321	2	None	None	G5	S3	null	BLM_S-Sensitive, CDF_S-Sensitive, CDFW_FP-Fully	Broadleaved upland forest, Cismontane woodland, Coastal prairie, Great Basin grassland, Great Basin scrub, Lower montane coniferous forest, Pinon & juniper woodlands, Upper montane coniferous forest, Valley & foothill grassland

EEC ORIGINAL PKG

											Protected, CDFW_WL-Watch List, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	
Ardea alba	great egret	Birds	ABNGA04040	43	1	None	None	G5	S4	null	CDF_S-Sensitive, IUCN_LC-Least Concern	Brackish marsh, Estuary, Freshwater marsh, Marsh & swamp, Riparian forest, Wetland
Ardea herodias	great blue heron	Birds	ABNGA04010	156	3	None	None	G5	S4	null	CDF_S-Sensitive, IUCN_LC-Least Concern	Brackish marsh, Estuary, Freshwater marsh, Marsh & swamp, Riparian forest, Wetland
Arizona elegans occidentalis	California glossy snake	Reptiles	ARADB01017	260	2	None	None	G5T2	S2	null	CDFW_SSC-Species of Special Concern	null
Asio flammeus	short-eared owl	Birds	ABNSB13040	11	1	None	None	G5	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Great Basin grassland, Marsh & swamp, Meadow & seep, Valley & foothill grassland, Wetland
Astragalus insularis var. harwoodii	Harwood's milk-vetch	Dicots	PDFAB0F491	120	12	None	None	G5T4	S2	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes, Desert wash, Mojavean desert scrub
Astragalus magdalenae var. peirsonii	Peirson's milk-vetch	Dicots	PDFAB0F532	3	1	Threatened	Endangered	G3G4T1	S1	1B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes
Astragalus sabulonum	gravel milk-vetch	Dicots	PDFAB0F7R0	19	5	None	None	G4G5	S2	2B.2	null	Desert dunes, Mojavean desert scrub, Sonoran desert scrub
Athene cunicularia	burrowing owl	Birds	ABNSB10010	1989	262	None	None	G4	S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Coastal prairie, Coastal scrub, Great Basin grassland, Great Basin scrub, Mojavean desert scrub, Sonoran desert scrub, Valley & foothill grassland
Ayenia compacta	California ayenia	Dicots	PDSTE01020	74	1	None	None	G4	S3	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert wash, Mojavean desert scrub, Sonoran desert scrub
Bombus crotchii	Crotch bumble bee	Insects	IIHYM24480	276	1	None	Candidate Endangered	G3G4	S1S2	null	null	null
Bombus occidentalis	western bumble bee	Insects	IIHYM24250	279	1	None	Candidate Endangered	G2G3	S1	null	USFS_S-Sensitive, XERCES_IM-Imperiled	null

EEC ORIGINAL PKG

Bursera microphylla	little-leaf elephant tree	Dicots	PDBUR01020	18	3	None	None	G4	S2	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert wash, Sonoran desert scrub
Buteo regalis	ferruginous hawk	Birds	ABNKC19120	107	2	None	None	G4	S3S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Great Basin grassland, Great Basin scrub, Pinon & juniper woodlands, Valley & foothill grassland
Calliandra eriophylla	pink fairy-duster	Dicots	PDFAB0N040	53	48	None	None	G5	S3	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Sonoran desert scrub
Carnegiea gigantea	saguaro	Dicots	PDCAC12010	30	6	None	None	G5	S1	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Sonoran desert scrub
Castela emoryi	Emory's crucifixion-thorn	Dicots	PDSIM03030	55	7	None	None	G3G4	S2S3	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Alkali playa, Desert wash, Mojavean desert scrub, Sonoran desert scrub
Chaenactis carphoclinia var. peirsonii	Peirson's pincushion	Dicots	PDAST20042	12	7	None	None	G5T2	S2	1B.3	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Sonoran desert scrub
Chaetodipus fallax pallidus	pallid San Diego pocket mouse	Mammals	AMAFD05032	79	3	None	None	G5T34	S3S4	null	CDFW_SSC-Species of Special Concern	Desert wash, Pinon & juniper woodlands, Sonoran desert scrub
Charadrius alexandrinus nivosus	western snowy plover	Birds	ABNNB03031	138	2	Threatened	None	G3T3	S2S3	null	CDFW_SSC-Species of Special Concern, NABCI_RWL-Red Watch List, USFWS_BCC-Birds of Conservation Concern	Great Basin standing waters, Sand shore, Wetland
Charadrius montanus	mountain plover	Birds	ABNNB03100	90	23	None	None	G3	S2S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_NT-Near Threatened, NABCI_RWL-Red Watch List, USFWS_BCC-Birds of Conservation Concern	Chenopod scrub, Valley & foothill grassland
Chylismia	sand evening-	Dicots	PDONA03020	16	7	None	None	G4?	S2S3	2B.2	null	Sonoran desert scrub

EEC ORIGINAL PKG

arenaria	primrose											
Coccyzus americanus occidentalis	western yellow-billed cuckoo	Birds	ABNRB02022	165	16	Threatened	Endangered	G5T2T3	S1	null	BLM_S-Sensitive, NABCI_RWL-Red Watch List, USFS_S-Sensitive, USFWS_BCC-Birds of Conservation Concern	Riparian forest
Colaptes chrysoides	gilded flicker	Birds	ABNYF10040	25	7	None	Endangered	G5	S1	null	BLM_S-Sensitive, IUCN_LC-Least Concern, NABCI_YWL-Yellow Watch List, USFWS_BCC-Birds of Conservation Concern	Riparian forest, Riparian woodland
Coleonyx switaki	barefoot gecko	Reptiles	ARACD01040	13	7	None	Threatened	G4	S1	null	BLM_S-Sensitive, IUCN_LC-Least Concern	Mojavean desert scrub, Sonoran desert scrub
Colubrina californica	Las Animas colubrina	Dicots	PDRHA05030	38	3	None	None	G4	S2S3	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert wash, Mojavean desert scrub, Sonoran desert scrub
Corynorhinus townsendii	Townsend's big-eared bat	Mammals	AMACC08010	635	7	None	None	G3G4	S2	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, USFS_S-Sensitive, WBWG_H-High Priority	Broadleaved upland forest, Chaparral, Chenopod scrub, Great Basin grassland, Great Basin scrub, Joshua tree woodland, Lower montane coniferous forest, Meadow & seep, Mojavean desert scrub, Riparian forest, Riparian woodland, Sonoran desert scrub, Sonoran thorn woodland, Upper montane coniferous forest, Valley & foothill grassland
Crotalus ruber	red-diamond rattlesnake	Reptiles	ARADE02090	192	2	None	None	G4	S3	null	CDFW_SSC-Species of Special Concern, USFS_S-Sensitive	Chaparral, Mojavean desert scrub, Sonoran desert scrub
Croton wigginsii	Wiggins' croton	Dicots	PDEUP0H140	12	12	None	Rare	G2G3	S2	2B.2	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes, Sonoran desert scrub
Crucifixion Thorn Woodland	Crucifixion Thorn Woodland	Woodland	CTT75200CA	2	1	None	None	G3	S1.2	null	null	null
Cyclocephala wandae	Wandae dune beetle	Insects	IICOL33020	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Cylindropuntia	Munz's cholla	Dicots	PDCAC0D0V0	6	6	None	None	G3	S1	1B.3	BLM_S-	Sonoran desert scrub

EEC ORIGINAL PKG

munzii											Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	
Cyprinodon macularius	desert pupfish	Fish	AFCNB02060	74	41	Endangered	Endangered	G1	S1	null	AFS_EN-Endangered, IUCN_VU-Vulnerable	Aquatic, Artificial flowing waters, Artificial standing waters, Colorado River basin flowing waters, Colorado River basin standing waters
Desert Fan Palm Oasis Woodland	Desert Fan Palm Oasis Woodland	Riparian	CTT62300CA	80	5	None	None	G3	S3.2	null	null	Riparian woodland
Digitaria californica var. californica	Arizona cottontop	Monocots	PMPOA27051	3	1	None	None	G5T5	S2	2B.3	null	Mojavean desert scrub, Sonoran desert scrub
Ditaxis claryana	glandular ditaxis	Dicots	PDEUP080L0	26	9	None	None	G3G4	S2	2B.2	null	Desert wash, Mojavean desert scrub, Sonoran desert scrub
Efferia macroxipha	Glamis robberfly	Insects	IIDIP07040	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Empidonax traillii extimus	southwestern willow flycatcher	Birds	ABPAE33043	70	7	Endangered	Endangered	G5T2	S1	null	NABCI_RWL-Red Watch List	Riparian woodland
Eriastrum harwoodii	Harwood's eriastrum	Dicots	PDPLM030B1	80	1	None	None	G2	S2	1B.2	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden, SB_USDA-US Dept of Agriculture	Desert dunes
Eryngium aristulatum var. parishii	San Diego button-celery	Dicots	PDAPI0Z042	82	1	Endangered	Endangered	G5T1	S1	1B.1	SB_CRES-San Diego Zoo CRES Native Gene Seed Bank, SB_RSABG-Rancho Santa Ana Botanic Garden	Coastal scrub, Valley & foothill grassland, Vernal pool, Wetland
Eucnide rupestris	annual rock-nettle	Dicots	PDLOA02020	6	4	None	None	G3	S1	2B.2	null	Sonoran desert scrub
Eumops perotis californicus	western mastiff bat	Mammals	AMACD02011	296	10	None	None	G5T4	S3S4	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, WBWG_H-High Priority	Chaparral, Cismontane woodland, Coastal scrub, Valley & foothill grassland
Euparagia unidentata	Algodones euparagia	Insects	IIHYMBC010	3	1	None	None	G1G2	S1S2	null	null	Desert dunes
Euphorbia abramsiana	Abrams' spurge	Dicots	PDEUP0D010	109	15	None	None	G4	S2	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Mojavean desert scrub, Sonoran desert scrub
Euphorbia arizonica	Arizona spurge	Dicots	PDEUP0D060	11	1	None	None	G5	S3	2B.3	null	Sonoran desert scrub
Euphorbia platysperma	flat-seeded spurge	Dicots	PDEUP0D1X0	3	1	None	None	G3	S1	1B.2	SB_RSABG-Rancho Santa	Desert dunes, Mojavean desert scrub

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											Ana Botanic Garden	
Falco columbarius	merlin	Birds	ABNKD06030	37	6	None	None	G5	S3S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	Estuary, Great Basin grassland, Valley & foothill grassland
Falco mexicanus	prairie falcon	Birds	ABNKD06090	460	7	None	None	G5	S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Great Basin grassland, Great Basin scrub, Mojavean desert scrub, Sonoran desert scrub, Valley & foothill grassland
Galium angustifolium ssp. borregoense	Borrego bedstraw	Dicots	PDRUB0N042	20	1	None	Rare	G5T3?	S3?	1B.3	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Sonoran desert scrub
Gelochelidon nilotica	gull-billed tern	Birds	ABNNM08010	6	5	None	None	G5	S1	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, NABCI_YWL-Yellow Watch List, USFWS_BCC-Birds of Conservation Concern	null
Geraea viscida	sticky geraea	Dicots	PDAST42020	112	1	None	None	G2G3	S2	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Chaparral
Gila elegans	bonytail	Fish	AFCJB13100	3	2	Endangered	Endangered	G1	SH	null	AFS_EN-Endangered, IUCN_EN-Endangered	Aquatic, Colorado River basin flowing waters, Colorado River basin standing waters
Gopherus agassizii	desert tortoise	Reptiles	ARAAF01012	970	439	Threatened	Threatened	G3	S2S3	null	IUCN_VU-Vulnerable	Joshua tree woodland, Mojavean desert scrub, Sonoran desert scrub
Haliaeetus leucocephalus	bald eagle	Birds	ABNKC10010	327	1	Delisted	Endangered	G5	S3	null	BLM_S-Sensitive, CDF_S-Sensitive, CDFW_FP-Fully Protected, IUCN_LC-Least Concern, USFS_S-Sensitive, USFWS_BCC-Birds of Conservation Concern	Lower montane coniferous forest, Oldgrowth
Helianthus niveus ssp. tephrodes	Algodones Dunes	Dicots	PDAST4N0Z2	3	1	None	Endangered	G4T2T3	S1	1B.2	BLM_S-Sensitive,	Desert dunes

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	sunflower										SB_USDA-US Dept of Agriculture	
Heloderma suspectum cinctum	banded Gila monster	Reptiles	ARACE01011	21	3	None	None	G4T4	S1	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_NT-Near Threatened	Mojavean desert scrub, Riparian scrub, Sonoran desert scrub
Herissantia crispa	curly herissantia	Dicots	PDMAL0F010	2	1	None	None	G5	S1	2B.3	null	Sonoran desert scrub
Hulsea mexicana	Mexican hulsea	Dicots	PDAST4Z050	3	1	None	None	G3G4	S1	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Chaparral
Hydroprogne caspia	Caspian tern	Birds	ABNNM08020	3	1	None	None	G5	S4	null	IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	null
Hymenoxys odorata	bitter hymenoxys	Dicots	PDAST530E0	6	2	None	None	G5	S2	2B.1	null	Riparian scrub, Sonoran desert scrub
Icteria virens	yellow-breasted chat	Birds	ABPBX24010	100	15	None	None	G5	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Riparian forest, Riparian scrub, Riparian woodland
Imperata brevifolia	California satintail	Monocots	PMPOA3D020	32	1	None	None	G4	S3	2B.1	SB_RSABG-Rancho Santa Ana Botanic Garden, SB_SBBG-Santa Barbara Botanic Garden, USFS_S-Sensitive	Chaparral, Coastal scrub, Meadow & seep, Mojavean desert scrub, Riparian scrub, Wetland
Incilius alvarius	Sonoran desert toad	Amphibians	AAABB01010	6	5	None	None	G5	SH	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Aquatic, Artificial flowing waters, Desert wash, Wetland
Ipomopsis effusa	Baja California ipomopsis	Dicots	PDPLM060U0	1	1	None	None	G3?	SH	2B.1	SB_RSABG-Rancho Santa Ana Botanic Garden	Chaparral, Desert wash, Sonoran desert scrub
Ipomopsis tenuifolia	slender-leaved ipomopsis	Dicots	PDPLM060J0	17	4	None	None	G4	S2	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden	Chaparral, Pinon & juniper woodlands, Sonoran desert scrub
Ixobrychus exilis	least bittern	Birds	ABNGA02010	10	5	None	None	G4G5	S2	null	CDFW_SSC-Species of Special Concern, IUCN_LC-	Marsh & swamp, Wetland

EEC ORIGINAL PKG

											Least Concern, USFWS_BCC-Birds of Conservation Concern	
Junco hyemalis caniceps	gray-headed junco	Birds	ABPBXA5021	9	1	None	None	G5T5	S1	null	CDFW_WL-Watch List	Upper montane coniferous forest
Kinosternon sonoriense	Sonoran mud turtle	Reptiles	ARAAE01040	5	5	None	None	G4	SH	null	CDFW_SSC-Species of Special Concern, IUCN_VU-Vulnerable	Colorado River basin flowing waters
Koeberlinia spinosa var. tenuispina	slender-spined all thorn	Dicots	PDCPP05012	12	9	None	None	G4T4?	S2	2B.2	null	Desert wash, Riparian woodland, Sonoran desert scrub
Lanius ludovicianus	loggerhead shrike	Birds	ABPBR01030	110	3	None	None	G4	S4	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Broadleaved upland forest, Desert wash, Joshua tree woodland, Mojavean desert scrub, Pinon & juniper woodlands, Riparian woodland, Sonoran desert scrub
Larus californicus	California gull	Birds	ABNNM03110	8	1	None	None	G5	S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	null
Lasiurus cinereus	hoary bat	Mammals	AMACC05030	238	2	None	None	G5	S4	null	IUCN_LC-Least Concern, WBWG_M-Medium Priority	Broadleaved upland forest, Cismontane woodland, Lower montane coniferous forest, North coast coniferous forest
Lasiurus xanthinus	western yellow bat	Mammals	AMACC05070	58	8	None	None	G5	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_H-High Priority	Desert wash
Laterallus jamaicensis coturniculus	California black rail	Birds	ABNME03041	303	37	None	Threatened	G3G4T1	S1	null	BLM_S-Sensitive, CDFW_FP-Fully Protected, IUCN_NT-Near Threatened, NABCI_RWL-Red Watch List, USFWS_BCC-Birds of Conservation Concern	Brackish marsh, Freshwater marsh, Marsh & swamp, Salt marsh, Wetland
Lepismadora	Algodones	Insects	IICOLX1110	1	1	None	None	G1	S1	null	null	null

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algodones	sand jewel beetle											
Linanthus maculatus ssp. emaculatus	Jacumba Mountains linanthus	Dicots	PDPLM041Y2	5	2	None	None	G2T1	S1	1B.1	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes, Sonoran desert scrub
Lithobates pipiens	northern leopard frog	Amphibians	AAABH01170	19	1	None	None	G5	S2	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Freshwater marsh, Great Basin flowing waters, Great Basin standing waters, Marsh & swamp, Wetland
Lithobates yavapaiensis	lowland leopard frog	Amphibians	AAABH01250	7	6	None	None	G4	SX	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	null
Lupinus albifrons var. medius	Mountain Springs bush lupine	Dicots	PDFAB2B1J5	48	10	None	None	G4T2	S2	1B.3	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden, SB_USDA-US Dept of Agriculture	Desert wash, Pinon & juniper woodlands, Sonoran desert scrub
Lycium parishii	Parish's desert-thorn	Dicots	PDSOL0G0D0	21	15	None	None	G4	S1	2B.3	null	Coastal scrub, Sonoran desert scrub
Macrotus californicus	California leaf-nosed bat	Mammals	AMACB01010	46	16	None	None	G4	S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_H-High Priority	Riparian scrub, Sonoran desert scrub
Malperia tenuis	brown turbans	Dicots	PDAST67010	30	20	None	None	G4?	S2?	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden, SB_USDA-US Dept of Agriculture	Sonoran desert scrub
Matelea parvifolia	spear-leaf matelea	Dicots	PDASC0A0J0	68	1	None	None	G5	S3	2B.3	USFS_S-Sensitive	Mojavean desert scrub, Sonoran desert scrub
Melanerpes uropygialis	Gila woodpecker	Birds	ABNYF04150	62	36	None	Endangered	G5	S1	null	BLM_S-Sensitive, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Riparian forest, Riparian woodland

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Melitta californica	California mellitid bee	Insects	IIHYM74010	5	2	None	None	G4?	S2?	null	null	null
Mentzelia hirsutissima	hairy stickleaf	Dicots	PDLOA030K0	28	11	None	None	G4?	S3	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden, SB_USDA-US Dept of Agriculture	Desert wash, Sonoran desert scrub
Mentzelia puberula	Darlington's blazing star	Dicots	PDLOA031F0	11	3	None	None	G5	S2	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Mojavean desert scrub, Sonoran desert scrub
Mentzelia tricuspis	spiny-hair blazing star	Dicots	PDLOA031T0	16	1	None	None	G4	S2	2B.1	null	Mojavean desert scrub
Mesquite Bosque	Mesquite Bosque	Riparian	CTT61820CA	14	1	None	None	G3	S2.1	null	null	Riparian forest
Micrathene whitneyi	elf owl	Birds	ABNSB09010	17	6	None	Endangered	G5	S1	null	BLM_S-Sensitive, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Riparian woodland
Microbembex elegans	Algodones elegant sand wasp	Insects	IIHYM90010	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Myiarchus tyrannulus	brown-crested flycatcher	Birds	ABPAE43080	18	7	None	None	G5	S3	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	Riparian forest, Riparian woodland
Myotis ciliolabrum	western small-footed myotis	Mammals	AMACC01140	82	1	None	None	G5	S3	null	BLM_S-Sensitive, IUCN_LC-Least Concern, WBWG_M-Medium Priority	null
Myotis occultus	Arizona Myotis	Mammals	AMACC01160	3	1	None	None	G4	S1	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_M-Medium Priority	null
Myotis velifer	cave myotis	Mammals	AMACC01050	9	1	None	None	G5	S1	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_M-	Riparian scrub, Sonoran desert scrub

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											Medium Priority	
Myotis yumanensis	Yuma myotis	Mammals	AMACC01020	265	2	None	None	G5	S4	null	BLM_S-Sensitive, IUCN_LC-Least Concern, WBWG_LM-Low-Medium Priority	Lower montane coniferous forest, Riparian forest, Riparian woodland, Upper montane coniferous forest
Nama stenocarpa	mud nama	Dicots	PDHYD0A0H0	22	3	None	None	G4G5	S1S2	2B.2	null	Marsh & swamp, Wetland
Nemacaulis denudata var. gracilis	slender cottonheads	Dicots	PDPGN0G012	24	2	None	None	G3G4T3?	S2	2B.2	null	Coastal dunes, Desert dunes, Sonoran desert scrub
Neotoma albigula venusta	Colorado Valley woodrat	Mammals	AMAFF08031	22	12	None	None	G5T3T4	S1S2	null	null	Sonoran desert scrub
Nyctinomops femorosaccus	pocketed free-tailed bat	Mammals	AMACD04010	90	5	None	None	G4	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_M-Medium Priority	Joshua tree woodland, Pinon & juniper woodlands, Riparian scrub, Sonoran desert scrub
Nyctinomops macrotis	big free-tailed bat	Mammals	AMACD04020	32	1	None	None	G5	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, WBWG_MH-Medium-High Priority	null
Oliarces clara	cheeseweed owlfly (cheeseweed moth lacewing)	Insects	IINEU04010	11	1	None	None	G1G3	S2	null	null	Sonoran desert scrub
Onychomys torridus ramona	southern grasshopper mouse	Mammals	AMAFF06022	28	1	None	None	G5T3	S3	null	CDFW_SSC-Species of Special Concern	Chenopod scrub
Opuntia wigginsii	Wiggins' cholla	Dicots	PDCAC0D1P0	6	2	None	None	G3?Q	S1?	3.3	null	Sonoran desert scrub
Oreothlypis luciae	Lucy's warbler	Birds	ABPBX01090	2	1	None	None	G5	S2S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, USFWS_BCC-Birds of Conservation Concern	Riparian woodland
Ovis canadensis nelsoni	desert bighorn sheep	Mammals	AMALE04013	46	3	None	None	G4T4	S3	null	BLM_S-Sensitive,	Alpine, Alpine dwarf scrub, Chaparral, Chenopod scrub, Great Basin scrub, Mojavean desert scrub, Montane dwarf

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											CDFW_FP-Fully Protected, USFS_S-Sensitive	scrub, Pinon & juniper woodlands, Riparian woodland, Sonoran desert scrub
Ovis canadensis nelsoni pop. 2	Peninsular bighorn sheep DPS	Mammals	AMALE04012	7	2	Endangered	Threatened	G4T3Q	S1	null	CDFW_FP-Fully Protected	Alpine, Alpine dwarf scrub, Chaparral, Chenopod scrub, Great Basin scrub, Mojavean desert scrub, Montane dwarf scrub, Pinon & juniper woodlands, Riparian woodland, Sonoran desert scrub
Palafoxia arida var. gigantea	giant spanish-needle	Dicots	PDAST6T012	6	6	None	None	G5T3?	S2	1B.3	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes
Panicum hirticaule ssp. hirticaule	roughstalk witch grass	Monocots	PMPOA4K170	18	4	None	None	G5T5	S2	2B.1	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes, Joshua tree woodland, Mojavean desert scrub, Sonoran desert scrub
Pelecanus occidentalis californicus	California brown pelican	Birds	ABNFC01021	27	6	Delisted	Delisted	G4T3T4	S3	null	BLM_S-Sensitive, CDFW_FP-Fully Protected, USFS_S-Sensitive	null
Penstemon pseudospectabilis ssp. pseudospectabilis	desert beardtongue	Dicots	PDSCR1L562	25	3	None	None	G4G5T4	S3	2B.2	null	Mojavean desert scrub, Sonoran desert scrub
Perdita algodones	Algodones perdita	Insects	IIHYM01130	1	1	None	None	G1G2	S1S2	null	null	Desert dunes
Perognathus longimembris bangsi	Palm Springs pocket mouse	Mammals	AMAFD01043	30	3	None	None	G5T2	S2	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern	Desert wash, Sonoran desert scrub
Petalonyx linearis	narrow-leaf sandpaper-plant	Dicots	PDLOA04010	26	6	None	None	G4	S3?	2B.3	null	Mojavean desert scrub, Sonoran desert scrub
Pholisma sonorae	sand food	Dicots	PDLNN02020	14	14	None	None	G2	S2	1B.2	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Desert dunes, Sonoran desert scrub
Pholistoma auritum var. arizonicum	Arizona pholistoma	Dicots	PDHYD0D011	23	5	None	None	G5T4?	S3	2B.3	SB_RSABG-Rancho Santa Ana Botanic Garden, SB_USDA-US Dept of Agriculture	Mojavean desert scrub
Phrynosoma mcallii	flat-tailed horned lizard	Reptiles	ARACF12040	340	268	None	None	G3	S2	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_NT-	Desert dunes, Mojavean desert scrub, Sonoran desert scrub

EEC ORIGINAL PKG

											Near Threatened	
Pilostyles thurberi	Thurber's pilostyles	Dicots	PDRAF01010	26	22	None	None	G5	S4	4.3	null	Sonoran desert scrub
Piranga rubra	summer tanager	Birds	ABPBX45030	21	5	None	None	G5	S1	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Riparian forest
Plegadis chihi	white-faced ibis	Birds	ABNGE02020	20	2	None	None	G5	S3S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	Marsh & swamp, Wetland
Polioptila melanura	black-tailed gnatcatcher	Birds	ABPBJ08030	34	13	None	None	G5	S3S4	null	CDFW_WL-Watch List, IUCN_LC-Least Concern	Mojavean desert scrub, Sonoran desert scrub
Pseudocotalpa andrewsi	Andrew's dune scarab beetle	Insects	IICOL37020	29	29	None	None	G1	S1	null	null	Desert dunes, Sonoran desert scrub
Pseudorontium cyathiferum	Deep Canyon snapdragon	Dicots	PDSCR2R010	3	1	None	None	G4G5	S1	2B.3	null	Sonoran desert scrub
Ptychocheilus lucius	Colorado pikeminnow	Fish	AFCJB35020	3	2	Endangered	Endangered	G1	SX	null	CDFW_FP-Fully Protected, IUCN_VU-Vulnerable	Aquatic, Colorado River basin flowing waters
Puma concolor browni	Yuma mountain lion	Mammals	AMAJH04013	1	1	None	None	G5T1T2Q	S1	null	CDFW_SSC-Species of Special Concern	null
Pyrocephalus rubinus	vermilion flycatcher	Birds	ABPAE36010	25	7	None	None	G5	S2S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Marsh & swamp, Riparian forest, Riparian scrub, Riparian woodland, Wetland
Rallus obsoletus yumanensis	Yuma Ridgway's rail	Birds	ABNME0501A	58	37	Endangered	Threatened	G5T3	S1S2	null	CDFW_FP-Fully Protected, NABCI_RWL-Red Watch List	Freshwater marsh, Marsh & swamp, Wetland
Rynchops niger	black skimmer	Birds	ABNNM14010	7	3	None	None	G5	S2	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, NABCI_YWL-Yellow Watch List, USFWS_BCC-Birds of Conservation Concern	Alkali playa, Sand shore
Salvia greatae	Orocopia sage	Dicots	PDLAM1S0P0	25	2	None	None	G2G3	S2S3	1B.3	BLM_S-Sensitive, SB_RSABG-	Desert wash, Mojavean desert scrub, Sonoran desert scrub

EEC ORIGINAL PKG

											Rancho Santa Ana Botanic Garden	
Scaphiopus couchii	Couch's spadefoot	Amphibians	AAABF01020	6	3	None	None	G5	S2	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	null
Selaginella eremophila	desert spike-moss	Ferns	PPSEL010G0	75	3	None	None	G4	S2S3	2B.2	null	Chaparral, Sonoran desert scrub
Senna covesii	Cove's cassia	Dicots	PDFAB491X0	55	1	None	None	G5	S3	2B.2	SB_RSABG-Rancho Santa Ana Botanic Garden	Desert wash, Sonoran desert scrub
Setophaga petechia	yellow warbler	Birds	ABPBX03010	78	2	None	None	G5	S3S4	null	CDFW_SSC-Species of Special Concern, USFWS_BCC-Birds of Conservation Concern	Riparian forest, Riparian scrub, Riparian woodland
Setophaga petechia sonorana	Sonoran yellow warbler	Birds	ABPBX03017	4	1	None	None	G5T2T3	S2	null	CDFW_SSC-Species of Special Concern, USFWS_BCC-Birds of Conservation Concern	Riparian forest
Sigmodon arizonae plenus	Colorado River cotton rat	Mammals	AMAFF07022	6	1	None	None	G5T2T3	S1S2	null	CDFW_SSC-Species of Special Concern	null
Sigmodon hispidus eremicus	Yuma hispid cotton rat	Mammals	AMAFF07013	23	23	None	None	G5T2T3	S2	null	CDFW_SSC-Species of Special Concern	null
Sonoran Cottonwood Willow Riparian Forest	Sonoran Cottonwood Willow Riparian Forest	Riparian	CTT61810CA	21	11	None	None	G2	S1.1	null	null	Riparian forest
Stabilized and Partially Stabilized Desert Dunes	Stabilized and Partially Stabilized Desert Dunes	Dune	CTT22200CA	3	1	None	None	G4	S3.2	null	null	Desert dunes
Streptanthus campestris	southern jewelflower	Dicots	PDBRA2G0B0	65	1	None	None	G3	S3	1B.3	BLM_S-Sensitive, USFS_S-Sensitive	Chaparral, Lower montane coniferous forest, Pinon & juniper woodlands
Symphyotrichum defoliatum	San Bernardino aster	Dicots	PDASTE80C0	102	1	None	None	G2	S2	1B.2	SB_CRES-San Diego Zoo CRES Native Gene Seed Bank, SB_RSABG-Rancho Santa Ana Botanic	Cismontane woodland, Coastal scrub, Lower montane coniferous forest, Marsh & swamp, Meadow & seep, Valley & foothill grassland

EEC ORIGINAL PKG

											Garden, USFS_S-Sensitive	
Taxidea taxus	American badger	Mammals	AMAJF04010	592	13	None	None	G5	S3	null	CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Alkali marsh, Alkali playa, Alpine, Alpine dwarf scrub, Bog & fen, Brackish marsh, Broadleaved upland forest, Chaparral, Chenopod scrub, Cismontane woodland, Closed-cone coniferous forest, Coastal bluff scrub, Coastal dunes, Coastal prairie, Coastal scrub, Desert dunes, Desert wash, Freshwater marsh, Great Basin grassland, Great Basin scrub, Interior dunes, Ione formation, Joshua tree woodland, Limestone, Lower montane coniferous forest, Marsh & swamp, Meadow & seep, Mojavean desert scrub, Montane dwarf scrub, North coast coniferous forest, Oldgrowth, Pavement plain, Redwood, Riparian forest, Riparian scrub, Riparian woodland, Salt marsh, Sonoran desert scrub, Sonoran thorn woodland, Ultramafic, Upper montane coniferous forest, Upper Sonoran scrub, Valley & foothill grassland
Teucrium cubense ssp. depressum	dwarf germander	Dicots	PDLAM20032	5	2	None	None	G4G5T3T4	S2	2B.2	null	Alkali playa, Desert dunes, Sonoran desert scrub
Tidestromia eliassoniana	Eliasson's woolly tidestromia	Dicots	PDAMA0J070	5	1	None	None	G5	S2	2B.2	null	Mojavean desert scrub, Sonoran desert scrub
Toxostoma crissale	Crissal thrasher	Birds	ABPBK06090	67	16	None	None	G5	S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern	Riparian woodland
Toxostoma lecontei	Le Conte's thrasher	Birds	ABPBK06100	238	15	None	None	G4	S3	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_LC-Least Concern, NABCI_RWL-Red Watch List, USFWS_BCC-Birds of Conservation Concern	Desert wash, Mojavean desert scrub, Sonoran desert scrub
Transmontane Alkali Marsh	Transmontane Alkali Marsh	Marsh	CTT52320CA	7	1	None	None	G3	S2.1	null	null	Marsh & swamp, Wetland
Uma notata	Colorado Desert fringe-toed lizard	Reptiles	ARACF15020	16	11	None	None	G3	S2	null	BLM_S-Sensitive, CDFW_SSC-Species of Special Concern, IUCN_NT-Near Threatened	Desert dunes, Desert wash, Sonoran desert scrub
Vireo bellii arizonae	Arizona bell's vireo	Birds	ABPBW01111	38	12	None	Endangered	G5T4	S1S2	null	BLM_S-Sensitive, IUCN_NT-Near	Riparian forest

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											Threatened, USFWS_BCC-Birds of Conservation Concern	
Vireo bellii pusillus	least Bell's vireo	Birds	ABPBW01114	503	1	Endangered	Endangered	G5T2	S2	null	IUCN_NT-Near Threatened, NABCI_YWL-Yellow Watch List	Riparian forest, Riparian scrub, Riparian woodland
Xylorhiza orcuttii	Orcutt's woody-aster	Dicots	PDASTA1040	66	26	None	None	G3?	S2	1B.2	BLM_S-Sensitive, SB_RSABG-Rancho Santa Ana Botanic Garden	Desert wash, Sonoran desert scrub
Xyrauchen texanus	razorback sucker	Fish	AFCJC11010	28	16	Endangered	Endangered	G1	S1S2	null	AFS_EN-Endangered, CDFW_FP-Fully Protected, IUCN_EN-Endangered	Aquatic, Colorado River basin flowing waters

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SAFETY AND HEALTH PROTECTION ON THE JOB

State of California
Department of Industrial Relations

California law provides workplace safety and health protections for workers through regulations enforced by the Division of Occupational Safety and Health (Cal/OSHA). This poster explains some basic requirements and procedures to comply with the state's workplace safety and health standards and orders. The law requires that this poster be displayed. Failure to do so could result in a substantial penalty. Cal/OSHA standards can be found at www.dir.ca.gov/samples/search/query.htm.

WHAT AN EMPLOYER MUST DO:

All employers must provide work and workplaces that are safe and healthful. In other words, as an employer, you must follow state laws governing job safety and health. Failure to do so can result in a threat to the life or health of workers, and substantial monetary penalties.

You must display this poster in a conspicuous place where notices to employees are customarily posted so everyone on the job can be aware of basic rights and responsibilities.

You must have a written and effective Injury and Illness Prevention Program (IIPP) meeting the requirements of California Code of Regulations, title 8, section 3203 (www.dir.ca.gov/title8/3203.html).

You must be aware of hazards your employees face on the job and keep records showing that each employee has been trained in the hazards unique to each job assignment.

You must correct any hazardous condition that you know may result in injury to employees. Failure to do so could result in criminal charges, monetary penalties, and even incarceration.

You must notify a local Cal/OSHA district office of any serious injury or illness, or death, occurring on the job. Be sure to do this immediately after calling for emergency help to assist the injured employee. Failure to report a serious injury or illness, or death, within 8 hours can result in a minimum civil penalty of $5,000.

WHAT AN EMPLOYER MUST NEVER DO:

Never permit an employee to do work that violates Cal/OSHA workplace safety and health regulations.

Never permit an employee to be exposed to harmful substances without providing adequate protection.

Never allow an untrained employee to perform hazardous work.

EMPLOYEES HAVE CERTAIN WORKPLACE SAFETY & HEALTH RIGHTS:

As an employee, you (or someone acting for you) have the right to file a confidential complaint and request an inspection of your workplace if you believe conditions there are unsafe or unhealthful. This is done by contacting the local Cal/OSHA district office (see list of offices). Your name is not revealed by Cal/OSHA, unless you request otherwise.

You also have the right to bring unsafe or unhealthful conditions to the attention of the Cal/OSHA investigator inspecting your workplace.

Any employee has the right to refuse to perform work that would violate an occupational safety or health standard or order where such violation would create a real and apparent hazard to the employee or other employees.

You may not be fired or punished in any way for filing a complaint about unsafe or unhealthful working conditions, or for otherwise exercising your rights to a safe and healthful workplace. If you feel that you have been fired or punished for exercising your rights, you may file a complaint about this type of discrimination by contacting the nearest office of the California Department of Industrial Relations, Division of Labor Standards Enforcement (Labor Commissioner's Office) or the San Francisco office of the U.S. Department of Labor, Occupational Safety and Health Administration. (Employees of state or local government agencies may only file these complaints with the California Labor Commissioner's Office.) Consult your local telephone directory for the office nearest you.

EMPLOYEES ALSO HAVE RESPONSIBILITIES:

To keep the workplace and your coworkers safe, you should tell your employer about any hazard that could result in an injury or illness to an employee.
While working, you must always obey state workplace safety and health laws.

SPECIAL RULES APPLY FOR WORK AROUND HAZARDOUS SUBSTANCES:

Employers who use any substance that is listed as a hazardous substance in California Code of Regulations, title 8, section 339 (www.dir.ca.gov/title8/339.html), or is covered by the Hazard Communication standard (www.dir.ca.gov/title8/5194.html) must provide employees information on the hazardous chemicals in their work areas, access to safety data sheets, and training on how to use hazardous chemicals safely.

Employers shall make available on a timely and reasonable basis a safety data sheet on each hazardous substance in the workplace upon request of an employee, an employee's collective bargaining representative, or an employee's physician.

Employees have the right to see and copy their medical records and records of exposure to potentially toxic materials or harmful physical agents.

Employers must allow access by employees or their representatives to accurate records of employee exposures to potentially toxic materials or harmful physical agents, and notify employees of any exposures in concentration or levels exceeding the exposure limits allowed by Cal/OSHA standards.

Any employee or their representative has the right to observe monitoring or measuring of employee exposure to hazards conducted to comply with Cal/OSHA regulations.

WHEN CAL/OSHA COMES TO THE WORKPLACE:

A trained Cal/OSHA safety engineer or industrial hygienist may visit the workplace to make sure your company is obeying workplace safety and health laws.

Inspections are also conducted when an employee files a valid complaint with Cal/OSHA.

Cal/OSHA also goes on-site to the workplace to investigate a serious injury or illness, or fatality.

When an inspection begins, the Cal/OSHA investigator will show official identification.

The employer, or someone the employer chooses, will be given an opportunity to accompany the investigator during the inspection. An authorized representative of the employees will be given the same opportunity. Where there is no authorized employee representative, the investigator will talk to a reasonable number of employees about safety and health conditions at the workplace.

VIOLATIONS, CITATIONS, AND PENALTIES:

If the investigation shows that the employer has violated a safety and health standard or order, Cal/OSHA may issue a citation. Each citation carries a monetary penalty and specifies a date by which the violation must be abated. A notice, which carries no monetary penalty, may be issued in lieu of a citation for certain non-serious violations.

Penalty amounts depend in part on the classification of the violation as regulatory, general, serious, repeat, or willful; and whether the employer failed to abate a previous violation involving the same hazardous condition. Base penalty amounts, penalty adjustment factors, and minimum and maximum penalty amounts are set forth in California Code of Regulations, title 8, section 336 (www.dir.ca.gov/title8/336.html). In addition, a willful violation that causes death or permanent impairment of the body of any employee can result, upon conviction, in a fine of up to $250,000 or imprisonment up to three years, or both, and if the employer is a corporation or limited liability company, the fine may be up to $1.5 million.

The law provides that employers may appeal citations within 15 working days of receipt to the Occupational Safety and Health Appeals Board.

An employer who receives a citation, Order to Take Special Action, or Special Order must post it prominently at or near the place of the violation for three working days, or until the unsafe condition is corrected, whichever is longer, to warn employees of danger that may exist there. Any employee may protest the time allowed for correction of the violation to the Division of Occupational Safety and Health or the Occupational Safety and Health Appeals Board.

HELP IS AVAILABLE:

To learn more about workplace safety rules, you may contact Cal/OSHA Consultation Services for free information, required forms, and publications. You can also contact a local district office of Cal/OSHA. If you prefer, you may retain a competent private consultant, or ask your workers' compensation insurance carrier for guidance in obtaining information.

Call the FREE Worker Information Helpline – (866) 924-9757

DIVISION OF OCCUPATIONAL SAFETY AND HEALTH (CAL/OSHA)

HEADQUARTERS: 1515 Clay Street, Ste. 1901, Oakland, CA 94612 – Telephone (510) 286-7000

District Offices

American Canyon	3419 Broadway St., Ste. H8, American Canyon 94503	(707) 649-3700
Bakersfield	7718 Meany Ave., Bakersfield 93308	(661) 588-6400
Foster City	1065 East Hillsdale Bl., Ste. 110, Foster City 94404	(650) 573-3812
Fremont	39141 Civic Center Dr., Ste. 310, Fremont 94538	(510) 794-2521
Fresno	2550 Mariposa St., Rm. 4000, Fresno 93721	(559) 445-5302
Long Beach	3939 Atlantic Ave., Ste. 212, Long Beach 90807	(562) 506-0810
Los Angeles	320 West Fourth St., Rm. 820, Los Angeles 90013	(213) 576-7451
Modesto	4206 Technology Dr., Ste. 3, Modesto 95356	(209) 545-7310
Monrovia	800 Royal Oaks Dr., Ste. 105, Monrovia 91016	(626) 239-0369
Oakland	1515 Clay St., Ste. 1303, Box 41, Oakland 94612	(510) 622-2916
Redding	381 Hemsted Dr., Redding 96002	(530) 224-4743
Sacramento	2424 ArdenWay, Ste. 160, Sacramento 95825	(916) 263-2800
San Bernardino	464 West Fourth St., Ste. 332, San Bernardino 92401	(909) 383-4321
San Diego	7575 Metropolitan Dr., Ste. 207, San Diego 92108	(619) 767-2280
San Francisco	455 Golden Gate Ave., Rm. 9516, San Francisco 94105	(415) 557-0100
Santa Ana	2 MacArthur Place, Ste. 720, Santa Ana 92707	(714) 558-4451
Van Nuys	6150 Van Nuys Blvd., Ste. 405, Van Nuys 91401	(818) 901-5403

Regional Offices

San Francisco	455Golden Gate Ave., Rm 9516, San Francisco 94102	(415) 557-0300
Sacramento	2424 Arden Way, Ste. 300, Sacramento 95825	(916) 263-2803
Santa Ana	2 MacArthur Place, Ste. 720, Santa Ana 92707	(714) 558-4300
Monrovia	750 Royal Oaks Dr., Ste. 105, Monrovia 91016	(626) 470-9122

Cal OSHA Consultation Services

Field / Area Offices

•Fresno / Central Valley	2550 Mariposa Mall, Rm. 2005 Fresno 93721	(559) 445-6800
•La Palma / Los Angeles / Orange County	1 Centerpointe Dr., Ste. 150 La Palma 90623	(714) 562-5525
•Oakland/ Bay Area	1515 Clay St., Ste 1103 Oakland 94612	(510) 622-2891
•Sacramento / Northern CA	2424 Arden Way, Ste. 410, Sacramento 95825	(916) 263-0704
•San Bernardino	464 West Fourth St., Ste. 339 San Bernardino 92401	(909) 383-4567
•San Diego / Imperial County	7575 Metropolitan Dr., Ste. 204 San Diego 92108	(619) 767-2060
•San Fernando Valley	6150 Van Nuys Blvd., Ste. 307 Van Nuys 91401	(818) 901-5754

Consultation Region Office

•Fresno	2550 Mariposa Mall, Rm. 3014 Fresno 93721	(559) 445-6800

Enforcement of Cal/OSHA workplace safety and health standards is carried out by the Division of Occupational Safety and Health, under the California Department of Industrial Relations, which has primary responsibility for administering the Cal/OSHA program. Safety and health standards are promulgated by the Occupational Safety and Health Standards Board. Anyone desiring to register a complaint alleging inadequacy in the administration of the California Occupational Safety and Health Plan may do so by contacting the San Francisco Regional Office of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor Tel: (415) 625-2547. OSHA monitors the operation of state plans to assure that continued approval is merited.

August 2019

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As required by AB 75 (Strom Martin, Chapter 764, Statutes of 1999), each state agency and large state facility was required to develop an integrated waste management plan by July 1, 2000. The plan was to lay out how the agency or facility would divert at least 25 percent of its solid waste from landfills or transformation facilities by January 1, 2002, and 50 percent by January 1, 2004. Annual reporting on implementation of the plans is also required. These plans (and the annual reports, once submitted) can be reviewed in the State Agency Reporting Center (SARC).

Changes to Reporting Requirements for DAAs Starting January 1, 2015(
As of January 1, 2015 pursuant to AB 2490 (Eggman, Chapter 342, Statutes of 2014) Sections 10 and 15, California district agricultural associations (DAA) are excluded from the definition of "state agency" for purposes of the provisions in Public Resources Code Section 42926 (d). As such, DAAs are no longer required to submit an annual state agency waste management report to CalRecycle's State Agency Reporting Center (SARC) by May 1 of each year. A full explanation of AB 2490 changes for DAAs is available on the California Legislative Information site.

While AB 2490 exempts DAAs from reporting requirements, each DAA is required to still maintain and monitor its waste diversion programs and activities to ensure adherence to the diversion requirements for State entities under AB 75 (Strom-Martin, Chapter 764, Statutes of 1999), AB 341 (Chesbro, Chapter 476, Statutes of 2011), SB 1016 (Wiggins, Chapter 343, Statutes of 2008), and PRC 42920-42926. See State Agency Laws and Regulations at for more information on diversion and recycled content purchasing requirements.

Any new agency or facility that has not yet completed a plan should contact CalRecycle staff for assistance. The following resources were provided to help agencies and facilities complete their plans.

- **State Agency Model Integrated Waste Management Plan** was drafted by the California Integrated Waste Management Board (now CalRecycle) to assist State agencies with meeting the new requirements.
- ***Conducting a Diversion Study--A Guide for Local Jurisdictions*** (Pub. #311-99-006). Includes volume-to-weight conversion factors for various material types.
- ***Waste Reduction Policies and Procedures for State Agencies*** (Pub. #441-99-017)
- ***Solid Waste Generation, Disposal, and Diversion Measurement Guide for State Agencies and Large State Facilities*** *(Final Draft for Peer Review)* (Pub. #321-00-007)
- **Volume-to-weight conversion factors** (approximate) for recovered materials, as found in Appendix I of *Conducting a Diversion Study: A Guide for California Jurisdictions* (Pub. #311-99-006)

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Introduction

- Background
- Benefits of Waste Reduction
- Elements of a Self-Sustaining Waste Reduction Program
- Establishing Departmental Policy and Goals
- Table of Contents

Background

California's Solid Waste Mandates

Assembly Bill 939 (Sher, Chapter 1095, Statutes of 1989) requires every California city and county to divert 50 percent of its waste from landfills by the year 2000. Current law also requires State agencies to institute waste reduction and buy recycled activities to assist local governments in this effort. With less than a year remaining to attain the solid waste diversion goals of AB 939, California has reached a commendable statewide 33 percent waste diversion rate. (Note: As of 2000, the statewide rate was at 42 percent.)

Changes to Reporting Requirements for DAAs Starting January 1, 2015

As of January 1, 2015 pursuant to AB 2490 (Eggman, Chapter 342, Statutes of 2014) Sections 10 and 15, California district agricultural associations (DAA) are excluded from the definition of “state agency” for purposes of those provisions (Food and Agricultural Code Section 4061(a) and PRC Section 42926 (d)). As such, DAAs are no longer required to submit an annual state agency waste management report to CalRecycle’s State Agency Reporting Center (SARC) by May 1 or a State Agency Buy Recycled Campaign report (SABRC) by March 1 of each year for “Calendar Year” reporters or October 31 for “Fiscal Year” reporters. A full explanation of AB 2490 changes for DAAs can be found here.

While AB 2490 exempts DAAs from reporting requirements, CalRecycle still requires each DAA to maintain and monitor its programs and waste diversion activities to ensure adherence to the diversion requirements for State entities under AB 75 (Strom-Martin, Chapter 764, Statutes of 1999), AB 341 (Chesbro, Chapter 476, Statutes of 2011), SB 1016 (Wiggins, Chapter 343, Statutes of 2008), PCC 12153-12217, and PRC 42920-42926. See State Agency Laws and Regulations for more information on diversion and recycled content purchasing requirements.

The Integrated Waste Management Hierarchy

To most efficiently achieve the waste reduction goals of AB 939, the legislature established a hierarchy of waste reduction practices: (1) waste prevention (also referred to as source reduction), (2) recycling and composting, (3) environmentally safe transformation and land disposal. Waste prevention is at the top of this hierarchy because when resources are used efficiently, less waste is created. If waste is not created, it does not need to be recycled or disposed. Waste prevention and reuse activities have been highlighted in this document as the most effective way to save money and resources in State government. However, a comprehensive and integrated approach to waste reduction is suggested including waste prevention, reuse, recycling collection, composting, and recycled-content product procurement activities.

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State Government's Role in Reducing Waste

Current law places state waste diversion responsibility on local government. As citizens, State employees have the responsibility to participate and contribute to the diversion activities of the communities in which they live and work. Equally, each State agency has the responsibility to divert waste to further the waste diversion goals of the jurisdiction or regions of the state in which the agency does business. Local governments are subject to fines of up to $10,000 per day if the waste diversion goals are not met. These penalties will ultimately affect all citizens if the State does not do its part in meeting the mandates.

Beyond responsibilities at the local level, the State of California should lead the way in exemplary waste reduction efforts. Although state government is diverse, opportunities exist in each agency to reduce waste. Implementing waste prevention, reuse, recycling, and buying recycled activities within each state agency will provide leadership, responsibility and economic and environmental benefits to the state, its people, business community, and government.

This guidance document provides California State agencies, offices, departments, divisions, boards, commissions, and facilities with a framework to develop and implement waste reduction and recycled-content product procurement policies and programs to:

- Demonstrate State government leadership and responsibility toward meeting the state's solid waste goals.
- Show environmental leadership in conserving natural resources.
- Maximize budget resources through the efficient use of all resources.
- Further compliance with laws requiring state agency waste reduction and buy recycled activities.

Benefits of Waste Reduction

Produces More Efficient Operations and Reduces Costs

The traditional use of the word "waste" means inefficient use of resources. Waste reduction is the efficient use of all resources. It begins with examining how business is conducted, including how materials are used, why individual business processes are performed, and what products are purchased. Efficient operations will minimize waste in materials, labor, and money. Specific benefits to an agency employing a waste reduction program include reduction in energy, water and utility costs; reduction in raw material usage, storage and disposal costs; and decreased printing and postage costs. Waste reduction, in whatever its form, results in direct cost savings for the State of California.

Develops Markets for Recycled Materials

Purchasing recycled-content products creates markets for recycled materials, thereby supporting the manufacturing capacity for those products. The State can make a significant impact on the development of markets for recycled materials by each department meeting or exceeding the purchasing and reporting goals of Public Contract Code (PCC) Sections 12205 (State Agency Buy Recycled Campaign) in each of the 11 product categories (See Procurement: Buying Recycled).

Elements of a Self-Sustaining Waste Reduction Program

Improves an Organization's Environmental Performance

A waste reduction program involves much more than placing recycling bins in common areas. In fact, the term "program" is misleading because it implies doing something "extra." A self-sustaining waste reduction

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program is simply a better, more efficient way to do the same thing—conduct business. It is an ongoing process that continually improves an organization's environmental performance. A comprehensive self-sustaining waste reduction program incorporates waste prevention, reuse, recycling, and recycled-content product procurement activities into everyday business. It originates with and is supported through management as an organizational policy. Employees are expected to be familiar with the policies and conduct business in that manner.

Includes Management Support and Employee Input
Management through policies and directives supports a successful waste reduction program; however, it also requires employee involvement. Staff responsible for performing the business functions is best able to identify wasteful practices and recommend areas for improvement. With upper management support, the improvements can be implemented and the waste reduction savings can be realized. This approach to encouraging employee input with the full support of upper management perpetuates employee "buy-in" and helps develop a sustainable waste reduction program.

Establishing Departmental Policies and Goals

Secure Organizational Support
Successful waste reduction requires commitment and support from both the upper management and staff level employees. The ultimate goal in recruiting organizational support is to make waste reduction part of the culture of the workplace. Waste reduction must become inherent to the way business is conducted.

Management must be clear on waste issues and see that the benefits of waste reduction outweigh the costs. It must be understood that it is not a problem to be fixed, it is an ongoing improvement to internal processes.

There are many support materials available through the CalRecycle to help document the benefits of waste reduction and to encourage top management support. See "Encouraging Top Management to Support Waste Reduction Efforts" on page 36 of *Trainers' Manual: Establishing a Waste Reduction Program at Work*, and U.S. EPA WasteWise fact sheet, *Steps for Implementing a Waste Prevention Program*.

Know Your Waste Types
There are two methods to identify waste: waste assessment and analysis of business functions.

Waste Assessment. The traditional method of estimating waste generation, a waste assessment or audit, identifies materials and items that are major contributors to an organization's waste stream. A waste assessment also provides a baseline for measuring the effects of waste reduction practices. Waste assessments can range from visual peeks into garbage cans to more formal retrieval, separation and weighing of disposed materials. For health and safety concerns in an office environment, visual assessments are recommended.

For more information on how to perform a waste assessment, see CalRecycle Pub. #500-94-004, *Reduce, Reuse, Recycle—A Guide for California Business*; CalRecycle Pub # 442-95-070, *Establishing a Waste Reduction Program at Work*; and U.S. EPA's WasteWise fact sheet, *Conducting a Waste Assessment*.

Analysis of Business Functions. Examining major business processes for opportunities to reduce materials, labor or time will produce greater overall cost savings, and reduce waste at the same time.

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An example of a business function change that improved efficiency and reduced waste is a change the Fair Political Practices Commission (FPPC) instituted for completion of their Form 700, Statement of Economic Interest. Formerly, hard copies (at 31 pages each) were provided to each State employee required to comply. Each State employee would complete and return the package to FPPC. A majority of the completions required only a signature on the front page, leaving the other 30 pages unused.

The FPPC now provides the Form 700 as a downloadable PDF (portable document format) file that agencies can provide electronically to their employees. Employees access the form electronically and print only pages of the form they need to return to the FPPC, i.e., the signature page, in most cases. By implementing the PDF version of the Form 700, the FPPC realizes savings in several areas: reductions in paper, postage, storage, and labor costs required to manage the volume of paper previously used as well as the reduction in paper waste.

An analysis of business functions to improve efficiencies and reduce waste should be ongoing in any State agency. As part of a waste reduction program, it can provide immediate and measurable results.

Set Waste Reduction Policies and Goals

Waste reduction policies reflect the visions and priorities of the department. Policies should be drafted early in the process of implementing a waste reduction program and formally adopted by the agency. Formal adoption by the agency demonstrates support and commitment. Once adopted, standard operating procedures, new employee orientations, etc. should highlight the waste reduction policies.

Waste reduction goals should be adopted based on the policies of the agency. This can be as part of the policies themselves, or as a separate document. The goals should be for a specified time period, such as one or two years. Setting realistic and measurable goals will ensure success.

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Last updated: May 15, 2020
State Agency Waste Management Programs: https://www.calrecycle.ca.gov/StateAgency/
Contact: Recycling Coordinator SARC@calrecycle.ca.gov, (916) 341-6199
Contact: Buy Recycled Campaign SABRC@calrecycle.ca.gov, (916) 341-6199

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Implementing Waste Reduction

- Waste Prevention and Reuse
- Recycling/Collection
- Procurement: Buying Recycled
- Building Green
- Landscape Materials Management
- Table of Contents

The following outlines the steps to establishing a waste reduction program within a state agency.

Many of these steps are consistent with those used by the private sector. Realizing that "one size does not fit all" in practicing waste reduction, this is a general outline for guidance purposes, mostly pertaining to an office setting.

Each agency should take into consideration the primary business function performed when applying these steps. For instance, the California Department of Corrections, with diverse operations and facilities, would employ different steps in implementing waste reduction than a small office department, such as the Department of Boating and Waterways. Regardless of the size of the organization or the function, there are common components to any successful program.

Designate a Waste Reduction Team and Coordinator
A waste reduction coordinator should be appointed by management to ensure the policies and goals of the department are met. The coordinator should have strong organizational, leadership, and communication skills, and have enthusiasm for waste reduction.

A waste reduction team of staff should be designated to assist the coordinator in implementing and maintaining the program. The team can be voluntary or mandatory; however, voluntary recruitment with team duties included in the staff's duty statement to formalize the efforts results in the most committed team. The size of the team depends on the size of the agency. Representatives from each functional area and level of the agency must be represented.

The waste reduction coordinator and team are responsible for educating, planning, and maintaining the program. The team should meet regularly. The CalRecycle's Waste Reduction Committee meets biweekly to monthly, depending on the items to be discussed. Subcommittees may be formed to address specific action items related to the agency policies and goals.

Develop an Action Plan
An action plan to achieve each established goal should be drafted by the team as a working document. The action plan outlines tasks to be accomplished, staff responsible for each task, and a timeline for completion of each task.

Measure Savings
Measuring savings from waste reduction efforts provides information to help sustain current efforts and improve upon them. Highlighting savings keeps employees and management involved and enthusiastic

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about the changes that have been made. Measuring also provides a monitoring system to identify and correct unexpected problems quickly.

It's important to determine the method of measurement early in the program. Whether through a waste audit or through changes to business functions, measuring waste reduction requires establishing a baseline of the materials to be measured.

For more information on measuring savings through waste reduction, see *Measuring the Success of Office Paper Reduction Efforts*, or #442-95-070, *Establishing a Waste Reduction Program at Work*.

Educate/Publicize Results
Once the savings are measured, they can be used to educate staff and management of the goals achieved and the success of the campaign. Education is an ongoing effort. The goal is to have waste reduction become the way daily business is conducted.

Waste Prevention and Reuse

What Is Not Created Does Not Need to Be Destroyed

Waste prevention and reuse, sometimes referred to as source reduction, is preventing or reducing waste during its production rather than managing it after its generation, as in recycling and disposal. Preventing waste means using less material, such as paper, to do the same job. Reusing materials also is a form of waste prevention because materials go further, thereby producing less overall waste.

Waste prevention is accomplished by getting the maximum use of any material before it is recycled or thrown away. It includes replacing disposable materials with reusable materials, eliminating a particular item altogether, repairing or maintaining equipment so it last longer, and using electronic communications instead of paper.

Waste prevention and reuse measures are the first steps in a comprehensive waste reduction program. Successful waste prevention requires creative and analytical thinking first about how a reduction in materials can be accomplished, and then what can be done to reuse the materials that have been used once. Too often only recycling systems are considered rather than reducing and reusing systems.

Successful waste prevention requires making changes to materials that come in as raw materials, supplies, or packaging as opposed to thinking about waste reduction as only trash going out. All materials that are recycled or disposed have been paid for in some way. It is important to consider purchasing practices to see if materials can be moved "upstream" into the waste prevention and reuse categories instead of focusing on recycling as the first and only treatment of materials. By minimizing the volume of raw materials, supplies or packaging used, direct savings are realized.

Case Study
CalRecycle has undertaken a comprehensive waste prevention initiative in its office headquarters. The CalRecycle formed an in-house committee to develop and implement a waste prevention program to reduce waste at the CalRecycle and serve as a model for other public and private sector office settings. Highlights from the first nine months of the program include the following.

White office paper use was reduced by 25 percent by:

- Discouraging avoidable or excess copying and printing

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- Encouraging communications via electronic mail.
- Encouraging two-sided copying and printing.
- Making two-sided printing an automatic computer feature.
- Reducing the size of documents.
- Streamlining document review processes.
- Turning one-sided paper into scratch pads.
- Pruning mailing lists.

These efforts are estimated to produce annual savings of:

- 364 cases (3640 reams or 1.8 million sheets) of white paper.
- $16,724 in reduced postage costs.
- $68,370 in photocopying costs.
- $5,500 in reduced printing costs.
- $10,151 in reduced purchasing costs (paper and note pads).

Recycling/Collection

Recycling Is Not Enough

Recycling has traditionally been the first action taken when implementing a waste reduction program. Too often it is the only action implemented. An agency that implements recycling collection programs without implementing the other elements of an integrated system may be lacking the true benefits of waste reduction and resource efficiency. To realize the full cost and resource savings a comprehensive waste reduction program can provide, an agency should first focus on waste prevention and reuse activities. However, recycling is a critical component to an integrated waste management system.

Materials to Collect for Recycling

Before determining what materials to collect for recycling, the agency must first determine what materials are generated in sufficient quantities to support a recycling program. The materials to collect for recycling and the methods used to collect those materials are specific to the organization and site. Current law requires State agencies and facilities to collect office paper, corrugated cardboard, newsprint, beverage containers (as defined in section 14505 of the Public Resources Code [PRC]), waste oil, and any other material at the discretion of the CalRecycle (see Applicable Statutes, next page).

A majority of State agencies will comply with these mandates as they operate in office settings generating these materials. However, State agencies or facilities with specific functions may generate other waste materials in significant quantities sufficient for recycling. For instance, the Department of Transportation generates construction and demolition (C&D) materials in sufficient quantities to support a C&D collection program. (For more information on C&D debris or other special wastes, see Appendix B, Waste Reduction Resources for State Agencies.)

Collection Methods

The methods used to collect, separate, store, and remove recyclables depends on the material types, volume, space availability, and organizational structure to remove the materials. General recycling program options include:

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Source Separation. Materials such as white paper, mixed paper, aluminum, glass, plastic, and cardboard are segregated by type into bins where initially discarded. This is the traditional approach to office recycling. Characteristics of a source separated recycling program are:

- Potential high recovery value of recyclables.
- Provides an adequate recovery rate to contribute to State waste diversion goals.
- Provides significant avoided disposal costs for building management (approximately $800 to $1400 per month according to BFI).
- Requires only 5 percent more custodial staff time to handle discarded materials.
- Success (high recovery rate) based on employee education and involvement.

Dry Commingled (unseparated). All dry waste materials are mixed where initially discarded, then compacted, and hauled away for a fee (about 8 percent less than the charge for municipal solid waste or MSW). The materials are mechanically/manually sorted at a transfer station or "clean" materials recovery facility (MRF). Unacceptable materials typically include cafeteria and restroom waste, food/beverages, liquids, pallets, construction debris, and landscape waste. Characteristics of a dry commingled system are:

- Reduced recovery value of recyclables.
- Provides a high recovery rate to contribute to state waste diversion goals.
- Avoided disposal costs for building management depends on fee to haul away dry commingled recyclables vs. MSW.
- Requires minimal additional custodial staff time to handle discarded materials.
- Requires less employee education and involvement to achieve a high recovery rate.

Education is Key to Success

Education is important to the success of any waste reduction program. With recycling collection programs, education is critical. Staff should be trained about the collection system being implemented and how their participation determines the success of the program. This training should include materials being diverted, the proper location to put the recyclables, and clearly identified lists of unacceptable materials. Education increases participation in the program and minimizes contamination of recyclables thereby increasing the volume of recyclables and the overall success of program.

Applicable Statutes

Current law requires each State agency/office to initiate activities for the collection, separation, and recycling of recyclable materials whether in State-owned or -leased facilities in Sacramento, Los Angeles, and San Francisco counties, and in any other area the CalRecycle determines is feasible. With assistance from the CalRecycle, each State agency shall recycle office paper, corrugated cardboard, newsprint, beverage containers (as defined in section 14505 of the PRC), waste oil, and any other material at the discretion of the Board.

Additional Resources

The CalRecycle has a Web site for State agencies, which links to other useful pages within the site, including the following:

For more information on statutes pertaining to the collection and recycling of materials in State offices (PCC Section 12165 (a) and PRC Sections 42560-42562), contact the CalRecycle's Project Recycle staff (See Appendix B).

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For more information on office paper recycling, waste assessments, and cost-benefit analysis of office paper recycling, see the many publications available through the CalRecycle's Business Waste Reduction Fact Sheets and Case Studies.

Procurement: Buying Recycled

Completes the Materials "Loop"
Buying recycled-content products (RCP) completes the recycling loop by creating markets for recycled materials to use as feedstock in the manufacturing of recycled-content products. It is the demand side of the recycling equation. A demand for recycled-content products in turn supports recycling collection as the most economical and desirable method of disposal.

Purchasing Power of State Government
The State's role in RCP procurement is twofold. On the one hand, State purchases can definitely be an asset to markets for recycled materials. The State purchases billions of dollars of products each year. State government is the single largest purchasing entity in California. Through this buying power, the State has the ability to create and maintain stable markets for recycled materials.

The second role the State fulfills by purchasing RCPs is that of leadership and an example to other government entities throughout the State as well as the private sector. If the private sector believes that the State is committed to buying RCPs, it too will respond by manufacturing more RCPs and by increasing its own RCP purchases. In this way the State and the private sector create a synergy that will build and sustain markets for recyclable materials.

State Agency Buy Recycled Campaign
Activities pertaining to RCP procurement by State agencies increased considerably with the passage of Assembly Bill 4, (Eastin, Stats. 1989, c. 1094). This statute, added to the Public Contract Code and revised by several subsequent bills, constituted the major components of what has become known as the State Agency Buy Recycled Campaign (SABRC). The current laws require State agencies to:

- Purchase recycled-content products in sufficient quantities to attain the annual goals for specified product categories.
- Report annual purchases of recycled and nonrecycled products in specified product categories.
- Submit plans identifying how the annual goals for recycled-content products will be attained.
- Require contractors to certify, under penalty of perjury, the recycled content of the products they offer to the State.
- Purchase ALL recycled-content products instead of nonrecycled products whenever they are available at no more than the total cost of nonrecycled products, and fitness and quality are comparable.
- Attain the mandated recycled-content product procurement goals regardless of the price differences between recycled- and nonrecycled-content products.

Staff from CalRecycle, with assistance from the Department of General Services (DGS) provide a SABRC manual and training to implement the statutory requirements. As of FY 97/98, 113 out of 133 agencies submitted reports (84 percent) and reported $24,483,218 in RCP purchases.

Elements of a Successful State Agency Buy Recycled Campaign

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There are many elements that go into a successful SABRC within any agency. Depending on the size of the institution, the way it is organized, the extent to which purchasing is centralized, and the commitment made to these mandates, each agency's results can vary considerably. The access to computers and software dedicated to purchasing and accounting and the individual staff working on these issues will effect the amount of RCP purchases and the ability of that agency to accurately report those purchases. Based on the experience that CalRecycle staff has gained over the past four years of implementing the SABRC and on comments received from State agencies, the following items have been identified as key elements of a successful buy recycled campaign.

Commitment From the Top

Because of the need for multiple offices to be involved in identifying, purchasing, tracking, and reporting RCPs for an agency, it is often necessary to have a high level manager oversee these activities. Therefore, a critical factor to a successful SABRC is support throughout the levels of management. Middle and upper level support and backup are critical to overcoming hesitation or complacency when it comes to purchasing RCPs rather than non-RCPs. Because staff from several offices may need to be involved in the SABRC activities, a manager must be responsible for communicating the needs to the other managers and for coordinating the efforts of the team.

Dedicated Personnel

Those responsible for the SABRC mandates must purchase RCPs rather than non-RCPs whenever possible. Without personal dedication by the agency coordinator, increased RCP procurement will be very difficult. Much of the time, the responsibilities for the SABRC are simply added to the responsibilities of one particular person. This is often not realistic nor appreciated. At the very least, the SABRC coordinator responsibilities should be those of someone in an appropriate position of authority, overseeing procurement and related administrative functions with an interest in environmental issues.

Internal Communication/Coordination

For most State agencies, attaining the SABRC mandates will require a coordinated effort among multiple branches or offices within an agency. The individual responsible for generating the report may not work in the procurement office. At the very least, a close relationship must exist between the buyers, the users, and those generating the report. It would not be uncommon for another person or office to be responsible for collecting the procurement data during the year, and the users of the products (the copy room, painters, plumbers, vehicle pool, etc.) to also play a part in the process. Each of the people in these positions needs to be part of the team that becomes responsible for attaining the SABRC mandates and generating the report. Full responsibility cannot be placed upon one individual for an agency's compliance with the mandates.

External Information Sharing

Another element that cannot be overlooked is education. Some people have had bad experiences with RCPs in the past or have heard of such experiences from others. RCPs have improved a great deal in recent years with corporate America coming into the manufacturing arena for many product categories. With considerable research and development going into this new generation of RCPs, many of them compare very favorably to, and some are simply better than, non-RCPs with respect to price, quality, and availability. These advancements need to be discussed among buyers and sellers. Buyers need to

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communicate with suppliers, and a concerted effort must be made by the State as a whole to inform product manufacturers of the preferences for RCPs. Additionally, SABRC contacts representing various agencies need to communicate and share experiences with each other.

Evaluation and Improvement

The final element to a successful SABRC is the ability to analyze past purchases with respect to product performance, price, delivery, and vendor satisfaction, as should be done with all purchases regardless of material content. This type of information will be used to develop a history of RCP procurements.

Analysis of purchases necessitates the development of some type of procurement tracking mechanism. Staff must have a system to gather the information, organize it in a meaningful manner, and be able to manipulate the data by a variety of criteria. Each member of the team—buyers, users, management, and those tracking the purchases—must fully analyze past purchases from each of their particular areas of expertise so that they will lead to more successful future purchases. This will result in establishing "best RCP purchasing practices," prevent some mistakes from being repeated, and should result in feedback for the RCP suppliers on how to improve the RCPs that were not purchased.

Building Green

The Benefits of Green Buildings

A "green" or sustainable building is a structure that is designed, built, renovated, operated, or reused in an ecological and resource efficient manner. Green buildings are designed to meet certain objectives, such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing environmental impacts associated with the production of raw materials and building construction.

Green buildings provide significant savings in energy and operating costs over the life of the building. Cost savings are fully realized when they are incorporated at the conceptual design phase through construction, and with the assistance of an integrated team of professionals. Additionally, building green promotes waste reduction and the efficient use of resources by reusing building products and utilizing recycled-content products, thereby supporting markets for recycled materials.

The State has the opportunity, when planning and constructing new State buildings, to realize the operating cost savings green buildings provide while providing leadership in waste reduction and recycled-content product procurement practices in the construction industry. The CalRecycle, in coordination with CalEPA, is actively working to incorporate sustainable building measures into several developing State building projects to demonstrate the performance and economic success of sustainable construction in the state.

Available Resources

The CalRecycle, with assistance from the City of Santa Monica and Gottfried Technology, Inc. (GTek), is developing a statewide plan for a sustainable building program. The program, now in the conceptual stage, will address the benefits and provide support for sustainable buildings in the State, local, and private sectors.

The CalRecycle develops and distributes educational materials relating to green buildings and provides comments and technical assistance for specific building projects. For more information, visit CalRecycle's green building Web site.

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Landscape Materials Management

Waste-Efficient Landscape Maintenance Practices

Landscape sites at State agency facilities and institutions can be maintained in an environmentally sound and cost-effective manner by using responsible landscape management practices that reduce green waste generation, reuse trimmings and prunings on site, and recycle organic products (mulch and compost) back into the landscape. These management practices include:

- Controlled Irrigation—Water just enough to maintain plant health and appearance.
- Precise Fertilization—Only apply precise amounts of necessary plant nutrients.
- Grasscycling—The natural practice of leaving clippings on the lawn when mowing.
- Selective Pruning—Use techniques that result in less green waste and healthier plants.
- On-Site Composting and Mulching—Use site-generated trimmings as feedstock.
- Proper Organic Materials Application—Use products derived from urban green waste.
- Environmentally Beneficial Design—Install low-maintenance, drought-tolerant plants and waste-efficient landscape design features to reduce trimmings and prunings.

Benefits of the "Three Rs" in Landscape Management

Practices that reduce green waste generation produce significant economic and environmental benefits. Direct savings can be realized by reduced maintenance, labor, water and fertilizer cost. Indirect cost benefits include reduced hauling expenses as well as disposal fees and less exposure to workers' compensation claims due to crew injury from lifting heavy loads. On-site management of yard trimmings returns valuable, high-quality nutrients and organic matter to the soil. This encourages healthier, disease and pest resistant plants that improve appearance, prevent erosion, and increase property values.

Using recycled organic materials in landscapes enhances soil fertility and water holding capacity, slows evaporation losses, increases plant drought tolerance, conserves water, and also suppresses the spread of wildfires. Using the environmentally beneficial landscape maintenance practices outlined above will reduce fertilizer and water usage, which in turn reduces toxic runoff that can lead to surface and groundwater pollution.

Case Study

Fountain Circle on the west side of California's State Capitol was selected as a demonstration ground for grasscycling. This was a cooperative effort among the CalRecycle, Department of General Services, the Office of Buildings and Grounds, and the Toro Company, which supplied the mulching mower. This initial demonstration was so well received that DGS/OBG is now converting its entire fleet to grasscycling mowers.

Results of Grasscycling Demo at State Capitol:

- Mowing time reduced by over 50 percent. Bagging and disposal cost eliminated.
- More than 300 pounds of grass clippings per 1000 square feet recycled annually.
- Nitrogen content of recycled clippings reduced fertilization requirements by 25 percent.
- Similar savings in water usage noted.

Available CalRecycle Resources

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CalRecycles's organics Web site has sections containing specific information on the practices outlined above, a compost and mulch source list, a section for publications, reports, articles, and fact sheets available for downloading or online ordering and a section on composting regulations.

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State Agency Waste Management Programs: https://www.calrecycle.ca.gov/StateAgency/
Contact: Recycling Coordinator SARC@calrecycle.ca.gov, (916) 341-6199
Contact: Buy Recycled Campaign SABRC@calrecycle.ca.gov, (916) 341-6199

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Appendices

- Appendix A: Definitions
- Appendix B: Waste Reduction Resources for State Government Agencies
- Appendix C: Sample Waste Reduction and RCP Procurement Policy Statements

Appendix A: Definitions

Recycled Content Product (RCP) Procurement. The term recycled content product procurement refers to purchasing practices that support markets for recycled materials and minimize environmental impact.

California State Agency. Refers to every State office, department, division, board, commission, or other agency of the State of California.

Waste Reduction. The term waste reduction, as used in this document, refers to the comprehensive efforts of waste prevention, reuse, recycling/collection, and procurement practices.

Appendix B: Waste Reduction Resources for State Government Agencies

General Resources. CalRecycle's resource page for State agencies includes links to pertinent information, including the other programs in this section.

CalRecycle Publications. CalRecycle's online publications catalog provides information on more than 500 CalRecycle publications. Most are available on line or can be downloaded. Hard copies can be ordered via e-mail.

Business Resource Efficiency and Waste Reduction Program. Developed primarily to assist the business community to divert waste, this program provides fact sheets and guides on waste prevention and resource efficiency. Many of the materials are applicable to any office setting and are available to California State agencies. For more information on CalRecycle's Business Assistance resources, please visit our Business Assistance Portal for more information on growing or greening a business.

State Agency Waste Management Manual. The CalRecycle coordinates implementation of waste prevention, reuse, and recycling programs at State-owned and leased buildings and facilities including offices, prisons, youth authority facilities, developmental centers, hospitals, maintenance facilities, and parks.

The Board coordinates and assists State facilities by:

- Managing State recycling contracts.
- Training and advising State employees and recycling coordinators.
- Acting as a liaison between State facilities and recyclers.
- Providing recycling information, supplies, and equipment.
- Gathering and reporting data on materials collected for recycling.

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As of January 1999, Project Recycle was coordinating and monitoring programs at more than 1,800 State facilities. During 1998 over 63,000 tons of material were reported collected for recycling from California State facilities.

State Agency Buy Recycled Campaign. The State Agency Buy Recycled Campaign (SABRC) consists of mandates for State agencies to purchase recycled-content products (RCP) in 11 categories ranging from copy paper to steel products. The mandates, located in the Public Contract Code (PCC), require each State agency to submit a Recycled Product Procurement Plan and a Recycled Product Procurement Report annually to CalRecycle. The reports are used to determine compliance with the RCP procurement mandates.

The State Agency Buy Recycled Campaign provides a recycled-content product database for State agencies to assist in procuring recycled-content products, and a guidance document to assist agencies with both procurement and reporting compliance. For more information, visit the SABRC Web site.

Appendix C: Sample Waste Reduction and RCP Procurement Policy Statements

The following are sample waste reduction policies and individual action items to support an agency's steps toward reducing waste. Agencies may need to add, modify, or delete items depending on the particular goals of the organization.

Waste Reduction Policy Statements (General)

1. It is the policy of the (Agency) to assist local government and business in meeting California's waste diversion mandates by practicing waste reduction and recycled content product procurement in all aspects of its internal and external operations.
2. The (Agency) shall continually strive to minimize the generation of waste and support markets for recycled materials through waste prevention, reuse, collection/recycling and composting, and the procurement of recycled content products.
3. The (Agency) recognizes the trust placed in it by the people of California to wisely use resources in the most effective and efficient manner possible so that waste is minimized in all areas of operation, so that procured products contain the maximum amount of recycled content, and so that savings are accounted for and measured.

Waste Prevention Policy Statements and Action Items

The (Agency) shall:

1. Use available information technology to maximize the efficient use of paper.

    1. Set all electronic systems to default double-sided printing, including individual and network software.
    2. Print all documents and communications double-sided.
    3. Use electronic mail and voice mail.
    4. Promote electronic access of agency information and publications to customers via the Internet prior to providing paper copies.

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2. Review standard documents, templates, and publications for waste reduction opportunities.

    1. Eliminate unnecessary reports and reduce report size.
    2. Use 1/2 sheets of paper for fax cover sheets instead of a full sheet (and use both sides).
    3. Design mailers to avoid use of envelopes.
    4. Proofread documents on screen and preview before printing.
    5. Annually purge and remove duplicate names and out of date entries from mailing lists.

3. Submit internal documents with minor legible handwritten corrections.

4. Utilize a centralized mailing system.

5. Review standard distribution/circulation procedures for waste reduction opportunities

    1. Circulate memos, documents, reports, periodicals, and publications.
    2. Post announcements on bulletin boards or circulate copies.

6. Maximize waste prevention practices in the custodial, maintenance and landscaping practices of state-owned buildings. Contractual arrangements with facility management in leased buildings shall maximize waste prevention in the custodial, maintenance and landscaping practices.

    1. Encourage cafeteria discounts for use of own cup, plate, and utensils.
    2. Encourage use of air dryers or cloth wipes in restrooms instead of paper towels.
    3. Encourage landscape maintenance to implement grasscycling.

Reuse Policy Statements and Action Items

The (Agency) shall:

1. Establish systems that routinely reuse paper and other office supplies.

    1. Reuse paper printed on one side:
        - In fax machines.
        - In copiers for draft copies, except where specifically prohibited by equipment warranties.
        - To make scratch paper and pads through DGS.
    2. Reuse envelopes by placing a label over the old address.
    3. Institute an office "trading post" next to supplies area to reuse office supplies, etc.
    4. Investigate whether local libraries, schools, hospitals, nursing homes, etc. could use old trade journals or magazines.

Employee Education/Outreach Policy Statements and Action Items

The (Agency) shall:

1. Develop an ongoing employee education and outreach campaign.

    1. Use intranet (internal web site) to post in-house waste reduction information (policy, goals, procedures, and accomplishments) for easy reference.
    2. Provide all new employees with an in-house Waste reduction policy orientation.
    3. Conduct employee educational activities on at least a quarterly basis.

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2. Become a government member of U.S. EPA's WasteWi$e program to show commitment to waste reduction practices.

3. Ensure all (Agency) documents carry a recycled logo and/or environmental policy statement.

Recycling Collection Policy Statements and Action Items

The (Agency) shall:

1. Work with CalRecycle to set up, implement, or expand collection programs.

2. Utilize CalRecycle collection contracts when feasible.

3. Provide, at a minimum, for collection of the following materials: white paper, newspaper, mixed paper, magazines, plastic, glass, and aluminum.

1. Provide desktop recycling containers for employees.
2. Provide clearly labeled recycling bins near copiers, shipping and receiving areas, and in employee eating areas.
3. Print directly on envelopes rather than using labels to increase envelope recyclability.

4. Periodically increase the level of white paper recycling and correspondingly decrease contaminants in white paper bins.

1. Don't buy paper that is a contaminant in recycling, e.g., thermal fax paper, glossy/plastic coatings, envelopes with plastic windows, or bright colors (including goldenrod).
2. Eliminate use of pressure sensitive adhesives.

Recycled Content Product Procurement Policy Statements and Action Items

The (Agency) shall:

1. Buy recycled-content products rather than nonrecycled content products. Quality and availability being comparable, the (Board/Agency) shall:

1. Buy only white copy/xerographic paper with at least 30 percent postconsumer recycled content.
2. Purchase the product with the greater recycled content when faced with a choice of two recycled products.
3. Use recycled-only bids and RCP set-asides to purchase products.

2. Attain the mandated RCP procurement goals.

1. Appoint SABRC contact.
2. Require recycled content information for all of the products purchased.
3. Track all RCP and non-RCP purchases within the product categories.
4. Annually submit the SABRC procurement report and plan.

Prevention and Reuse Procurement Policy Statements and Action Items

The (Agency) shall:

1. Purchase products that prevent waste.

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1. Purchase high-quality, durable products.
2. Purchase photocopiers with a fast, reliable duplex function designed for heavy loads.
3. Purchase refillable pens.

2. Purchase used or reused products at every opportunity.

1. Purchase reused diskettes.
2. Reuse disks from software purchases.
3. Purchase remanufactured toner cartridges.

2. Purchase products with no packaging, less packaging, or reusable packaging.

1. Purchase products in bulk.
2. Discuss with suppliers a reduction in the amount of packaging of the products purchased.

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Certified Unified Program Agencies (CUPA)

The Enforcement and Emergency Response Division (EERD) administers the technical implementation of the state's Unified Program – a consolidation of six environmental programs at the local level. EERD conducts triennial reviews of Unified Program agencies to ensure their programs are consistent statewide, conform to standards, and deliver quality environmental protection at the local level. EERD oversees the hazardous waste generator and onsite waste treatment surveillance and enforcement program carried out by local Unified Programs. DTSC was certified, effective January 1, 2005, to be the CUPA for Imperial and Trinity Counties.

Guidance

- Permit by Rule Permanent Household Hazardous Waste Collection Facility Inspection Checklist
- Permit by Rule Temporary Household Hazardous Waste Collection Facility Inspection Checklist
- Unified Program Strategic Plan
- Frequently Asked Questions

Forms

- Storage Extension Application for Generators
- UPA Model Application For Corrective Action Delegation Form 1447
- UPA Model Application For Corrective Action Delegation Form 1447 – Interactive
- UPA Model Application For Corrective Action Delegation Form 1447 – Instructions

Reports/Notices – Corrective Action Delegation

Tier 2 Level Implementation and Enforcement of Environmental Assessment and Corrective Action

- **LA County CUPA:** Notice of Approval
- **Merced County CUPA:** Notice of Approval
- **Sacramento County CUPA:** Notice of Approval
- **San Diego County CUPA:** Notice of Approval
- **San Mateo County CUPA:** Notice of Approval
- **Ventura County CUPA:** Notice of Approval

Resources

- Cal CUPA
- U.S. EPA Compliance
- U.S. EPA Enforcement
- U.S. Envirofacts

Unified Program Training

EERD Training

DTSC supports the training needs and activities for the CUPAs, DTSC staff, industry, and the regulated community. EERD staff are members of the Unified Program Trainers Committee which is composed of state and local training coordinators, and addresses CUPA training issues. Through this committee EERD staff worked closely with the CUPAs to assess training needs and plan and coordinate

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CUPA training.

- DTSC Calendar
- Training for CUPA Inspectors (CalEPA website)
- California CUPA Forum Training Calendar
- CalEPA Basic Inspector Academy
- CalEPA Environmental Enforcement Training
- SWRCB UST Inspector Training

For regulations regarding the Unified Program Administration and programs, please click on the link for CalEPAs Unified Program Laws and Regulations.

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Imperial CUPA Hazardous Materials Release Response Plans and Inventory Program Business Plan

Program Overview

When hazardous materials are improperly handled or stored they can result in a threat to employees, public health, and/or the contamination of the environment. State and Federal Community Right-to-Know laws were passed in 1986. These laws allow public access to information about the types and amounts of chemicals being used at local businesses. The laws also require businesses to plan and prepare for a chemical emergency through the preparation of a Hazardous Materials Inventory and a Hazardous Materials Business Plan that are certified annually. Businesses are inspected at least once every three years by a CUPA inspector to verify compliance with the California Health and Safety Code and California Code of Regulations.

Regulatory Authority

Law: California Health and Safety Code, Chapter 6.95, Article 1, Sections 25500 – 25519
Regulation: California Code of Regulations, Title 19, Division 2, Chapters 4 and 4.1, Sections 2620 – 2671

Who is Subject to the Business Plan Program?

A Business Emergency Response Plan and Inventory is required of any facility which handles hazardous materials or hazardous waste in amounts greater than:

- 55 gallons for liquids
- 500 pounds for solids
- 200 cubic feet for compressed gases

There are exemptions to reporting requirements for certain hazardous materials that allow for storage greater than the above thresholds. Some of these exemptions are:

1. For a solid or liquid hazardous material that is classified as a hazard solely as an irritant or sensitizer, the new reporting quantity is 5,000 pounds and 550 gallons, respectively.

2. For a hazardous material that is a gas, at standard temperature and pressure, and for which the only health and physical hazards are simple asphyxiation and the release of pressure, the new reporting quantity is 1,000 cubic feet. (Reporting of gases in a cryogenic state remains unchanged).

3. There are other compressed gases that do not have to be reported until the 1,000 cubic feet threshold is met, such as carbon dioxide and nonflammable refrigerant gases, as defined in the California Fire Code, that are used in refrigeration systems, even when they don't meet paragraph 2 above.

4. For oil-filled electrical equipment that is not contiguous to an electrical facility, the new reporting quantity for the oil is 1,320 gallons. There are other exemptions your facility may be qualified to use. For more information on these exemptions please contact us.

Please note that if extremely hazardous materials or radiological materials are handled, the business may be subject to this program even if the minimum quantities indicated are not met. For more information you should contact your local CUPA.

Contact Us

DTSC Imperial CUPA Office
627 Wake Avenue
El Centro, California 92243
Phone: (760) 352-0381
Fax: (760) 352-1641

Toll Free Number: 1-866-357-3990

Hazardous Materials Forms and Publications

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All CUPA regulated businesses are required to submit business information electronically through the California Environmental Reporting System (CERS). Many of the Unified Program forms are no longer available on our website and instead must be completed online in CERS.

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Unified Program

The Unified Program protects Californians from hazardous waste and hazardous materials by ensuring consistency throughout the state regarding the implementation of administrative requirements, permits, inspections, and enforcement at the local regulatory level. CalEPA oversees the statewide implementation of the Unified Program and its 81 certified local agencies, known as Certified Unified Program Agencies (CUPAs), which apply regulatory standards established by the Governor's Office of Emergency Services (Cal OES), the Department of Toxic Substances Control (DTSC), the Office of the State Fire Marshal (OSFM), the State Water Resources Control Board (State Water Board), and the California Environmental Protection Agency. Read more about the Unified Program.

Electronic Reporting

Effective January 1, 2009, all regulated businesses and local Unified Program Agencies (UPAs) are required to submit Unified Program information electronically, either to the local regulatory agency or to the California Environmental Reporting System (CERS). CERS supports electronic data exchange among businesses, UPAs, state agencies, and U.S. EPA. Read more about Electronic Reporting.

CUPA Performance Evaluations

A periodic performance evaluation of each CUPA is conducted to ensure adequate and effective implementation of the Unified Program by the local agency. Read more about the CUPA performance evaluation process, evaluation schedule, and evaluation results.

State Surcharges

The State Surcharges, paid by all businesses regulated under applicable program elements of the Unified Program, are used to fund the reasonable costs for all State Agencies with Unified Program Responsibilities. CUPAs are responsible for billing and collecting the state surcharges from each regulated business or facility as part of the Single Fee System. **State Surcharges for Unified Program elements are as follows**:

- Oversight: $49.00 per business/facility
- Underground Storage Tank Program: $20.00 per tank
- California Accidental Release Prevention Program: $270.00 per regulated business
- Aboveground Petroleum Storage Act Program: $26.00 per tank facility
- Refinery Safety: Assessed to Refinery Facilities according to the daily barrel capacity (DBC)
  - $45,000 – Tier 1 (equal to or greater than 200,000 DBC)
  - $27,500 – Tier 2 (100,000 to 199,999 DBC)
  - $13,750 – Tier 3 (50,000 to 99,999 DBC)
  - $3,500 – Tier 4 (Less than 50,000 DBC)

Unified Program News

AB 1429: CERS HMBP Annual Certification

Background:
Assembly Bill 1429 of 2019 (Health and Safety Code Chapter 6.95 Article 1, Section 25508) modifies the Hazardous Material Business Plan (HMBP) program by changing the business plan submittal period from annually to once every three years for businesses not subject to EPCRA Tier II reporting requirements or the Aboveground Petroleum Storage Act. AB 1429 also requires these businesses to annually review and certify that the information in the California Environmental Reporting System (CERS) is complete, accurate, and in compliance with EPCRA. An electronic HMBP submittal to CERS satisfies this certification requirement. The businesses who are not subject to the EPCRA or APSA requirements will still be required to submit a complete HMBP every three years.

CERS currently does not have this HMBP certification functionality. CalEPA is currently working to develop the HMBP certification functionality in CERS, which will allow businesses to annually certify that the HMBP information in CERS is complete, accurate, and in compliance with EPCRA.

CERS Solution:
The CERS solution will create the functionality in CERS that will allow a business to certify annually that the information in CERS is complete, accurate, and in compliance with EPCRA in lieu of a complete HMBP submittal in CERS. The primary components of the CERS solution are:

- HMBP Certification Option to User Interface – insert a certification button to allow businesses to certify the HMBP information in CERS is accurate and complete instead of submitting a complete HMBP.
- Determining/Validating HMBP Certification Eligibility – submittal in past 36 months, not subject to EPCRA or APSA, etc.

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- Add New Submittal Status “Certified” – The submittal will come in the system as certified and be automatically accepted with no further action required by CUPA.
- Add New Event Types/Notifications for “Certified” Submittals – email notifications, etc.
- Update Affected Reports – to add “certified” submissions.
- Update Windows Services – used for large user print jobs, large submittal, and inventory downloads, etc., to ease the burden on the server.
- Testing certification functionality (internal, external and portal CUPA’s) – This will be an ongoing process as the CalEPA IT Team completes sections of the overall update requirements. Subject matter experts and key stakeholders are involved in user acceptance testing for each of the major requirements. The deployment of new features will be created in the CERS test environment as they are completed. When there are testable units of functionality, SMEs and key stakeholders will be asked to participate in testing.
- Deployment in CERS – Once all requirements and functionality are completed, tested, and approved by the Unified Program and stakeholder community, the final solution will be deployed to the CERS production environment. At this point, eligible businesses can certify that the HMBP information in CERS is complete, accurate, and in compliance with EPCRA.

Status:
The Cal EPA IT Team have began development of the Annual HMBP Certification functionality in CERS. Development of each of the major requirements will use an iterative process where subject matter experts and key stakeholders are involved in each development iteration to provide input for the development of each requirement.

Anticipated Completion Date:
Mid-August – Early September 2020

Potential Future Additional Modifications:

- Allow businesses with multiple facilities to certify all qualified facilities at one time, rather than a single facility at a time;
- EDT Tier changes.

CalEPA Denies Imperial County Fire Department CUPA Application,Opens the Opportunity for CUPA Participation

(Posted Aug. 6, 2019)

CalEPA Secretary for Environmental Protection Jared Blumenfeld issued a final notice of denial to the Imperial County Fire Department (ICFD) in response to its application to assume authority as the county’s Certified Unified Program Agency (CUPA). The state Department of Toxic Substances Control (DTSC) has served as the CUPA for Imperial County on the public’s behalf since 2005 and will continue to do so.

ICFD submitted the application to become the CUPA on Aug. 31, 2018. A public hearing on the matter was held in December 2018. On March 19, Secretary Blumenfeld issued a Notice of Intent to Deny the ICFD application, citing a number of inconsistencies and gaps in the ICFD’s plans and capabilities. On May 6, ICFD submitted a revised application and requested a second public hearing. CalEPA and the state agencies that participate in CUPA oversight reviewed then revised the application and CalEPA held a second public hearing July 17.

The Secretary’s letter cites several unresolved deficiencies in ICFD’s application and notes that DTSC has not withdrawn from its obligations to implement the Unified Program. Applicable laws and regulations do not provide authority to decertify DTSC while it is in good standing. Nonetheless, the Secretary has directed DTSC to work with ICFD to develop a Participating Agency agreement, allowing ICFD to implement the Hazardous Material Business Plan program element of the Unified Program by Dec. 31. A Participating Agency agreement presents an opportunity for ICDF to demonstrate its commitment and capacity to effectively implement the Unified Program, with close oversight by DTSC and CalEPA. There are 24 other local participating agencies now operating within the Unified Program in other counties throughout the state. The CalEPA staff report accompanying the Secreatary’s letter contains further recommendations for terms of the agreement.

To learn more, read the Documents on the Imperial County Fire Department CUPA Application.

Resources:

- **CalEPA Regulated Site Portal**
  The CalEPA Regulated Site Portal is a website that combines data about environmentally regulated sites and facilities in California into a single, searchable database and interactive map. The portal was created to provide a more holistic view of regulated activities statewide. By combining data from a variety of state and federal databases, the portal provides an overview of regulated activities across the spectrum of environmental programs for any given location in California. These activities include hazardous materials and waste, state and federal cleanups, impacted ground and surface waters, and toxic materials. The portal combines information from the following databases:
- Cal/OSHA – Inspection and enforcement information reported to federal OSHA
- CERS – The California Environmental Reporting System
- CIWQS – The California Integrated Water Quality System
- EIS – U.S. EPA’s Air Emission Inventory System
- EnviroStor – Permitting, enforcement and cleanup activities at hazardous waste facilities and sites with known or suspected contamination
- GeoTracker – Impacted groundwater sites within the state, such as leaking underground storage tanks, cleanup sites, and permitted facilities such as landfills and operating underground storage tank facilities
- SMARTS – The Stormwater Multiple Application and Report Tracking System

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- SWIS – The Solid Waste Information System
- TRI – The Toxics Release Inventory

Unified Program Listservs

- Unified Program (General)
- CERS Regulator Users

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More about the Unified Program

Certified Unified Program Agencies (CUPAs) and Program Agencies (PAs) throughout the state created a partnership and formed the California CUPA Forum. Together, members of the California CUPA Forum and representatives of local, state and federal agencies established the Unified Program Administration and Advisory Group (UPAAG) to effectively address policy decisions, training and problem solving. The UPAAG's goals and objectives are listed in the UPAAG Strategic Plan (PDF).

The Unified Program consolidates the administration, permit, inspection, and enforcement activities of the following environmental and emergency management programs:

- Aboveground Petroleum Storage Act (APSA) Program
- Area Plans for Hazardous Materials Emergencies
- California Accidental Release Prevention (CalARP) Program
- Hazardous Materials Release Response Plans and Inventories (Business Plans)
- Hazardous Material Management Plan (HMMP) and Hazardous Material Inventory Statements (HMIS) (California Fire Code)
- Hazardous Waste Generator and Onsite Hazardous Waste Treatment (tiered permitting) Programs
- Underground Storage Tank Program

State agency partners involved in the implementation of the Unified Program are responsible for setting program element standards, working with CalEPA to ensure program consistency and providing technical assistance to CUPAs and PAs. The following state agencies are involved with the Unified Program:

California Environmental Protection Agency (CalEPA) The Secretary of the California Environmental Protection Agency is directly responsible for coordinating and evaluating the administration of the Unified Program and certifying Unified Program Agencies (UPAs). UPAs are accountable for carrying out responsibilities previously handled by approximately 1,300 different state and local agencies.

Department of Toxic Substances Control (DTSC) The Department of Toxic Substances Control evaluates and provides technical assistance for the Hazardous Waste Generator Program, including Onsite Treatment (Tiered Permitting) and the Resource Conservation Recovery Act (RCRA).

Governor's Office of Emergency Services (Cal OES) The Governor's Office of Emergency Services evaluates and provides technical assistance for the Hazardous Material Release Response Plan (Business Plan) Program and the Area Plan Programs, as well as the California Accidental Release Prevention Program.

CAL FIRE- Office of the State Fire Marshal (CAL FIRE-OSFM) The Office of the State Fire Marshal evaluates and provides technical assistance for the Hazardous Material Management Plan (HMMP), the Hazardous Materials Inventory Statement (HMIS) and the Aboveground Petroleum Storage Act (APSA) Programs. The HMMP and HMIS Program are closely tied to the Business Plan Program.

State Water Resources Control Board (State Water Board) The State Water Resources Control Board evaluates and provides technical assistance for the Underground Storage Tank Program.

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Unified Program Administration and Advisory Group

Unified Program Strategic Plan 2018-2022



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California Environmental Protection Agency

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CalEPA
California Environmental Protection Agency

Unified Program Administration and Advisory Group

Unified Program Strategic Plan 2018-2022

CALIFORNIA CUPA FORUM

Edmund G. Brown Jr.
Governor

Matthew Rodriquez
Secretary for Environmental Protection

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Executive Summary

In 1993, the Legislature enacted Health and Safety Code Chapter 6.11 directing the Secretary of the California Environmental Protection Agency (CalEPA) to establish, by January 1, 1996, a "unified hazardous waste and hazardous materials management regulatory program" (Unified Program). This year marks the 22nd anniversary of establishment of the Unified Program and the collaboration between CalEPA and the Certified Unified Program Agencies (CUPA) Forum for strategic planning and cooperative problem solving in the field of hazardous material regulation and enforcement. As for prior strategic plans, the collaboration known as the Unified Program Administration and Advisory Group (UPAAG), has developed the 2018-2022 Strategic Plan to:

- Incorporate an update of the previous 2012 Strategic Plan to identify successes, missed opportunities and maintain continuity of efforts.
- Identify key issues and challenges facing the Unified Program as well as gaps or barriers in existing statutes, regulations and program implementation.
- Assess and apply the resources available to key stakeholders to increase the efficacy and functionality of the Unified Program.
- Evaluate the program against new statutory and regulatory requirements.
- Identify and recommend opportunities to align current operations with the goals of an effective organization, including updating statutes and regulations if the Unified Program can evolve to become more effective.

The Unified Program has a unique governance structure. CalEPA oversees the implementation of the six regulatory program elements as a whole, including periodic evaluation and certification of individual CUPAs' performance. State Program Agencies have the responsibility of maintaining regulations, setting program element standards, working with CalEPA to achieve optimal consistency, and providing technical assistance to the CUPAs. CalEPA and the State Program Agencies also work closely with U.S. EPA to ensure harmony with federal environmental requirements. CalEPA has currently certified eighty-one CUPAs and a number of subordinate participating agencies (PAs) to implement the Unified Program at the local level.

UPAAG develops and executes five-year strategic plans, of which this is the fourth, to guide the Unified Program's continuous long-term improvement. Interim reviews and assessments are essential means of monitoring progress and making interim course corrections when warranted. UPAAG typically reviews specific program tasks, action items and assignments at its quarterly meetings. Beginning in 2019, UPAAG will review the Strategic Plan holistically each May to assess the progress of goals and to ensure we are meeting objectives in accordance with agreed-upon priorities and work plans.

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Unified Program Overview

The Unified Program protects California's environment and public health from hazardous materials and hazardous waste by ensuring adherence to established regulatory standards throughout the state that are consolidated, coordinated and consistent relative to the implementation and enforcement of environmental and release prevention programs. The following state agencies collaborate with CalEPA in the implementation of the Unified Program and are responsible for setting the standards for each of the six Unified Program elements, indicated with bullets, in table below:

State Program Agencies with Unified Program Responsibilities	Unified Program Element
CalEPA H&SC Sec. 25404 et. seq.	Overall development and administration of the Unified Program, CUPA certifications and CUPA performance evaluation standards
Governor's Office of Emergency Services (Cal OES) H&SC Sec. 25500 et. seq.	Hazardous Materials Release Response Plan (Business Plan) California Accidental Release Prevention (CalARP) Program
Department of Toxic Substances Control (DTSC) H&SC Sec. 25100 et. seq.	Hazardous Waste Management Generators Onsite Hazardous Waste Treatment (Tiered Permitting)
CAL FIRE- Office of the State Fire Marshal (OSFM) CFC Sec. 5001 et. seq., H&SC Sec. 25270 et. seq.	California Fire Code: Hazardous Materials Management Plans (HMMP) Hazardous Materials Inventory Statements (HMIS) Aboveground Petroleum Storage Act (APSA) Program
State Water Resources Control Board (State Water Board) H&SC Sec. 25280 et. seq.	Underground Storage Tank (UST) Program

With CalEPA oversight, local agencies (generally city or county environmental health departments or fire departments) carry out compliance and enforcement of the standards for each Unified Program element. Once certified, these local agencies are referred to as Certified Unified Program Agencies (CUPAs). There are eighty-one CUPAs currently responsible for implementing the Unified Program. Within its local jurisdiction, each CUPA may enter a formal agreement with another local agency, referred to as a Participating Agency (PA), to carry out one or more Unified Program elements. Collectively, CUPAs and PAs are known as Unified Program Agencies (UPAs).

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Structure of the Unified Program Administration and Advisory Group (UPAAG)

CalEPA's Unified Program Policy Group (UPPG) and the California CUPA Forum Board (CUPA Forum Board) work in cooperation through the Unified Program Administration and Advisory Group (UPAAG) to achieve common goals as set forth in this Plan and to foster effective working partnerships between local, state, and federal agencies. UPAAG serves at the request of the CalEPA Secretary to provide the opportunity to gather, process, discuss, refine, and develop solutions to issues concerning local and statewide implementation of the Unified Program. Steering Committees and various Workgroups established by UPAAG assist in fulfillment of these responsibilities.

CalEPA's Unified Program Manager chairs UPPG, comprised of managers from each State Program Agency: CalOES, DTSC, OSFM and the State Water Boards. UPPG's purpose is to coordinate Unified Program policy and practice at the State level. UPPG ensures that the latest regulations for all six program elements, and best practices for their implementation, are incorporated into the Unified Program.

CUPA Forum Board provides a single statewide representative organization of CUPAs and PAs to consolidate and improve local Unified Program implementation efforts. The CUPA Forum strives to achieve consistency, consolidation, and coordination in the implementation of the Unified Program in an efficient and effective manner. CUPA Forum Board issue coordinators oversee the efforts of Technical Advisory Groups (TAGs), which primarily address technical issues and develop resolutions to propose to the CUPA Forum. A TAG Strike Team is established when a focused effort is needed to address urgent issues.

UPAAG Vision Statement

State and local agency members collaborate to protect public health and safety from hazardous material and hazardous waste releases, restore and enhance environmental quality, and sustain economic vitality through effective and efficient implementation of the Unified Program.

UPAAG Mission Statement

UPAAG leads the policy oversight and implementation of the Unified Program through development and execution of a strategic plan, and an orderly application of resources to maximize compliance with regulatory program standards. All Unified Program participants at the local, state, and federal level engage in cooperative development of best practices, with a quality of communication that enhances the inclusion of all agency stakeholders. The chart below depicts the relationships between UPPAG, UPPG and CUPA Forum Board.

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Opportunities, Challenges, Goals and Objectives

Together as a UPAAG workgroup, UPPG and CUPA Forum Board representatives continuously assess near-term and future needs for further refining and improving statewide implementation of the Unified Program. Based on recent achievements and the assessment of future opportunities, challenges and needs, UPAAG has established the following seven goals to compose the 2018-2022 iteration of the UPAAG Strategic Plan. The Strategic Plan recognizes and details opportunities associated with each goal and provides a framework of objectives and specific, measurable tasks appropriate to meeting the challenges of each goal over the five-year planning horizon.

Priority	Goal
1	Emphasize State and local collaboration and consistency in implementing the Unified Program.
2	Review and enhance the CUPA Performance Evaluation process.
3	Develop and implement methodologies and tools for prioritizing local program implementation based on risk and cumulative impacts to public health and safety.
4	Develop exceptionally trained and skilled Unified Program personnel for employment at state and agencies.
5	Improve the capabilities and functionality of the California Environmental Reporting System (CERS) for current and future needs.
6	Enrich and curate CERS data to make informed decisions that advance the Unified Program goals, objectives and public safety.
7	Minimize and mitigate the impact of local disaster emergency response on essential Unified Program functions at the local level.

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Goal 1: Emphasize State and local collaboration and consistency in implementing the Unified Program.

Opportunities and Challenges

There are many government agencies with different regulations and policy frameworks in the Unified Program. Managing the Unified Program efficiently and effectively requires collaboration, communication and consistency.

Objectives

1.1	Maintain a collaborative process to prioritize local, state and federal activities to ensure efficient and effective CUPA planning and program implementation.
1.2	Use CUPA, federal, state and local partnerships to govern the Unified Program effectively.
1.3	Develop and apply improved practices and processes for effective communication.

Objective 1.1: Maintain a collaborative process to prioritize local, state and federal activities to ensure efficient and effective CUPA planning and program implementation.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
1.1.1	Include a standing agenda item to quarterly UPAAG meetings for each State Program Agency and the CUPA Forum Board to report on the status of their top three program priorities. Agenda items include: State Program Agency expectations of CUPAs What State Program Agencies need from CUPAs to implement each priority Impacts identified for each priority What CUPAs need from State Program Agencies to implement each priority	UPAAG Co-Chairs	Quarterly	August 2018	December 2022
1.1.2	Develop and implement a plan to communicate the activity, sequence, and message to the regulated community, industry and other stakeholders (regulated businesses and organizations, consultants, etc.)	UPAAG	8 months	August 2018	March 2019
1.1.3	Monitor and improve communication plans as necessary, as State Program Agencies and CUPAs implement priority activities. Regularly review communication plans to improve coordination for each initiative so that participants understand details of each.	UPAAG	Semi-Annually	August 2019	December 2022

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1.1.4	Develop a format for open communication between industry representatives, the regulated community, and regulatory agencies (CUPAs and state agencies) regarding concerns of implementation of the Unified Program. The format should include various methods of communication and media, including those similar to the Industry Roundtable meeting at the Annual Training Conference and the CERS Business User Group.	UPAAG	9 months	April 2019	December 2019
1.1.5	Review the Strategic Plan annually to determine progress for meeting each goal. Dedicate adequate time the day before the May UPAAG meeting each year for review of the Strategic Plan. Lead executive groups or steering committees will provide progress updates on the status of each respective objective and task.	UPAAG	Annually	May 2019	May 2022

Objective 1.2: Use CUPA, federal, state and local partnerships to govern the Unified Program effectively.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
1.2.1	Discuss approaches to achieving best practices with local, state and federal partners as they relate to implementation of each program element.	UPAAG	6 months	August 2018	December 2022
1.2.2	Schedule discussions to identify different understandings and approaches to enforcement based on different CUPA organizational cultures. Discuss how different approaches affect Unified Program partners.	UPAAG	6 months	August 2018	January 2019
1.2.3	Coordinate enforcement approaches that consult, include and inform partnerships.	UPAAG	8 months	August 2018	March 2019
1.2.4	Identify means for easier reference to shared best practices using Unified Program, State Program Agency and CUPA Forum Board websites cooperatively, and continue to present those at training workshops, webinars and conferences.	UPAAG	12 months	August 2018	July 2019
1.2.5	Continue to assess emerging statutes, regulations, technologies, and best practices, and plan for impacts on the Unified Program.	UPAAG	Quarterly	August 2018	December 2022

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Objective 1.3: Develop and apply improved practices and processes for effective communication.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
1.3.1	Establish a communication workgroup to review current practices and approaches to communication.	UPAAG	3 months	June 2018	August 2018
1.3.2	Develop a communication plan that addresses how to communicate various information, what sequence, to whom and how. NOTE: For consistency, the Communications Workgroup will consider the DTSC Lean Six Sigma Workgroup recommendations scheduled for completion in July 2018.	Communications Workgroup	9 months	November 2018	July 2019
1.3.3	Disseminate the communication plan widely so all know how to coordinate communication.	Communications Workgroup	3 months	August 2019	October 2019

Goal 2: Review and enhance the CUPA Performance Evaluation process.

Opportunities and Challenges

The process of conducting CUPA Performance Evaluations has undergone various revisions in recent years and each state agency has experienced turnover in evaluation staff, resulting in various levels of experience among the evaluation team. CUPA Performance evaluation guidance documents and tools currently in use need updating and revision, and additional guidance needs to be developed. Establishing improved methods for training and mentoring evaluators will enable a desirable and collaborative approach toward the interaction among CalEPA and each state agency as well as with CUPAs, leading to the implementation of a greater constructive evaluation process.

Objectives

2.1:	Develop a collaborative approach to conducting CUPA Performance Evaluations.
2.2:	Revise the Unified Program Evaluation Manual with an updated set of criteria used by State Program Agencies and CUPAs for performance evaluations.
2.3:	Establish evaluation process training for State Program Agency evaluators and CUPA inspectors.

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Objective 2.1: Develop a collaborative approach to conducting CUPA Performance Evaluations.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
2.1.1	Define areas of the performance evaluation process that are resource intensive for state agencies and CUPAs, such as preparation, conduct, response to, and follow-up with deficiency corrective actions.	CalEPA and State Program Agencies	6 months	May 2018	October 2018
2.1.2	Define and clarify the mission and purpose of the performance evaluation process.	CalEPA and State Program Agencies	6 months	May 2018	October 2018
2.1.3	Identify modifications to the current performance evaluation process to improve efficiency and effectiveness.	CalEPA and State Program Agencies	12 months	January 2018	December 2018
2.1.4	Develop practices, procedures and guidance that outlines the current performance evaluation process.	CalEPA and State Program Agencies	6 months	May 2018	October 2018
2.1.5	Develop and implement metrics for measuring success in program elements of the performance evaluation process.	CalEPA and State Program Agencies	3 months	October 2018	December 2018
2.1.7	Define guidelines for information and facility file requests used to conduct CUPA performance evaluations.	CalEPA and State Program Agencies	4 months	August 2018	November 2018
2.1.8	Review, update and revise the following documents to reflect the NEW Evaluation Process: Summary of Findings Report (PRELIMINARY and FINAL) Evaluation Survey for CUPAs CUPA Performance Evaluation Manual Deficiency Library	CalEPA and State Program Agencies	4 months	August 2018	November 2018
2.1.9	Present NEW Evaluation Process to the Evaluation Workgroup.	CalEPA and State Program Agencies	1 month	December 2018	December 2018

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2.1.10	Review, update, revise and develop Performance Evaluation guidance documents for CUPAs to reference for improving the existing implementation of the Unified Program, such as: Inspection and Enforcement Plan Self-Audit Various policies and procedures developed by the CUPA to implement Unified Program processes, including: public notification, financial management, data management, etc.	CalEPA and State Program Agencies	Continuous	January 2019	December 2022
2.1.11	Implement the new evaluation process beginning with the 2019 Evaluation Schedule.	CalEPA and State Program Agencies	Continuous	January 2019	December 2022

Objective 2.2: Revise the Unified Program Evaluation Manual with an updated set of criteria used by State Program Agencies and CUPAs for performance evaluations.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
2.2.1	Identify existing CERS reports currently used, including specification of the report parameters.	CalEPA and State Program Agencies	2 months	August 2018	September 2018
2.2.2	Identify the need for any new CERS reports.	CalEPA and State Program Agencies	2 months	August 2018	September 2018
2.2.3	Review and revise existing CERS reports.	CalEPA and State Program Agencies	2 months	October 2018	November 2018
2.2.4	Create new CERS reports as necessary, including specifying the report parameters.	CalEPA IT staff	2 months	October 2018	November 2018
2.2.5	Modify existing CERS reports as necessary, including specifying the report parameters.	CalEPA IT staff	1 month	December 2018	December 2018

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Objective 2.3: Establish evaluation process training for State Program Agency evaluators and CUPA inspectors.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
2.3.1	Identify training modules for a training program.	UPPG, CUPA Forum Board	6 months	August 2018	January 2019
2.3.2	Develop training materials for each module.	State Program Agencies, CUPA Forum Board	12 months	February 2019	January 2020
2.3.3	Identify instructors and attendees.	State Program Agencies, CUPA Forum Board	6 months	February 2020	July 2020
2.3.4	Implement the training program.	State Program Agencies, CUPA Forum Board	Continuous	August 2020	December 2022

Goal 3: Develop and implement methodologies and tools for prioritizing local program implementation based on risk and cumulative impacts to public health and safety.

Opportunities and Challenges

Local programs and participating agencies must enforce a wide range of regulations and inspect diverse entities. CUPAs can better serve to protect public health, safety, and the environment by prioritizing activities based on risk or cumulative impacts associated with certain facilities, businesses types, business practices, and industry sectors. Developing and implementing criteria for flexibility in performance-based inspections within mandatory, CUPA-level inspection and enforcement plans is a key component of the Regulatory Performance Initiative.

Objectives

3.1:	Develop overall concept for risk prioritization.
3.2:	Communicate the risk-based inspection concept to key stakeholders to gain support for implementation.
3.3:	Create legislative language to adopt the risk-based inspection concept.

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Objective 3.1: Develop overall concept for risk prioritization.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
3.1.1	Develop a clear definition of goals and objectives for the process, including definition of CUPA compliance program prioritization, with respect to effective allocation of inspection and enforcement resources.	UPRPI Workgroup	6 months	May 2018	October 2018
3.1.2	Engage State Program Agencies to review and provide comment on the proposed risk-based inspection concept.	UPRPI Workgroup	2 months	August 2018	September 2018
3.1.3	Develop local agency model programs.	UPRPI Workgroup	6 months	July 2018	December 2018
3.1.4	Survey and report on risk-based programs of other states and agencies	UPRPI Workgroup	6 months	July 2018	December 2018
3.1.5	Develop and submit legislative and regulatory justification for the risk-based inspection concept (UPRPI).	UPRPI Workgroup, UPAAG	3 months	September 2018	November 2018

Objective 3.2: Communicate the risk-based inspection concept to key stakeholders to gain support for implementation.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
3.2.1	Provide outreach regarding the risk-based inspection concept to the public, including environmental groups, environmental justice groups, business groups and the regulated community.	UPRPI Workgroup	3 months	September 2018	November 2018
3.2.2	Consider feedback provided by the public.	UPRPI Workgroup	2 months	December 2018	January 2019
3.2.3	Present UPAAG with any feedback that would likely impact or result in changing the risk-based inspection concept previously approved by UPAAG.	UPRPI Workgroup	1 month	December 2018	December 2018
3.2.4	Make any necessary amendments to the risk-based inspection concept based on feedback provided by the public.	UPRPI Workgroup	4 months	November 2018	February 2019

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3.2.5	Obtain UPAAG approval of revisions to the risk-based inspection concept, if any revisions exist.	UPRPI Workgroup	1 month	March 2019	March 2019
3.2.6	Communicate the final risk-based inspection concept (RPI) to key stakeholders (businesses, state executives, and Legislature, labor and community organizations), the regulated community and Unified Program regulating agencies.	UPAAG	3 months	March 2019	May 2019

Objective 3.3: Create legislative language to adopt the risk-based inspection concept.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
3.3.1	Create legislative language for adopting the risk-based inspection concept approved by UPAAG.	Legislative and UPPRI Workgroups	3 months	October 2018	December 2018
3.3.2	Evaluate potential legislative support for an authorizing statute.	CUPA Forum Board	5 months	October 2018	February 2019

Goal 4: Develop exceptionally trained and skilled Unified Program personnel for employment at state and agencies.

Opportunities and Challenges

As experienced personnel retire or leave, CUPAs and State Program Agencies will need trained and skilled staff for ever-more complex enforcement and implementation of Unified Program regulatory requirements. Local CUPA and state agency programs must continuously recruit and train new staff, and provide ongoing training, to provide services that maintain the expected standards of the Unified Program.

Objective

4.1:	Conduct ongoing assessment of the Training Framework.
4.2:	Evaluate the effectiveness and accessibility of various training delivery methods.
4.3:	Develop statewide certification programs for CUPA inspectors and State Program Agency evaluators.
4.4:	Develop a statewide registration program for CUPA personnel.
4.5:	Support the Unified Program training culture.

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Objective 4.1: Conduct ongoing assessment of the Training Framework.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
4.1.1	Develop process and determine frequency for reviewing and updating the Training Framework	Training Steering Committee	3 months	August 2018	October 2018
4.1.2	Perform gap analysis to determine if all Knowledge, Skills and Abilities (KSAs) have associated existing courses in the Training Framework.	Training Steering Committee	6 months	October 2018	March 2019
4.1.3	Review statutes and regulations to determine if revisions to the Training Framework are necessary.	Training Steering Committee	Continuous	April 2019	December 2022
4.1.4	Revise the Training Framework.	Training Steering Committee	6 months	July 2019	December 2019
4.1.5	Develop metrics to evaluate the implementation of the Training Framework.	Training Steering Committee	6 months	January 2020	June 2020
4.1.6	Develop a communication/outreach strategy for implementing the Training Framework.	Training Steering Committee	6 months	July 2020	December 2020
4.1.7	Implement the Training Framework	Training Steering Committee	Continuous	January 2021	December 2022

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Objective 4.2: Evaluate the effectiveness and accessibility of various training delivery methods.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
4.2.1	Identify existing training delivery methods. The following should be considered: Inspector succession planning/training Implementation of various training delivery methods (classroom training, webinars, videos, etc.) A Mentoring program Joint inspections with U.S. EPA, state agency staff and/or CUPA staff or inspectors where each are given the opportunity to ask questions in the field as inspections are conducted and various issues are encountered	Training Steering Committee	3 months	January 2019	March 2019
4.2.2	Explore new technology for training delivery methods.	Training Steering Committee	3 months	April 2019	June 2019
4.2.3	Determine effectiveness of each training delivery method.	Training Steering Committee	Continuous	July 2019	December 2022
4.2.4	Apply most effective and efficient training delivery methods to Unified Program related training.	Training Steering Committee	3 months	October 2019	December 2019
4.2.5	Implement new training delivery methods.	Training Steering Committee, State Program Agencies, CUPAs	Continuous	January 2020	December 2022

Objective 4.3: Develop statewide certification programs for CUPA inspectors and State Program Agency evaluators.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
4.3.1	Hazardous Materials Certification Workgroup to develop specific criteria for a training certification program.	Hazardous Materials Certification Workgroup (CUPA Forum Board)	12 months	May 2018	April 2019

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4.3.2	Provide interpretive outreach to stakeholders (regulated businesses and organizations, consultants, etc.)	CUPA Forum Board	4 months	December 2018	March 2019
4.3.3	Complete the first cycle of the training certification program.	CUPA Forum Board	3 years	July 2018	July 2021

Objective 4.4: Develop a statewide registration program for CUPA personnel.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
4.4.1	Establish a Registration Workgroup to develop specific criteria for the statewide registration program.	UPAAG	1 month	March 2019	March 2019
4.4.2	Develop a statewide registration program.	Registration Workgroup	9 months	May 2019	January 2020
4.4.3	Provide interpretive outreach to stakeholders (regulated businesses and organizations, consultants, etc.)	Registration Workgroup	6 months	January 2020	June 2020
4.4.4	Develop proposed legislation.	Registration Workgroup	10 months	January 2020	October 2020
4.4.5	Consider feedback provided by stakeholders (regulated businesses and organizations, consultants, etc.)	Registration Workgroup	6 months	February 2020	July 2020
4.4.6	Identify, develop and recommend any needed statutory or regulatory language to affect changes.	Registration Workgroup	3 months	October 2020	December 2020

Objective 4.5: Support the Unified Program training culture.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
4.5.1	Expand the "Train the Trainer" program. Explore additional vendors for the "Train the Trainer" program. Enable State Program Agency staff to participate. Conduct the "Train the Trainer" program	CUPA Forum Board	6 months	January 2019	June 2019
4.5.2	Create a commitment and expectations policy for training volunteers to ensure succession planning occurs.	CUPA Forum Board	4 months	September 2018	December 2018
4.5.3	Share the trainer commitment and expectations policy with UPAAG and Training Steering Committee	CUPA Forum Board	4 months	December 2018	March 2019

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Goal 5: Improve the capabilities and functionality of the California Environmental Reporting System (CERS) for current and future needs.

Opportunities and Challenges

Electronic reporting systems require significant CUPA and PA resources to maintain functionality. Unified Program Agencies (UPAs) use various database platforms and/or system versions to meet CERS electronic reporting requirements. There may be a more effective and efficient means of meeting current and future requirements to electronically report Unified Program information to CERS, in order to comply with state and national regulatory requirements.

Objectives

5.1:	Examine functionality and efficiency of CERS and local CUPA business processes and database systems.
5.2:	Examine the concept of a CUPA management tool using data from CERS.

Objective 5.1: Examine functionality and efficiency of CERS and local CUPA business processes database systems.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
5.1.1	Business Process Modeling (BPM) document: Assess and document existing business processes and understand process requirements to provide business process improvement opportunities.	Data Steering Committee and CalEPA	18-24 months	December 2018	December 2020
5.1.2	CalEPA, UPAs and State Program Agencies to identify areas for improving business processes, improving the functionality of CERS or for amending the data requirements for electronic reporting as proposed CERS enhancements.	Data Steering Committee and CalEPA	18-24 months	December 2019	December 2021
5.1.3	Explore development of an inspection module or other tool to support enhanced inspection data capture, with the capability of creating outputs for regulating agencies and for regulated businesses.	CUPA Forum Board	12 months	December 2018	December 2019
5.1.4	Plan and make interim improvements to CERS and local reporting databases based on evaluation of CERS functionality and assessment of business processes.	Data Steering Committee and CalEPA	24 months	December 2019 2020	December 2022

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Objective 5.2: Examine the concept of a CUPA management tool using data from CERS.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
5.2.1	Document and implement governance structures to prioritize need of management tool, assess and develop business cases and objectives.	Data Steering Committee	12-18 months	January 2019	June 2020
5.2.2	Document and collaborate with UPAs and State Program Agency data owners to identify, define and development of centralized data warehouse in order to support consistently defined data sets and to support data management tool.	Data Steering Committee	24-36 months	January 2020	January 2023
5.2.3	Propose a funding mechanism for proceeding with the development of the data-management functionality of CERS.	Data Steering Committee	6 months	July 2019	December 2019
5.2.4	Obtain agreement among CalEPA, UPAs and State Program Agencies to develop CERS data-management capabilities in addition to data-reporting capabilities.	Data Steering Committee	6 months	January 2020	June 2020

Goal 6: Enrich and curate CERS data to make informed decisions that advance the Unified Program goals, objectives and public safety.

Opportunities and Challenges

Local programs devote significant resources to collecting data and reporting information to state agencies and other Unified Program partners. Together, all parties must ensure that the information is reliable and valid, and that investment in data collection and analyses are efficient and effective in fulfilling State oversight needs and requirements as well as improving program implementation.

Objectives

6.1:	Develop and implement a process to enrich data quality in the California Environmental Reporting System (CERS).
6.2:	Develop and share analytic methodologies for trend analysis of CERS data.
6.3:	Evaluate the needed enhancements for non-data exchange CUPAs.
6.4:	Promote the use and improve the functionality of the CalEPA Regulated Site Portal website and data services.

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Objective 6.1: Develop and implement a process to enrich data quality in the California Environmental Reporting System (CERS).

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
6.1.1	Develop a data quality enrichment process.	Data Steering Committee	9 months	January 2019	September 2019
6.1.2	Research applicability of QA/QC methods and standards used by State Program Agencies to verify facility-reported data.	Data Steering Committee	12-18 months	January 2019	June 2020
6.1.3	Define QA/QC methods and standards to ensure CERS data is not duplicated and to identify data entry and transfer errors for data reported directly in CERS by business and regulator users and for data transferred to CERS through Electronic Data Transfer (EDT).	Data Steering Committee	24 months	December 2019	December 2021
6.1.4	Define and recommend a priority for the implementation of data QA/QC methods and standards for UPAs, State Program Agencies and regulated businesses.	Data Steering Committee	12 months	December 2020	December 2021
6.1.5	Define how to apply standards to submittals from businesses to CERS.	Data Steering Committee	12 months	January 2021	December 2021
6.1.6	Define standards that should be applied by CUPAs when reviewing and accepting submittals.	Data Steering Committee	12 months	January 2021	December 2021
6.1.7	Assess ways to reduce data entry errors, i.e.: using linkages or tools to standardize submittal choices.	Data Steering Committee	12 months	January 2022	December 2022

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Objective 6.2: Develop and share analytic methodologies for trend analysis of CERS data.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
6.2.1	Identify Unified Program public, state agency and CUPA needs for trend analysis and define the metrics for analysis. Trend analysis should utilize Unified Program data to demonstrate the success and effectiveness of the implementation of the Unified Program to the public.	Data Steering Committee	6 months	July 2020	December 2020
6.2.2	Research and identify methodologies for conducting trend analysis, including measures to track success of implementation of the Unified Program.	Data Steering Committee	6 months	January 2021	June 2021
6.2.3	Perform and report on trend analysis to support and advance Unified Program efficiency and effectiveness.	Data Steering Committee	12 months	July 2021	June 2022

Objective 6.3: Evaluate the needed enhancements for non-data exchange CUPAs.

Task		Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
6.3.1	Survey CUPAs not utilizing electronic data transfer (EDT) to determine if additional CERS enhancements are necessary.	Data Steering Committee	9 months	January 2020	September 2020
6.3.2	Review survey responses.	Data Steering Committee	3 months	October 2020	December 2020
6.3.3	Determine actions necessary in response to surveys.	Data Steering Committee	6 months	January 2021	June 2021
6.3.4	Prioritize and develop scope and cost of effort for each new proposed CERS enhancement.	Data Steering Committee and CalEPA	6 months	July 2021	December 2021

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6.3.5	Proceed with development of CERS enhancements.	CalEPA and CUPA Data Services Vendors	12 months	January 2022	December 2022
6.3.6	Implement CERS enhancements in production environments.	CalEPA and CUPA Data Services Vendors	Continuous	January 2023	Continuous

Objective 6.4: Promote the use and improve the functionality of the CalEPA Regulated Site Portal website and data services.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
6.4.1	Develop and implement changes to the Regulated Site Portal to improve features and functionality with the incorporation of data from additional environmental databases.	CalEPA	15 months	June 2018	August 2019
6.4.2	Develop and update public outreach material to highlight uses and functionality.	CalEPA	6 months	March 2019	August 2019
6.4.3	Present updated outreach to all stakeholders (consultants, attorneys, regulated businesses, etc.).	Data Steering Committee and CalEPA	24 months	September 2019	September 2021

Goal 7: Minimize and mitigate the impact of local disaster emergency response on essential Unified Program functions at the local level.

Opportunities and Challenges

By statute, UPAs must routinely prepare for local disaster emergency roles and responsibilities, maintain response capabilities, and coordinate regularly with disaster emergency assistance agencies and organizations. In the face of growing disaster response costs and limited state/federal resources to respond to large disasters, CUPAs seek to improve collaboration and training for local mutual aid and disaster assistance. It remains critical for UPAs to ensure the ability to continue to protect environmental health and public safety by maintaining routine Unified Program responsibilities as effectively and efficiently as possible. For both provider and recipient agencies, best practices are necessary to balance response and assistance activities during declared disaster emergencies with continuity of executing Unified Program inspection and enforcement responsibilities as fully as possible.

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Objectives

7.1:	Help enable local agencies continue to protect environmental health and public safety and maintain Unified Program implementation effectively and efficiently while conducting disaster recovery or rendering Disaster Emergency Assistance (DEA) to other local agencies.

Objective 7.1: Ensure local agencies are able to continue to protect environmental health and public safety and maintain Unified Program implementation effectively and efficiently while participating in Disaster Emergency Assistance (DEA) for State-declared disasters.

	Task	Lead	Estimated Time for Completion	Estimated Start Date	Estimated Completion Date
7.1.1	Develop an evaluation process contingency plan for CUPAs that have experienced response demands to state-declared emergencies during the performance review period.	UPAAG Evaluation Workgroup	6 months	January 2019	June 2019
7.1.2	Identify necessary contingency planning for CUPAs in order to enable each CUPA to continue to perform routine Unified Program implementation amidst the establishment of disaster relief and need for supportive assistance in response to the disaster.	Cal OES and CUPAs	6 months	February 2018	July 2018
7.1.3	Determine if and how a state declared emergency disaster temporarily relieves requirements of regulated businesses in the area during the declared emergency.	CalEPA, CCDEH, CUPAs	12 months	August 2018	July 2019
7.1.4	Identify and develop statutory or regulatory revisions needed to alleviate resource/priority conflicts between Unified Program requirements and local emergency response needs.	UPAAG	24 months	August 2019	July 2021

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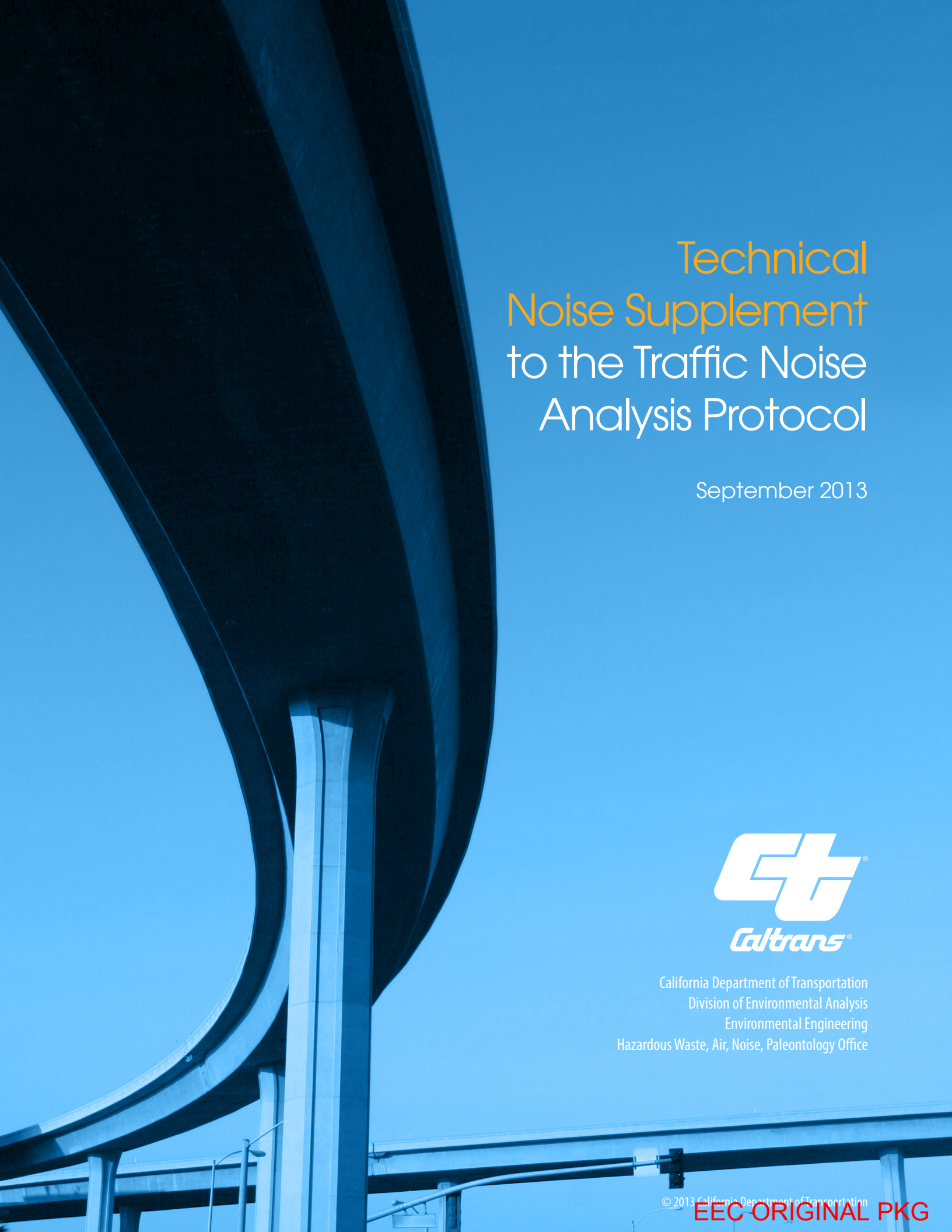

Technical Noise Supplement to the Traffic Noise Analysis Protocol

September 2013

California Department of Transportation
Division of Environmental Analysis
Environmental Engineering
Hazardous Waste, Air, Noise, Paleontology Office

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15. Abstract

This manual contains Caltrans noise analysis procedures, practices, and other useful technical background information related to the analysis and reporting of highway and construction noise impacts and abatement. It supplements and expands on concepts and procedures referred to in the *Traffic Noise Analysis Protocol*, which in turn is required by federal regulations in 23CFR772. *The contents of this document are not official policy, standard, or regulation*, and are for informational purposes—*unless they are referenced in the Protocol.* Except for some Caltrans-specific methods and procedures, most methods and procedures recommended in this document are in conformance with industry standards and practices. This document can be used as a stand-alone guide for highway noise training purposes or as a reference for technical concepts, methodology, and terminology needed to acquire a basic understanding of highway noise and construction noise-related issues.

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Technical Noise Supplement to the Caltrans Traffic Noise Analysis Protocol

A Guide for Measuring, Modeling, and Abating Highway Operation and Construction Noise Impacts

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Environmental Engineering
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Acronyms and Abbreviations

Δ	change
°F	degrees Farenheit
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ADT	average daily traffic
ANSI	American National Institute of Standards
B	bels
Caltrans	California Department of Transportation
CFR	Code of Federal Regulations
CNEL	community noise equivalent level
cps	cycles per second
dB	decibels
dB/s	decibels per second
dBA	A-weighted decibels
DGAC	dense-graded asphalt concrete
EWNR	Exterior Wall Noise Rating
FHWA	Federal Highway Administration
ft/s	feet per second
GPS	global positioning system
Guidance Manual	Technical Guidance Manual on the Effects on the Assessment and Mitigation of Hydroacoustic Effects of Pile Driving Sound on Fish
Hz	hertz
I-	Interstate
kHz	kilohertz
km/hr	kilometers per hour
kVA	kilovolt-amperes
L_{dn}	day-night noise level
L_{eq}	equivalent noise level
L_{max}	maximum noise level

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m/s	meters per second
mph	miles per hour
N	Newton
N/m^2	Newton per square meter
NAC	noise abatement criteria
NADR	Noise Abatement Decision Report
NIST	National Institute of Standards and Technology
Nm	Newton meter
NRC	noise reduction coefficient
OBSI	on-board sound intensity
OGAC	open-graded aspalt concrete
OSHA	Occupational Safety and Health Administration
PCC	Portland concrete cement
PLD	path length difference
Protocol	Traffic Noise Analysis Protocol
psi	pounds per square inch
pW	picowatt
REMEL	Reference Energy Mean Emission Level
rms	root mean square
SPL	sound pressure level
SR	State Route
STC	Sound Transmission Class
TeNS	Technical Noise Supplement
TL	transmission loss
TNM	Traffic Noise Model
VNTSC	Volpe National Transportation Systems Center
vph	vehicles per hour
W	watts
W/m^2	watts per square meter
$\mu N/m^2$	microNewtons per square meter
µPa	micro Pascals

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Dedication:

This edition of the Technical Noise Supplement is dedicated to Rudy Hendriks whose early work substantially contributed to the science of highway acoustics.

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Section 1
Introduction and Overview

1.1 Introduction

This 2013 Technical Noise Supplement (TeNS) to the California Department of Transportation (Caltrans) *Traffic Noise Analysis Protocol for New Highway Construction, Reconstruction, and Retrofit Barrier Projects* (Protocol) (California Department of Transportation 2011) is an updated version of the 2009 TeNS. This version of the TeNS is compatible with applicable sections of the 2011 Protocol that were prepared in response to changes to Title 23 Part 772 of the Code of Federal Regulations (CFR) which were published in July 2010. The current Protocol was approved by the Federal Highway Administration (FHWA) and became effective on July 13, 2011. Be sure to check for updates to the Protocol.

The purpose of this document is to provide technical background information on transportation-related noise in general and highway traffic noise in particular. It is designed to elaborate on technical concepts and procedures referred to in the Protocol. The contents of the TeNS are for informational purposes; *unless they are referenced in the Protocol, the contents of this document are not official policy, standard, or regulation*. Except for some Caltrans-specific methods and procedures, most methods and procedures recommended in TeNS are in conformance with industry standards and practices.

This document can be used as a stand-alone document for training purposes or as a reference for technical concepts, methodology, and terminology needed to acquire a basic understanding of transportation noise with emphasis on highway traffic noise.

Revisions to this document are listed below.

- Removal of references and discussion relating to traffic noise models that preceded the current FHWA Traffic Noise Model (TNM).

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- Abbreviated discussions of several topics such as bioacoustics and quieter pavement that are now covered in more detail in newer technical references.
- Elimination of metric units in accordance with Caltrans current standards. The exception to this is units of pressure that are traditionally expressed in metric units such as micro-pascals.
- Removal of the traffic noise analysis screening procedure which was removed from the Protocol.
- Removal of obsolete information.

The 2009 version of TeNS will remain available on the Caltrans website as a reference for information that has been removed from this edition. The 2009 version of TeNS contains a number of measurement procedures for non-routine noise studies.

1.2 Overview

The TeNS consists of eight sections. Except for Section 1, each covers a specific subject of highway noise. A brief description of the subjects follows.

- Section 1, *Introduction and Overview*, summarizes the subjects covered in the TeNS.
- Section 2, *Basics of Highway Noise*, covers the physics of sound as it pertains to characteristics and propagation of highway noise, effects of noise on humans, and ways of describing noise.
- Section 3, *Measurements and Instrumentation*, provides background information on noise measurements, and discusses various noise-measuring instruments and operating procedures.
- Section 4, *Detailed Analysis for Traffic Noise Impacts*, provides guidance for conducting detailed traffic noise impact analysis studies. This section includes identifying land use, selecting receptors, determining existing noise levels, predicting future noise levels, and determining impacts.
- Section 5, *Detailed Analysis for Noise Barrier Design Considerations*, outlines the major aspects that affect the acoustical design of noise barriers, including the dimensions, location, and material; optimization of noise barriers; possible noise reflections; acoustical design of overlapping noise barriers (to provide maintenance access to areas

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behind barriers); and drainage openings in noise barriers. Challenges and cautions associated with noise barrier design are also discussed.

- Section 6, *Noise Study Reports*, discusses the contents of noise study reports.
- Section 7, *Non-Routine Considerations and Issues*, covers non-routine situations involving the effects of noise on distant receptors, use of sound intensity and sound power as tools in characterizing sound sources, pavement noise, noise monitoring for insulating facilities, construction noise, earthborne vibrations, California Occupational Safety and Health Administration (OSHA) noise standards, and effects and abatement of transportation-related noise on marine and wildlife.
- Section 8, *Glossary*, provides terminology and definitions common in transportation noise.
- Appendix A, *References Cited*, provides a listing of literature directly cited or used for reference in the TeNS.

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Section 2
Basics of Highway Noise

The following sections introduce the fundamentals of sound and provide sufficient detail to understand the terminology and basic factors involved in highway traffic noise prediction and analysis. Those who are actively involved in noise analysis are encouraged to seek out more detailed textbooks and reference books to acquire a deeper understanding of the subject.

2.1 Physics of Sound

2.1.1 Sound, Noise, and Acoustics

Sound is a vibratory disturbance created by a moving or vibrating source in the pressure and density of a gaseous or liquid medium or in the elastic strain of a solid that is capable of being detected by the hearing organs. Sound may be thought of as the mechanical energy of a vibrating object transmitted by pressure waves through a medium to human (or animal) ears. The medium of primary concern is air. In absence of any other qualifying statements, sound is considered airborne sound, as opposed to structure- or earthborne sound, for example.

Noise is defined as sound that is loud, unpleasant, unexpected, or undesired. It therefore may be classified as a more specific group of sounds. Although the terms *sound* and *noise* are often used synonymously, perceptions of sound and noise are highly subjective.

Sound is actually a process that consists of three components: source, path, and receiver. All three components must be present for sound to exist. Without a source, no sound pressure waves would be produced. Similarly, without a medium, sound pressure waves would not be transmitted. Finally, sound must be received—a hearing organ, sensor, or other object must be present to perceive, register, or be affected by sound. In most situations, there are many different sound sources, paths, and receivers.

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In the context of an analysis pursuant to 23 CFR 772 the term *receptor* means a single dwelling unit or the equivalent of a single dwelling unit. A *receiver* is a single point that can represent one receptor or multiple receptors. As an example it is common when modeling traffic noise to use a single receiver in the model to represent multiple receptors. Acoustics is the field of science that deals with the production, propagation, reception, effects, and control of sound. The field is very broad, and transportation-related noise and abatement addresses only a small, specialized part of acoustics.

2.1.2 Speed of Sound

When the surface of an object vibrates in air, it compresses a layer of air as the surface moves outward and produces a rarefied zone as the surface moves inward. This results in a series of high and low air pressure waves (relative to the steady ambient atmospheric pressure) alternating in sympathy with the vibrations. These pressure waves, not the air itself, move away from the source at the speed of sound, approximately 1,126 feet per second (ft/s) in air with a temperature of 68 degrees Fahrenheit (°F). The speed of sound can be calculated from the following formula:

$$c = \sqrt{1.401\left(\frac{P}{\rho}\right)} \qquad \textbf{(2-1)}$$

Where:

c = speed of sound at a given temperature, in ft/s

P = air pressure in pounds per square foot (pounds/ft^2)

ρ = air density in slugs per cubic foot (slugs/ft^3)

1.401 = ratio of the specific heat of air under constant pressure to that of air in a constant volume

For a given air temperature and relative humidity, the ratio P/ρ tends to remain constant in the atmosphere because the density of air will reduce or increase proportionally with changes in pressure. Therefore, the speed of sound in the atmosphere is independent of air pressure. When air temperature changes, ρ changes, but P does not. Therefore, the speed of sound is temperature-dependent, as well as somewhat humidity-dependent because humidity affects the density of air. The effects of the latter with regard to the speed of sound, however, can be ignored for the purposes of the TeNS. The fact that the speed of sound changes with altitude has nothing to do with the change in air pressure and is only caused by the change in temperature.

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For dry air of 32ºF, ρ is 0.002509 slugs/ft^3. At a standard air pressure of 29.92 inches Hg, pressure is 14.7 pounds per square inch (psi) or 2,118 pounds/ft^2. Using Equation 2-1, the speed of sound for standard pressure and temperature can be calculated as follows:

$$\mathbf{c} = \sqrt{(1.401)(\frac{2{,}118}{0.002509})} = 1{,}087 \text{ ft/s.}$$

From this base value, the variation with temperature is described by the following equation:

$$c = 1051.3\sqrt{1+\frac{T_f}{459.7}} \text{ ft/s} \quad \textbf{(2-2)}$$

Where:

c = speed of sound

T_f = temperature in degrees Fahrenheit (include minus sign for less than 0ºF)

The above equations show that the speed of sound increases or decreases as the air temperature increases or decreases, respectively. This phenomenon plays an important role in the atmospheric effects on noise propagation, specifically through the process of refraction, which is discussed in Section 2.1.4.3.

2.1.3 Sound Characteristics

In its most basic form, a continuous sound can be described by its frequency or wavelength (pitch) and amplitude (loudness).

2.1.3.1 Frequency, Wavelength, and Hertz

For a given single pitch, the sound pressure waves are characterized by a sinusoidal periodic (i.e., recurring with regular intervals) wave, as shown in Figure 2-1. The upper curve shows how sound pressure varies above and below the ambient atmospheric pressure with distance at a given time. The lower curve shows how particle velocity varies above 0 (molecules moving right) and below 0 (molecules moving left). Please note that when the pressure fluctuation is at 0, the particle velocity is at its maximum, either in the positive or negative direction; when the pressure is at its positive or negative peak, the particle velocity is at 0. Particle velocity describes the motion of the air molecules in response to the pressure

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waves. It does not refer to the velocity of the waves, otherwise known as the speed of sound. The distance (λ) between crests of both curves is the wavelength of the sound.

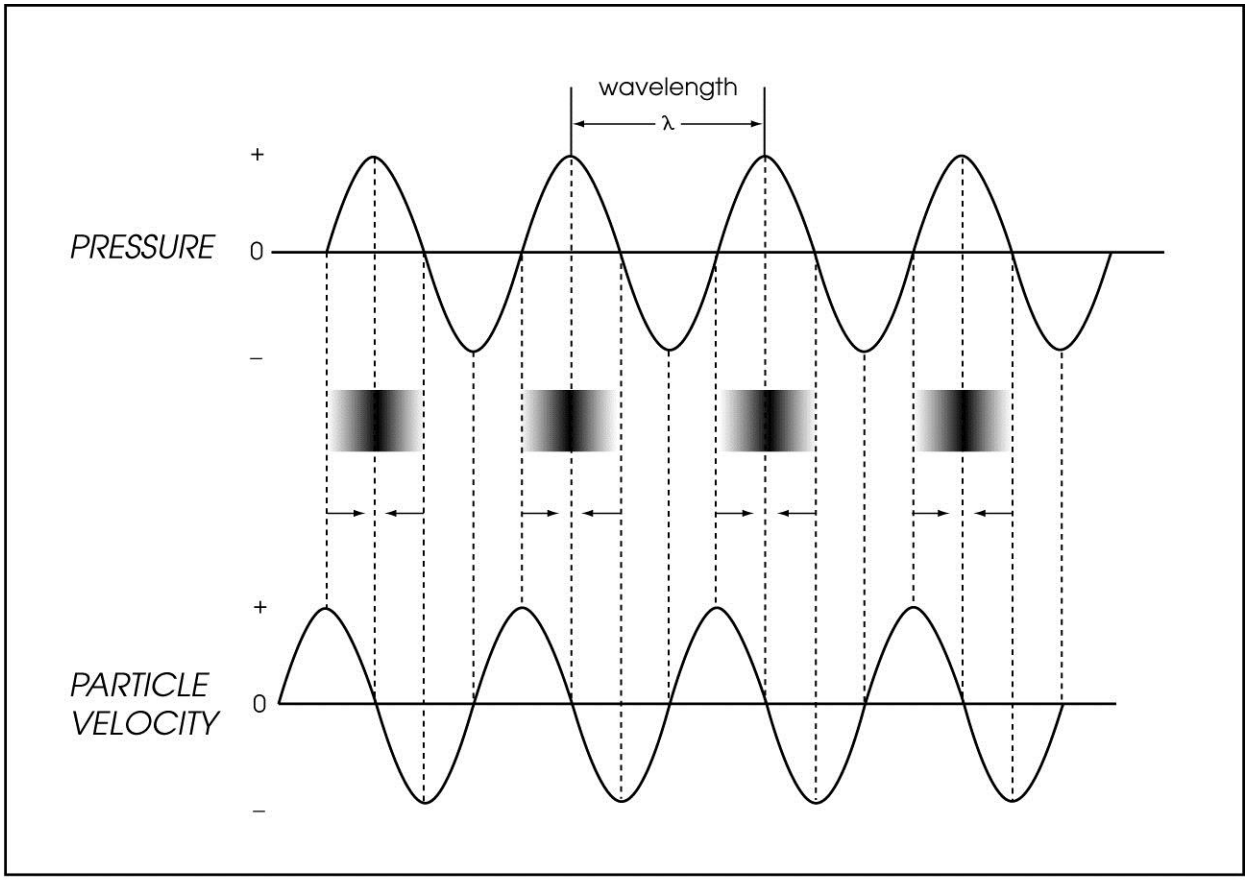

Figure 2-1. Sound Pressure vs. Particle Velocity

The number of times per second that the wave passes from a period of compression through a period of rarefaction and starts another period of compression is referred to as the frequency of the wave (Figure 2-2). Frequency is expressed in cycles per second, or hertz (Hz): 1 Hz equals one cycle per second. High frequencies are sometimes more conveniently expressed in units of kilohertz (kHz) or thousands of hertz. The extreme range of frequencies that can be heard by the healthiest human ears spans from 16 to 20 Hz on the low end to about 20,000 Hz (20 kHz) on the high end. Frequencies are heard as the pitch or tone of sound. High-pitched sounds produce high frequencies, and low-pitched sounds produce low frequencies. Very-low-frequency airborne sound of sufficient amplitude may be felt before it can be heard and is often confused with earthborne vibrations. Sound less than 16 Hz is referred to as infrasound, while high frequency sound above 20,000 Hz is called ultrasound. Both infrasound and ultrasound are not audible to humans, but many animals can hear or sense frequencies extending well into one or both of these regions.

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Ultrasound also has various applications in industrial and medical processes, specifically cleaning, imaging, and drilling.

The distance traveled by a sound pressure wave through one complete cycle is referred to as the wavelength. The duration of one cycle is called the period. The period is the inverse of the frequency. For example, the frequency of a series of waves with periods of 0.05 (1/20) second is 20 Hz; a period of 0.001 (1/1000) second is 1,000 Hz or 1 kHz. Although low frequency earthborne vibrations (e.g., earthquakes and swaying of bridges or other structures) often are referred to by period, the term rarely is used in expressing airborne sound characteristics.

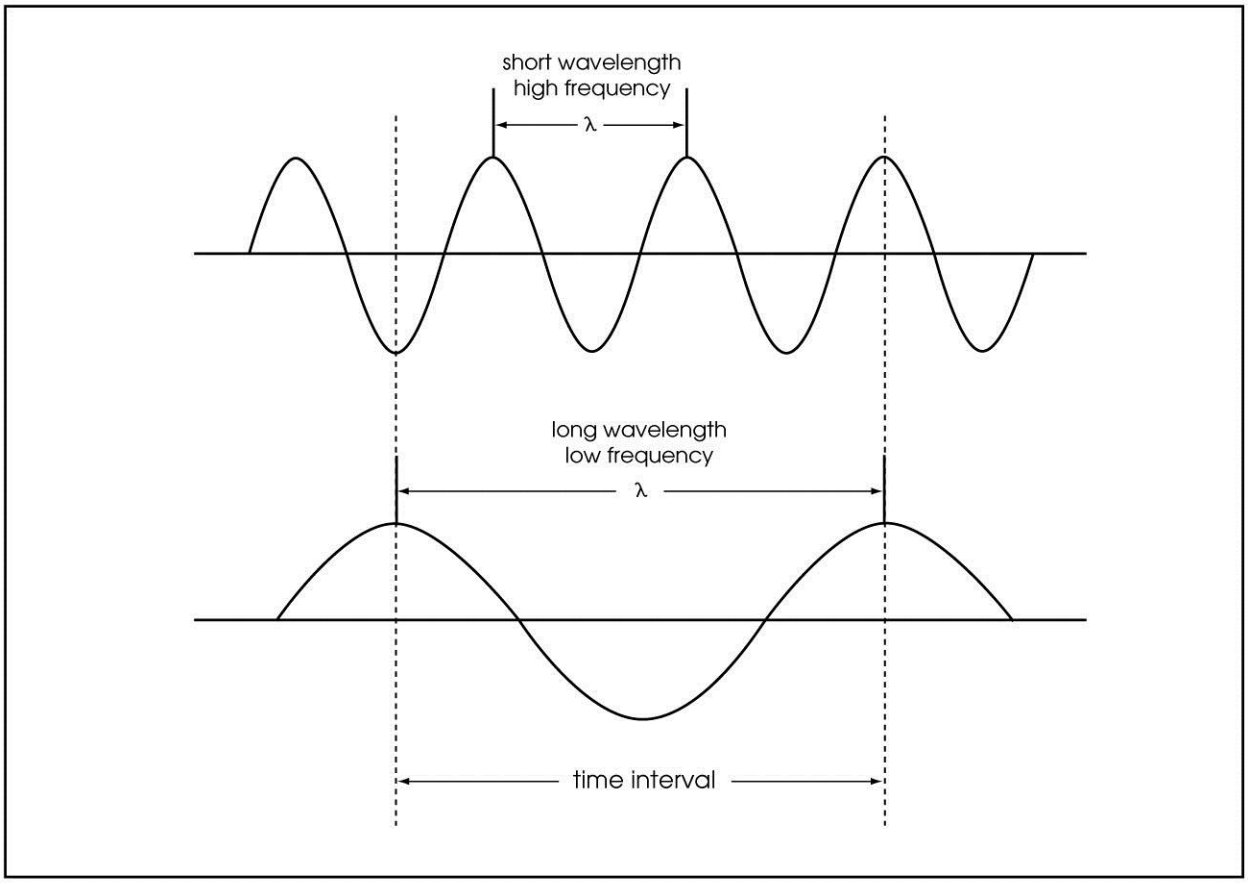

Figure 2-2. Frequency and Wavelength

Figure 2-2 shows that as the frequency of a sound pressure wave increases, its wavelength decreases, and vice versa. The relationship between frequency and wavelength is linked by the speed of sound, as shown in the following equations:

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$$\lambda = \frac{c}{f} \quad \textbf{(2-3)}$$

$$f = \frac{c}{\lambda} \quad \textbf{(2-4)}$$

$$c = f\lambda \quad \textbf{(2-5)}$$

Where:

λ = wavelength (feet)

c = speed of sound (1,126.5 ft/s at 68ºF)

f = frequency (Hz)

In these equations, care must be taken to use the same units (distance units in feet and time units in seconds) for wavelength and speed of sound. Although the speed of sound is usually thought of as a constant, it has been shown that it actually varies with temperature. These mathematical relationships hold true for any value of the speed of sound. Frequency normally is generated by mechanical processes at the source (e.g., wheel rotation, back and forth movement of pistons) and therefore is not affected by air temperature. As a result, wavelength usually varies inversely with the speed of sound as the latter varies with temperature.

The relationships between frequency, wavelength, and speed of sound can be visualized easily by using the analogy of a train traveling at a given constant speed. Individual boxcars can be thought of as the sound pressure waves. The speed of the train (and individual boxcars) is analogous to the speed of sound, while the length of each boxcar is the wavelength. The number of boxcars passing a stationary observer each second depicts the frequency (*f*). If the value of the latter is 2, and the speed of the train (*c*) is 68 miles per hour (mph), or 100 ft/s, the length of each boxcar (λ) must be: $c/f = 100/2 = 50$ feet.

Using Equation 2-3, a table can be developed showing frequency and associated wavelength. Table 2-1 shows the frequency and wavelength relationship at an air temperature of 68ºF.

Table 2-1. Wavelength of Various Frequencies

Frequency (Hz)	Wavelength at 68ºF (Feet)
16	70
31.5	36
63	18
125	9
250	4.5
500	2.3

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Frequency (Hz)	Wavelength at 68ºF (Feet)
1,000	1.1
2,000	0.56
4,000	0.28
8,000	0.14
16,000	0.07

The validity of Table 2-1 can be checked by multiplying each frequency by its wavelength, which should equal the speed of sound. Please notice that because of rounding, multiplying frequency and wavelength gives varying results for the speed of sound in air, which for 68ºF should be constant at 1,126.5 ft/s.

Frequency is an important component of noise analysis. Virtually all acoustical phenomena are frequency-dependent, and knowledge of frequency content is essential. Sections 2.1.3.6 and 2.1.3.7 discuss how frequency is considered in sound level measurements and sound analysis.

2.1.3.2 Sound Pressure Levels and Decibels

As indicated in Figure 2-1, the pressures of sound waves continuously change with time or distance and within certain ranges. The ranges of these pressure fluctuations (actually deviations from the ambient air pressure) are referred to as the amplitude of the pressure waves. Whereas the frequency of the sound waves is responsible for the pitch or tone of a sound, the amplitude determines the loudness of the sound. Loudness of sound increases and decreases with the amplitude.

Sound pressures can be measured in units of microNewtons per square meter ($\mu N/m^2$), also called micro Pascals (μPa): 1 μPa is approximately one-hundred-billionth (1/100,000,000,000) of the normal atmospheric pressure. The pressure of a very loud sound may be 200 million μPa, or 10 million times the pressure of the weakest audible sound (20 μPa). Expressing sound levels in terms of μPa would be very cumbersome because of this wide range. Sound pressure levels (SPLs) are described in logarithmic units of ratios of actual sound pressures to a reference pressure squared called bels. To provide a finer resolution, a bel is divided into tenths, or decibels (dB). In its simplest form, SPL in decibels is expressed as follows:

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$$\text{Sound pressure level (SPL)} = 10\log_{10}\left(\frac{p_1}{p_0}\right)^2 \text{ dB} \qquad \textbf{(2-6)}$$

Where:

P_1 = sound pressure

P_0 = reference pressure, standardized as 20 μPa

The standardized reference pressure, P_0, of 20 μPa corresponds to the threshold of human hearing. When the actual sound pressure is equal to the reference pressure, the expression results in a sound level of 0 dB:

$$10\log_{10}\left(\frac{p_1}{p_0}\right)^2 = 10\log_{10}(1) = 0 \text{ dB}$$

Please note that 0 dB does not represent an absence of any sound pressure. Instead, it is an extreme value that only those with the most sensitive ears can detect. Therefore, it is possible to refer to sounds as less than 0 dB (negative dB) for sound pressures that are weaker than the threshold of human hearing. For most people, the threshold of hearing is probably close to 10 dB.

2.1.3.3 Root Mean Square and Relative Energy

Figure 2-1 depicted a sinusoidal curve of pressure waves. The values of the pressure waves were constantly changing, increasing to a maximum value above normal air pressure, then decreasing to a minimum value below normal air pressure, in a repetitive fashion. This sinusoidal curve is associated with a single frequency sound, also called a pure tone. Each successive sound pressure wave has the same characteristics as the previous wave. The amplitude characteristics of such a series of simple waves then can be described in various ways, all of which are simply related to each other. The two most common ways to describe the amplitude of the waves is in terms of peak SPL and root mean square (rms) SPL.

Peak SPL simply uses the maximum or peak amplitude (pressure deviation) for the value of P_1 in Equation 2-6. Therefore, peak SPL only uses one value (absolute value of peak pressure deviation) of the continuously changing amplitudes. The rms value of the wave amplitudes (pressure deviations) uses all positive and negative instantaneous amplitudes, not just the peaks. It is derived by squaring the positive and negative instantaneous pressure deviations, adding these together, and dividing the sum by the number of pressure deviations. The result is called

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the mean square of the pressure deviations; the square root of this mean value is the rms value. Figure 2-3 shows the peak and rms relationship for sinusoidal or single-frequency waves. The rms is 0.707 times the peak value.

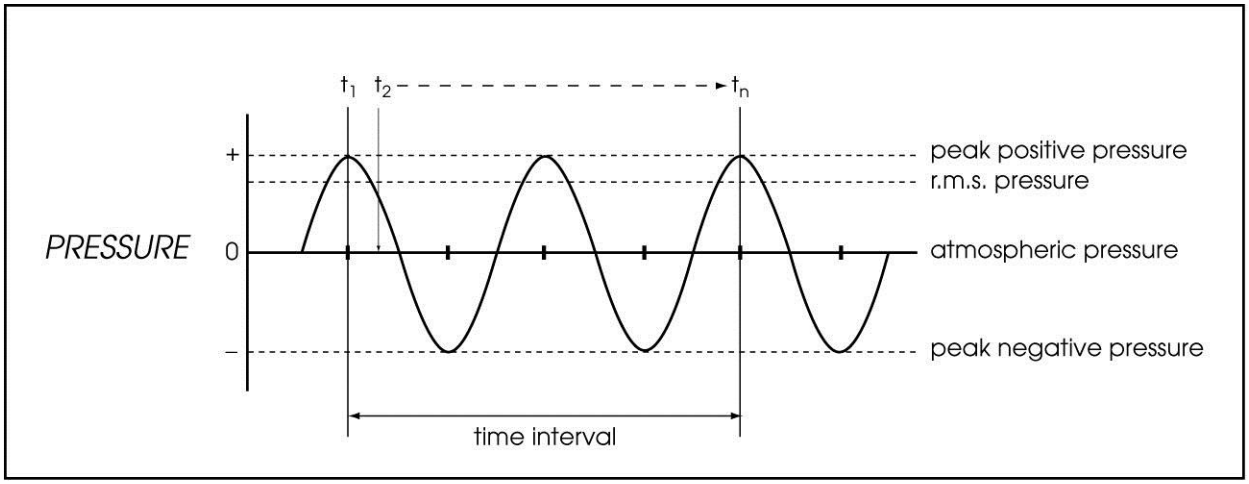

Figure 2-3. Peak and Root Mean Square Sound Pressure

In terms of discrete samples of the pressure deviations, the mathematical expression is as follows:

$$\text{rms} = \sqrt{({}_1\sum^n(t_1^2 + t_2^2 + \ldots t_n^2)/n)} \quad \textbf{(2-7)}$$

Where:

$t_1, t_2, \ldots t_n$ = discrete pressure values at times t_1 through t_n above (positive) and below (negative) the local atmospheric pressure

Sound pressures expressed in rms are proportional to the energy contents of the waves and are therefore the most important and often used measure of amplitude. Unless indicated otherwise, all SPLs are expressed as rms values.

2.1.3.4 Relationship between Sound Pressure Level, Relative Energy, Relative Pressure, and Pressure

Table 2-2 shows the relationship between rms SPL, relative sound energy, relative sound pressure, and pressure. Please note that SPL, relative energy, and relative pressure are based on a reference pressure of 20 µPa and by definition are all referenced to 0 dB. The pressure values are the actual rms pressure deviations from local ambient atmospheric pressure.

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The most useful relationship is that of SPL (dB) and relative energy. Relative energy is unitless. Table 2-2 shows that for each 10 dB increase in SPL the acoustic energy increases tenfold (e.g., an SPL increase from 60 to 70 dB increases the energy 10 times). Acoustic energy can be thought of as the energy intensity (energy per unit area) of a certain noise source, such as a heavy truck, at a certain distance. For example, if one heavy truck passing by an observer at a given speed and distance produces an SPL of 80 A-weighted decibels (dBA), the SPL of 10 heavy trucks identical to the single truck would be 90 dBA if they all could simultaneously occupy the same space and travel at the same speed and distance from the observer.

Because SPL is computed using $10\log_{10}(P_1/P_2)^2$, the acoustic energy is related to SPL as follows:

$$(P_1/P_2)^2 = 10^{SPL/10} \quad \textbf{(2-8)}$$

Table 2-2. Relationship between Sound Pressure Level, Relative Energy, Relative Pressure, and Sound Pressure

Sound Pressure Level (dB) $10\log_{10}\left(\frac{p_1}{p_0}\right)^2$	Relative Energy $\left(\frac{p_1}{p_0}\right)^2$	Relative Pressure $\left(\frac{p_1}{p_0}\right)$	Sound Pressure (μPa) (P_1)
200	10^{20}	10^{10}	
154			10^9 (1,000 Pa)
150	10^{15}		
140	10^{14}	10^7	
134			10^8 (100 Pa)
130	10^{13}		
120	10^{12}	10^6	
114			10^7 (10 Pa)
110	10^{11}		
100	10^{10}	10^5	
94			10^6 (1 Pa)
90	10^9		
80	10^8	10^4	
74			10^5 μPa
70	10^7		
60	10^6	10^3	
54			10^4 μPa
50	10^5		
40	10^4	10^2	

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Sound Pressure Level (dB) $10\log_{10}\left(\frac{p_1}{p_0}\right)^2$	Relative Energy $\left(\frac{p_1}{p_0}\right)^2$	Relative Pressure $\left(\frac{p_1}{p_0}\right)$	Sound Pressure (μPa) (P_1)
	34		10^3 μPa
30	10^3		
20	10^2	10^1	
	14		10^2 μPa
10	10^1		
0	**10^0 = 1 = Ref.**	**10^0 = 1 = Ref.**	**$P_1 = P_0 = 20$ μPa**

2.1.3.5 Adding, Subtracting, and Averaging Sound Pressure Levels

Because decibels are logarithmic units, SPL cannot be added or subtracted by ordinary arithmetic means. For example, if one automobile produces an SPL of 70 dB when it passes an observer, two cars passing simultaneously would not produce 140 dB; they would combine to produce 73 dB. The following discussion provides additional explanation of this concept. The SPL from any source observed at a given distance from the source may be expressed as $10\log_{10}(P_1/P_0)^2$ (see Equation 2-6). Therefore, the SPL from two equal sources at the same distance would be calculated as follows:

$$SPL = 10\log_{10}[(P_1/P_0)^2+(P_1/P_0)^2] = 10\log_{10}[2(P_1/P_0)^2]$$

This can be simplified as $10\log_{10}(2) + 10\log_{10}(P_1/P_0)^2$. Because the logarithm of 2 is 0.301, and 10 times that would be 3.01, the sound of two equal sources is 3 dB more than the sound level of one source. The total SPL of the two automobiles therefore would be 70 + 3 = 73 dB.

Adding and Subtracting Equal Sound Pressure Levels

The previous example of adding the noise levels of two cars may be expanded to any number of sources. The previous section described the relationship between decibels and relative energy. The ratio $(P_1/P_0)^2$ is the relative (acoustic) energy portion of the expression $SPL = 10\log_{10}(P_1/P_0)^2$, in this case the relative acoustic energy of one source. This must immediately be qualified with the statement that this is not the acoustic power output of the source. Instead, the expression is the relative acoustic energy per unit area received by the observer. It may be stated that *N* identical automobiles or other noise sources would yield an SPL calculated as follows:

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$$SPL_{Total} = SPL_1 + 10\log_{10}(N) \quad \textbf{(2-9)}$$

Where:

SPL_1 = SPL of one source

N = number of identical sources to be added (must be more than 0)

Example

If one noise source produces 63 dB at a given distance, what would be the noise level of 13 of the same source combined at the same distance?

Solution

$SPL_{Total} = 63 + 10\log_{10}(13) = 63 + 11.1 = 74.1$ dB

Equation 2-9 also may be rewritten as follows. This form is useful for subtracting equal SPLs:

$$SPL_1 = SPL_{Total} - 10\log_{10}(N) \quad \textbf{(2-10)}$$

Example

The SPL of six equal sources combined is 68 dB at a given distance. What is the noise level produced by one source?

Solution

$SPL_1 = 68$ dB $- 10\log_{10}(6) = 68 - 7.8 = 60.2$ dB

In these examples, adding equal sources actually constituted multiplying one source by the number of sources. Conversely, subtracting equal sources was performed by dividing the total. For the latter, Equation 2-9 could have been written as $SPL_1 = SPL_{Total} + 10\log_{10}(1/N)$. The logarithm of a fraction yields a negative result, so the answers would have been the same.

These exercises are very useful for estimating traffic noise impacts. For example, if one were to ask what the respective SPL increases would be along a highway if existing traffic were doubled, tripled, or quadrupled (assuming traffic mix, distribution, and speeds would not change), a reasonable prediction could be made using Equation 2-9. In this case, N would be the existing traffic (N = 1); N = 2 would be doubling, N = 3 would be tripling, and N = 4 would be quadrupling the existing traffic. Because $10\log_{10}(N)$ in Equation 2-9 represents the increase in SPL, the above values for N would yield +3, +4.8, and +6 dB, respectively.

Similarly, one might ask what the SPL decrease would be if traffic were reduced by a factor of 2, 3, or 4 (i.e., N = 1/2, N = 1/3, and N = 1/4, respectively). Applying $10\log_{10}(N)$ to these values would yield -3, -5, and -6 dB, respectively.

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The same problem also may arise in a different form. For example, the traffic flow on a given facility is 5,000 vehicles per hour, and the SPL is 65 dB at a given location next to the facility. One might ask what the expected SPL would be if future traffic increased to 8,000 vehicles per hour. The solution would be:

$$65 + 10\log_{10}(8{,}000/5{,}000) = 65 + 2 = 67 \text{ dB}.$$

Therefore, *N* may represent an integer, fraction, or ratio. However, *N* always must be more than 0. Taking the logarithm of 0 or a negative value is not possible.

In Equations 2-9 and 2-10, $10\log_{10}(N)$ was the increase from SPL_1 to SPL_{Total} and equals the change in noise levels from an increase or decrease in equal noise sources. Letting the change in SPLs be referred to as ΔSPL, Equations 2-9 and 2-10 can be rewritten as follows:

$$\Delta SPL = 10\log_{10}(N) \quad \textbf{(2-11)}$$

This equation is useful for calculating the number of equal source increments (N) that must be added or subtracted to change noise levels by ΔSPL. For example, if it is known that an increase in traffic volumes increases SPL by 7 dB, the factor change in traffic (assuming that traffic mix and speeds did not change) can be calculated as follows:

$7 \text{ dB} = 10\log_{10}(N)$
$0.7 \text{ dB} = \log_{10}(N)$
$10^{0.7} = N$
$N = 5.0$
Therefore, the traffic volume increased by a factor of 5.

Adding and Subtracting Unequal Sound Pressure Levels

If noise sources are not equal or equal noise sources are at different distances, $10\log_{10}(N)$ cannot be used. Instead, SPLs must be added or subtracted individually using the SPL and relative energy relationship in Equation 2-8. If the number of SPLs to be added is *N*, and SPL_1, SPL_2, and SPL_n represent the first, second, and *n*th SPL, respectively, the addition is accomplished as follows:

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$$SPL_{Total} = 10\log_{10}[10^{SPL_1/10} + 10^{SPL_2/10} + \ldots 10^{SPL_n/10}] \quad \textbf{(2-12)}$$

The above equation is the general equation for adding SPLs. The equation also may be used for subtraction (simply change "+" to "–"). However, the result between the brackets must always be more than 0. For example, determining the total SPL of 82, 75, 88, 68, and 79 dB would use Equation 2-12 as follows:

$$SPL = 10\log_{10}(10^{68/10} + 10^{75/10} + 10^{79/10} + 10^{82/10} + 10^{88/10}) = 89.6 \text{ dB}$$

Adding Sound Pressure Levels Using a Simple Table

When combining sound levels, a table such as the following may be used as an approximation.

Table 2-3. Decibel Addition

When Two Decibel Values Differ by:	Add This Amount to the Higher Value:	Example:
0 or 1 dB	3 dB	70 + 69 = 73 dB
2 or 3 dB	2 dB	74 + 71 = 76 dB
4 to 9 dB	1 dB	66 + 60 = 67 dB
10 dB or more	0 dB	65 + 55 = 65 dB

This table yields results within about 1 dB of the mathematically exact value and can be memorized easily. The table can also be used to add more than two SPLs. First, the list of values should be sorted, from lowest to highest. Then, starting with the lowest values, the first two should be combined, the result should be added to the third value, and so on until only the answer remains. For example, to determine the sum of the sound levels used in the preceding example using Table 2-3, the first step would be to rank the values from low to high: 68, 75, 79, 82, and 88 dB.

Using Table 2-3, the first two noise levels then should be added. The result then would be added to the next noise level, etc., as follows:

68 + 75 = 76,
76 + 79 = 81,
81 + 82 = 85,
85 + 88 = 90 dB
For comparison, using Equation 2-12, total SPL was 89.6 dB.

Two decibel-addition rules are important. First, when adding a noise level to an approximately equal noise level, the total noise level increases 3 dB.

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For example, doubling the traffic on a highway would result in an increase of 3 dB. Conversely, reducing traffic by one half would reduce the noise level by 3 dB. Second, when two noise levels are 10 dB or more apart, the lower value does not contribute significantly (less than 0.5 dB) to the total noise level. For example, 60 + 70 dB ≈ 70 dB. This means that if a noise level measured from a source is at least 70 dB, the background noise level (without the target source) must not be more than 60 dB to avoid risking contamination.

Averaging Sound Pressure Levels

There are two ways of averaging SPLs: arithmetic averaging and energy-averaging. Arithmetic averaging is simply averaging the decibel values. For example, the arithmetic average (mean) of 60 and 70 dB is:

$$(60 + 70)/2 = 65 \text{ dB}$$

Energy averaging is averaging of the energy values. Using the previous example, the energy average (mean) of 60 and 70 dB is:

$$10\log[(10^{6.0} + 10^{7.0})/2] = 67.4 \text{ dB}$$

Please notice that the energy average is always equal to or more than the arithmetic average. It is only equal to the arithmetic average if all values are the same. Averaging the values 60, 60, 60, and 60 dB yields equal results of 60 dB in both cases. The following discussion shows some examples of when each method is appropriate.

Energy Averaging

Energy averaging is the most widely used method of averaging noise levels. Sound energy relates directly to the sound source. For example, at a given distance the sound energy from six equal noise sources is three times that of two of the same sources at that same distance. To average the number of sources and calculate the associated noise level, energy averaging should be used. Examples of applications of energy averaging are provided below.

Example 1

To determine the average noise level at a specific receiver along a highway between 6 a.m. and 7 a.m., five 1-hour measurements were taken on random days during that hour. The energy-averaged measurement results were 68, 67, 71, 70, and 71 dB. What is a good estimate of the noise level at that receiver? Because the main reason for the fluctuations in noise levels is probably the differences in source strength (vehicle mix,

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volumes, and speeds), energy averaging is appropriate. Therefore, the result would be: $10\log[(10^{6.8} + 10^{6.7} + 10^{7.1} + 10^{7.0} + 10^{7.1})/5] = 69.6$ dB, or 70 dB.

Example 2

Another situation is where traffic volumes substantially change during a measurement period. Noise is measured at a location along a highway. Vehicles on that highway are distributed equally, are traveling at the same speed, and are of the same type (e.g., automobiles). Such traffic characteristics would produce a near steady-state noise level. The typical procedure would be to measure the traffic noise for an hour. After 15 minutes, the traffic volume suddenly increases sharply, but speeds remain the same and the vehicles, although closer together, are still equally distributed for the remaining 45 minutes. The noise level during the first 15 minutes was 70 dB and during the last 45 minutes was 75 dB. What was the energy-averaged noise level? Because the time periods were not the same, the energy average must be time-weighted by using the following equation:

$$\text{Energy-averaged noise level} = 10\log[(15 * 10^{7.0} + 45 * 10^{7.5})/60] = 74.2 \text{ dB}$$

In this example, the time was weighted in units of minutes. This also could have been accomplished using fractions of 1 hour, as follows:

$$\text{Energy-averaged noise level} = 10\log[(0.25 * 10^{7.0} + 0.75 * 10^{7.5})/1] = 74.2 \text{ dB}$$

Arithmetic Averaging

Arithmetic averaging is used less frequently, but it is used in situations such as the following. For example, the objective is to measure the noise of a machine with great accuracy. For simplicity, assume that the machine produces a steady noise level, which is expected to be constant, each time the machine is turned on. Because accuracy is of great importance, it is chosen to take repeat measurements with different sound level meters and to calculate the average noise level. In this case, it is appropriate to calculate the arithmetic mean by adding the measured decibel values and dividing by the number of measurements. Because the same source is measured repeatedly, any measured noise fluctuations are mainly from errors inherent in the instrumentation; method of measurement; environmental conditions; and, to a certain extent, source strength. Because the errors are distributed randomly, the expected value of the measurements is the arithmetic mean.

It is also appropriate to use arithmetic means for statistical comparisons of noise levels, or hypothesis testing, whether the noise levels were obtained

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by energy averaging or arithmetic means. Examples of applications of arithmetic averaging are provided below.

Example 1
In this example the objective is to compare the noise levels from Compressors A and B. It is decided to take five independent noise measurements at 25 feet from each compressor. Between each measurement, the compressors will be shut off and restarted. The following data are collected:

Compressor	Measured Noise Levels (dB)	Arithmetic Average (dB)
A	75, 76, 73, 74, 75	(75+76+73+74+75)/5 = 74.6
B	77, 75, 76, 78, 75	(77+75+76+78+75)/5 = 76.2

In addition, the hypothesis that Compressors A and B emit the same noise can be tested by calculating the standard deviations and using appropriate statistical tests assuming a certain level of significance. However, this is not the subject of discussion in this case.

Example 2
Residents A and B live next to the same highway. Resident A complains about the noise at night, while Resident B does not. One wishes to determine whether the nighttime noise level is higher at Residence A than Residence B. Four hours at night are randomly selected, and simultaneous energy-averaged noise measurements are taken at Residences A and B during the 4 hours. The measurement results are:

Hour	Residence A (dB)	Residence B (dB)
1	65	62
2	62	58
3	63	59
4	66	63
Arithmetic mean	64.0	60.5

The goal is a statistical comparison of noise levels at Residences A and B for the same randomly selected time periods, as well as the same traffic and environmental conditions. Although the 1-hour noise levels represent energy averages for each hour, arithmetic means should be calculated for the statistical comparison, as shown in the preceding measurement results.

The hypothesis that noise levels at Residence A equal noise levels at Residence B can be tested using the standard deviations, as well as the appropriate tests and significance levels. Please note, however, that statistical significance has no relationship to human significance. In this

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example, the noise level at Residence A is probably significantly higher statistically than at Residence B. In terms of human perception, however, the difference may be barely perceptible.

A good rule to remember is that whenever measurements or calculations must relate to the number of sources or source strength, energy averaging should be used. However, if improving accuracy in measurements or calculations of the same events or making statistical comparisons is the goal, the arithmetic mean is appropriate. Additional details about averaging and time-weighting are addressed in Section 2.2.2.

2.1.3.6 A-Weighting and Noise Levels

SPL alone is not a reliable indicator of loudness. Frequency or pitch also has a substantial effect on how humans respond. While the intensity (energy per unit area) of the sound is a purely physical quantity, loudness or human response depends on the characteristics of the human ear.

Human hearing is limited not only to the range of audible frequencies, but also in the way it perceives the SPL in that range. In general, the healthy human ear is most sensitive to sounds between 1,000 and 5,000 Hz and perceives both higher and lower frequency sounds of the same magnitude with less intensity. To approximate the frequency response of the human ear, a series of SPL adjustments is usually applied to the sound measured by a sound level meter. The adjustments, or weighting network, are frequency-dependent.

The A-scale approximates the frequency response of the average young ear when listening to most everyday sounds. When people make relative judgments of the loudness or annoyance of a sound, their judgments correlate well with the A-scale sound levels of those sounds. There are other weighting networks that have been devised to address high noise levels or other special problems (e.g., B-, C-, D-scales), but these scales rarely, if ever, are used in conjunction with highway traffic noise. Noise levels for traffic noise reports should be reported as dBA. In environmental noise studies, A-weighted SPLs commonly are referred to as noise levels.

Figure 2-4 shows the A-scale weighting network that is normally used to approximate human response. The 0-dB line represents a reference line; the curve represents frequency-dependent attenuations provided by the ear's response. Table 2-4 shows the standardized values (American National Standards Institute 1983). The use of this weighting network is signified by appending an "A" to the SPL as dBA or dB(A).

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The A-weighted curve was developed from averaging the statistics of many psychoacoustic tests involving large groups of people with normal hearing in the age group of 18 to 25 years. The internationally standardized curve is used worldwide to address environmental noise and is incorporated in virtually all environmental noise descriptors and standards. Section 2.2.2 addresses the most common descriptors applicable to transportation noise.

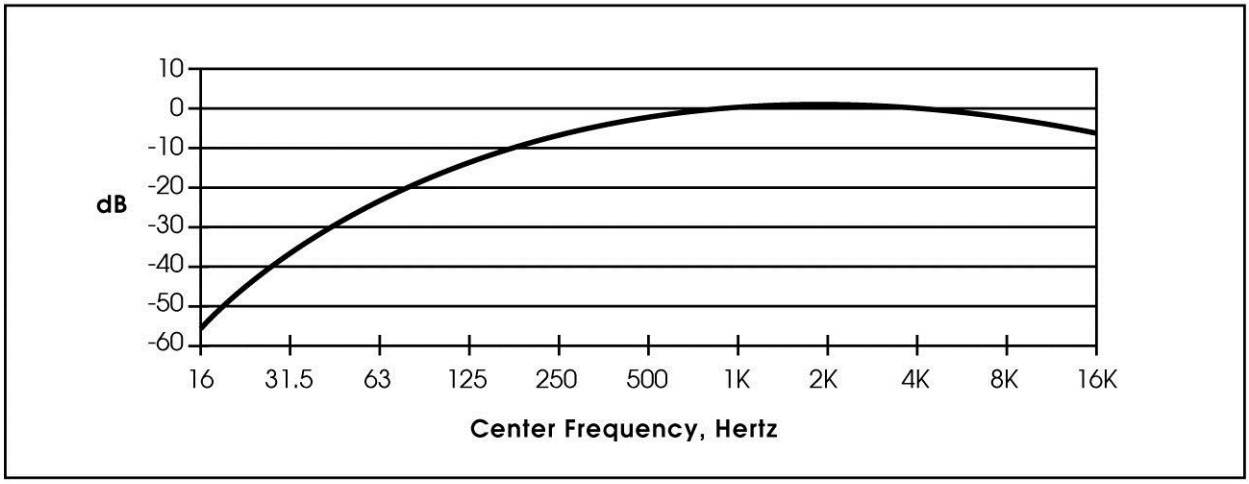

Figure 2-4. A-Weighting Network

Table 2-4. A-Weighting Adjustments for One-Third-Octave Center Frequencies

Frequency (Hz)	A-Weighting (dB)	Frequency (Hz)	A-Weighting (dB)	Frequency (Hz)	A-Weighting (dB)	Frequency (Hz)	A-Weighting (dB)
16	-56.7	100	-19.1	630	-1.9	4,000	+1.0
20	-50.5	125	-16.1	800	-0.8	5,000	+0.5
25	-44.7	160	-13.4	1,000	0	6,300	-0.1
31.5	-39.4	200	-10.9	1,250	+0.6	8,000	-1.1
40	-34.6	250	-8.6	1,600	+1.0	10,000	-2.5
50	-30.6	315	-6.6	2,000	+1.2	12,500	-4.3
63	-26.2	400	-4.8	2,500	+1.3	16,000	-6.6
80	-22.5	500	-3.2	3,150	+1.2	20,000	-9.3

Source: American National Standards Institute 1983.

Sound level meters used for measuring environmental noise have an A-weighting network built in for measuring A-weighted sound levels. This is accomplished through electronic filters, also called band pass filters. Each filter allows the passage of a selected range (band) of frequencies only and

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attenuates its SPL to modify the frequency response of the sound level meter to about that of the A-weighted curve and the human ear.

A range of noise levels associated with common indoor and outdoor activities is shown in Table 2-5. The decibel scale is open-ended. As discussed, 0 dB or 0 dBA should not be construed as the absence of sound. Instead, it is the generally accepted threshold of the best human hearing. SPLs in negative decibel ranges are inaudible to humans. On the other extreme, the decibel scale can go much higher than shown in Table 2-5. For example, gunshots, explosions, and rocket engines can reach 140 dBA or higher at close range. Noise levels approaching 140 dBA are nearing the threshold of pain. Higher levels can inflict physical damage on such things as structural members of air and spacecraft and related parts. Section 2.2.1.1 discusses the human response to changes in noise levels.

Table 2-5. Typical Noise Levels

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	110	Rock band
Jet flyover at 1,000 feet		
	100	
Gas lawnmower at 3 feet		
	90	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	80	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawnmower, 100 feet	**70**	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	**60**	
		Large business office
Quiet urban daytime	**50**	Dishwasher in next room
Quiet urban nighttime	**40**	Theater, large conference room (background)
Quiet suburban nighttime		
	30	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	20	
		Broadcast/recording studio
	10	
	0	

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2.1.3.7 Octave and One-Third-Octave Bands and Frequency Spectra

Very few sounds are pure tones (i.e., consisting of a single frequency). To represent the complete characteristics of a sound properly, it is necessary to divide the total sound into its frequency components (i.e., determine how much sound [SPL] comes from each of the multiple frequencies that make up the sound). This representation of frequency vs. SPL is called a frequency spectrum. Spectra usually consist of 8- to 10-octave bands, more or less spanning the frequency range of human hearing (20 to 20,000 Hz). Just as with a piano keyboard, an octave represents the frequency interval between a given frequency and twice that frequency. Octave bands are internationally standardized and identified by their "center frequencies" (geometric means).

Because octave bands are rather broad, they are frequently subdivided into thirds to create one-third-octave bands. These are also standardized. For convenience, one-third-octave bands are sometimes numbered from 1 (1.25-Hz one-third-octave center frequency, which cannot be heard by humans) to 43 (20,000-Hz one-third-octave center frequency). Within the extreme range of human hearing there are 30 one-third-octave bands ranging from band 13 (20-Hz one-third-octave center frequency) to band 42 (16,000-Hz one-third-octave center frequency). Table 2-6 shows the ranges of the standardized octave and one-third-octave bands, as well as band numbers.

Frequency spectra are used in many aspects of sound analysis, from studying sound propagation to designing effective noise control measures. Sound is affected by many frequency-dependent physical and environmental factors. Atmospheric conditions, site characteristics, and materials and their dimensions used for sound reduction are some of the most important examples.

Sound propagating through the air is affected by air temperature, humidity, wind and temperature gradients, vicinity and type of ground surface, obstacles, and terrain features. These factors are all frequency-dependent.

The ability of a material to transmit noise depends on the type of material (concrete, wood, glass, etc.) and its thickness. Effectiveness of different materials at transmitting noise depends on the frequency of the noise. See Section 5.1.1 for a discussion of transmission loss and sound transmission class.

Wavelengths serve to determine the effectiveness of noise barriers. Low frequency noise, with its long wavelengths, passes easily around and over

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a noise barrier with little loss in intensity. For example, a 16-Hz noise with a wavelength of 70 feet will tend to pass over a 16-foot-high noise barrier. Fortunately, A-weighted traffic noise tends to dominate in the 250- to 2,000-Hz range with wavelengths in the range of about 0.6 to 4.5 feet. As discussed later, noise barriers are less effective at lower frequencies and more effective at higher ones.

Table 2-6. Standardized Band Numbers, Center Frequencies, One-Third-Octave and Octave Bands, and Octave Band Ranges

Band	Center Frequency (Hz)	One-Third-Octave Band Range (Hz)	Octave Band Range (Hz)
12	**16**	14.1–17.8	**11.2–22.4**
13	20	17.8–22.4	
14	25	22.4–28.2	
15	**31.5**	28.2–35.5	**22.4–44.7**
16	40	35.5–44.7	
17	50	44.7–56.2	
18	**63**	56.2–70.8	**44.7–89.1**
19	80	70.8–89.1	
20	100	89.1–112	
21	**125**	112–141	**89.1–178**
22	160	141–178	
23	200	178–224	
24	**250**	224–282	**178–355**
25	315	282–355	
26	400	355–447	
27	**500**	447–562	**355–708**
28	630	562–708	
29	800	708–891	
30	**1,000**	891–1,120	**708–1,410**
31	1,250	1,120–1,410	
32	1,600	1,410–1,780	
33	**2,000**	1,780–2,240	**1,410–2,820**
34	2,500	2,240–2,820	
35	3,150	2,820–3,550	
36	**4,000**	3,550–4,470	**2,820–5,620**
37	5,000	4,470–5,620	
38	6,300	5,620–7,080	
39	**8,000**	7,080–8,910	**5,620–11,200**
40	10,000	8,910–11,200	
41	12,500	11,200–14,100	
42	**16,000**	14,100–17,800	**11,200–22,400**

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Band	Center Frequency (Hz)	One-Third-Octave Band Range (Hz)	Octave Band Range (Hz)
43	20,000	17,800–22,400	
Source: Harris 1979.			

Figure 2-5 shows a conventional graphical representation of a typical octave-band frequency spectrum. The octave bands are depicted as having the same width, although each successive band should increase by a factor of 2 when expressed linearly in terms of 1-Hz increments.

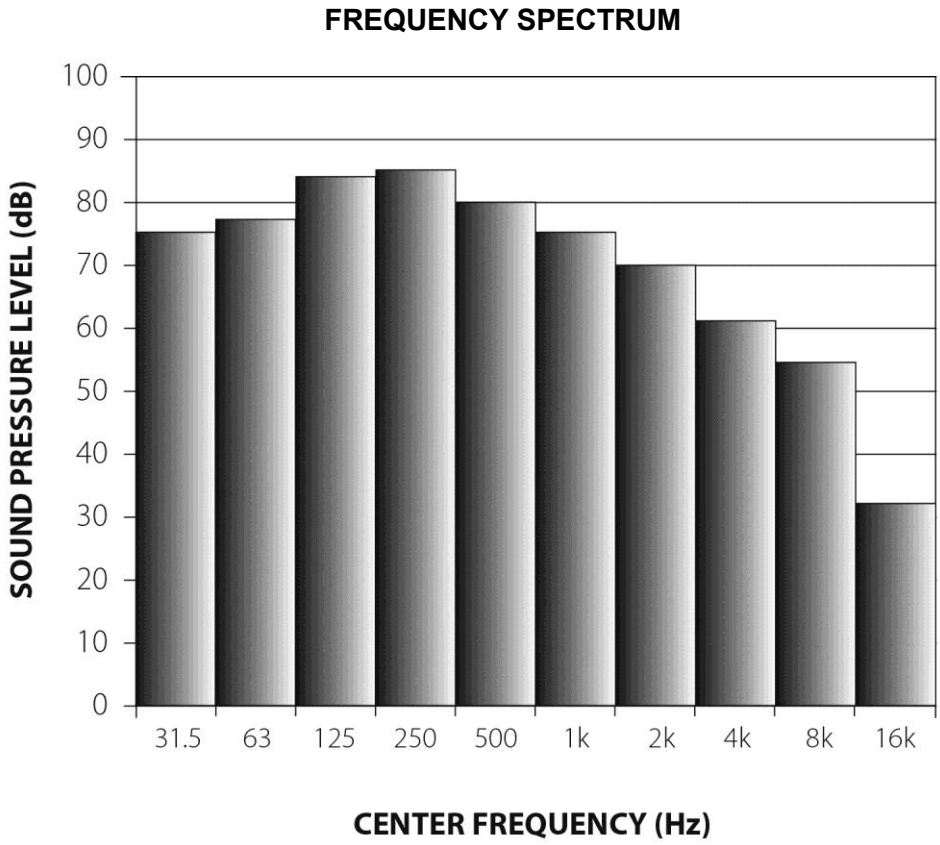

Figure 2-5. Typical Octave Band Frequency Spectrum

A frequency spectrum can also be presented in tabular form. For example, the data used to generate Figure 2-5 is illustrated in tabular form in Table 2-7.

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Table 2-7. Tabular Form of Octave Band Spectrum

Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)
31.5	75
63	77
125	84
250	85
500	80
1,000	75
2,000	70
4,000	61
8,000	54
16,000	32
Total sound pressure level = 89 dB	

Often, one is interested in the total noise level, or the summation of all octave bands. Using the data shown in Table 2-8, one may simply add all the SPLs, as was explained in Section 2.1.3.5. The total noise level for the above octave band frequency spectrum is 89 dB.

The same sorts of charts and tables can be compiled from one-third-octave band information. For example, if more detailed one-third-octave information for the above spectrum is available, a one-third-octave band spectrum could be constructed as shown in Figure 2-6 and Table 2-8. Note that the total noise level does not change, and that each subdivision of three one-third-octave bands adds up to the total octave band shown in the previous example.

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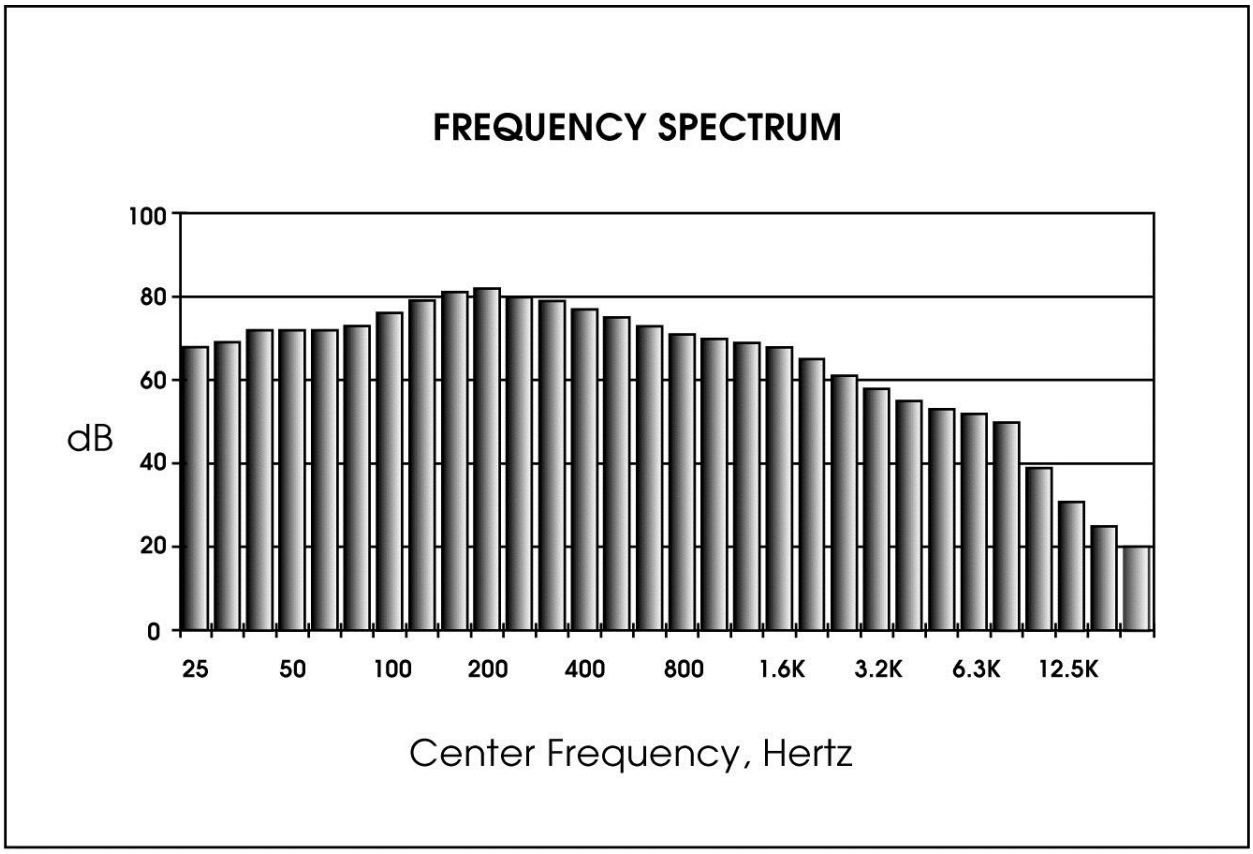

Figure 2-6. Typical One-Third-Octave Band Frequency Spectrum

Frequency spectrums are usually expressed in linear, unweighted SPLs (dB). However, they may also be A-weighted by applying the adjustments from Table 2-4. For example, the data in Table 2-8 can be A-weighted (rounded to nearest dB) as shown in Table 2-9.

Table 2-8. Tabular Form of One-Third Octave Band Spectrum

One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)	One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)	One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)
25	68	**250**	80	2,500	61
31.5	69	315	79	3,200	58
40	72	400	77	**4,000**	55
50	72	**500**	75	5,000	53
63	72	630	73	6,300	52
80	73	800	71	**8,000**	50
100	76	**1,000**	70	10,000	39
125	79	1,250	69	12,500	31
160	81	1,600	68	**16,000**	25

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One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)	One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)	One-Third-Octave Band Center Frequency (Hz)	Sound Pressure Level (dB)
200	82	**2,000**	65	20,000	20
Total sound pressure level = 89 dB					

Table 2-9. Adjusting Linear Octave Band Spectrum to A-Weighted Spectrum

Octave Band Center Frequency (Hz)	Sound Pressure Level (dBA)
31.5	75 – 39 = 36
63	77 – 26 = 51
125	84 – 16 = 68
250	85 – 9 = 76
500	80 – 3 = 77
1,000	75 – 0 = 75
2,000	70 + 1 = 71
4,000	61 + 1 = 62
8,000	54 – 1 = 53
16,000	32 – 7 = 25
Total sound pressure level = 89 dB (linear) and 81.5 dBA	

The total A-weighted noise level is 81.5 dBA, compared with the linear noise level of 89 dB. In other words, the original linear frequency spectrum with a total noise level of 89 dB is perceived as a total A-weighted noise level of 81.5 dBA.

A linear noise level of 89 dB with a different frequency spectrum distribution, could have produced a different A-weighted noise level, either higher or lower. The reverse may also be true. Theoretically, an infinite number of frequency spectrums could produce either the same total linear noise level or the same A-weighted spectrum. This is an important concept because it can help explain a variety of phenomena dealing with noise perception. For example, some evidence suggests that changes in frequencies are sometimes perceived as changes in noise levels, although the total A-weighted noise levels do not change significantly. Section 7 addresses with some of these phenomena.

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2.1.3.8 White and Pink Noise

White noise is noise with a special frequency spectrum that has the same amplitude (level) for each frequency interval over the entire audible frequency spectrum. It is often generated in laboratories for calibrating sound level measuring equipment, specifically its frequency response. One might expect that the octave or one-third-octave band spectrum of white noise would be a straight line, but this is not true. Beginning with the lowest audible octave, each subsequent octave spans twice as many frequencies than the previous ones, and therefore contains twice the energy. This corresponds with a 3-dB step increase for each octave band, and 1 dB for each one-third-octave band.

Pink noise, in contrast, is defined as having the same amplitude for each octave band (or one-third-octave band), rather than for each frequency interval. Its octave or one-third-octave band spectrum is truly a straight "level" line over the entire audible spectrum. Therefore, pink noise generators are conveniently used to calibrate octave or one-third-octave band analyzers.

Both white and pink noise sound somewhat like the static heard from a radio that is not tuned to a particular station.

2.1.4 Sound Propagation

From the source to receiver, noise changes both in level and frequency spectrum. The most obvious is the decrease in noise as the distance from the source increases. The manner in which noise reduces with distance depends on the following important factors.

- Geometric spreading from point and line sources.
- Ground absorption.
- Atmospheric effects and refraction.
- Shielding by natural and manmade features, noise barriers, diffraction, and reflection.

2.1.4.1 Geometric Spreading from Point and Line Sources

Sound from a small localized source (approximating a point source) radiates uniformly outward as it travels away from the source in a spherical pattern. The sound level attenuates or drops off at a rate of

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6 dBA for each doubling of the distance (6 dBA/DD). This decrease, resulting from the geometric spreading of the energy over an ever-increasing area, is referred to as the inverse square law. Doubling the distance increases each unit area, represented by squares with sides "a" in Figure 2-7, from a^2 to $4a^2$.

Because the same amount of energy passes through both squares, the energy per unit area at 2D is reduced four times from that at distance D. Therefore, for a point source the energy per unit area is inversely proportional to the square of the distance. Taking $10\log_{10}(1/4)$ results in a 6-dBA/DD reduction. This is the point source attenuation rate for geometric spreading.

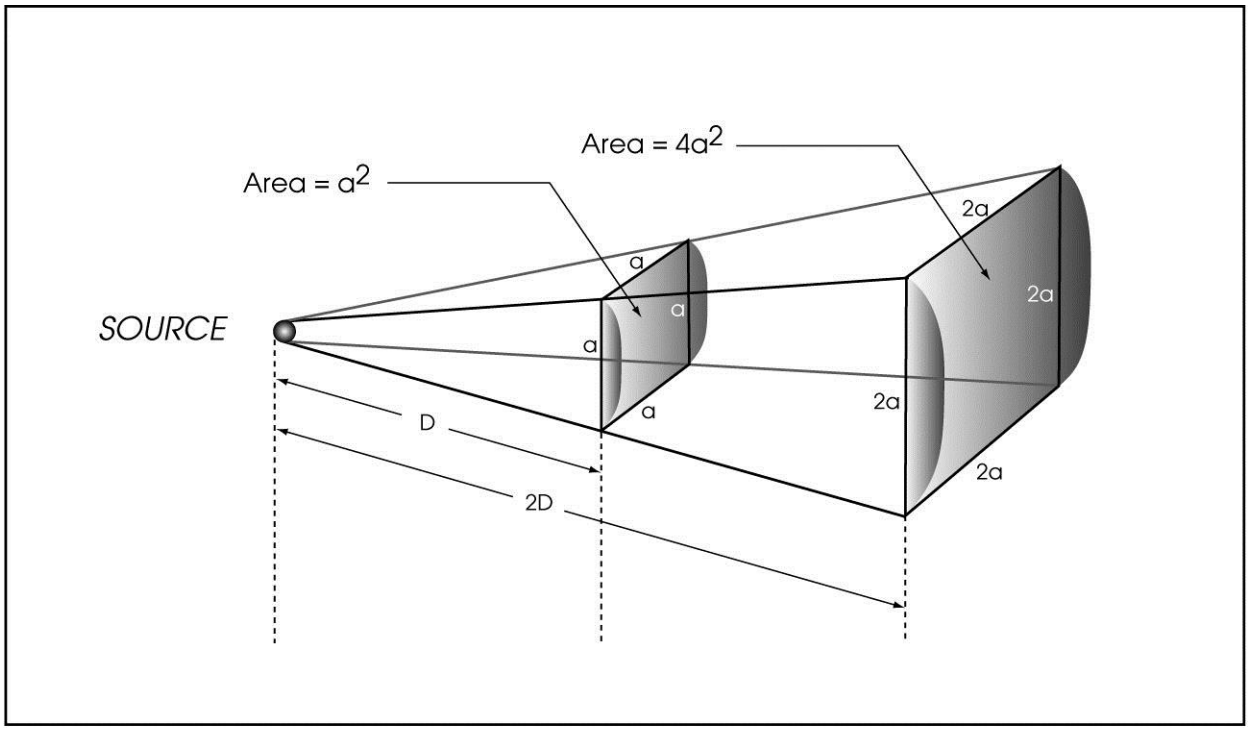

Figure 2-7. Point Source Propagation (Spherical Spreading)

As seen in Figure 2-8, based on the inverse square law the change in noise level between any two distances because of spherical spreading can be found using the following equation:

$$dBA_2 = dBA_1 + 10\log_{10}[(D_1/D_2)]^2 = dBA_1 + 20\log_{10}(D_1/D_2) \quad \textbf{(2-13)}$$

Where:

dBA_1 = noise level at distance D_1

dBA_2 = noise level at distance D_2

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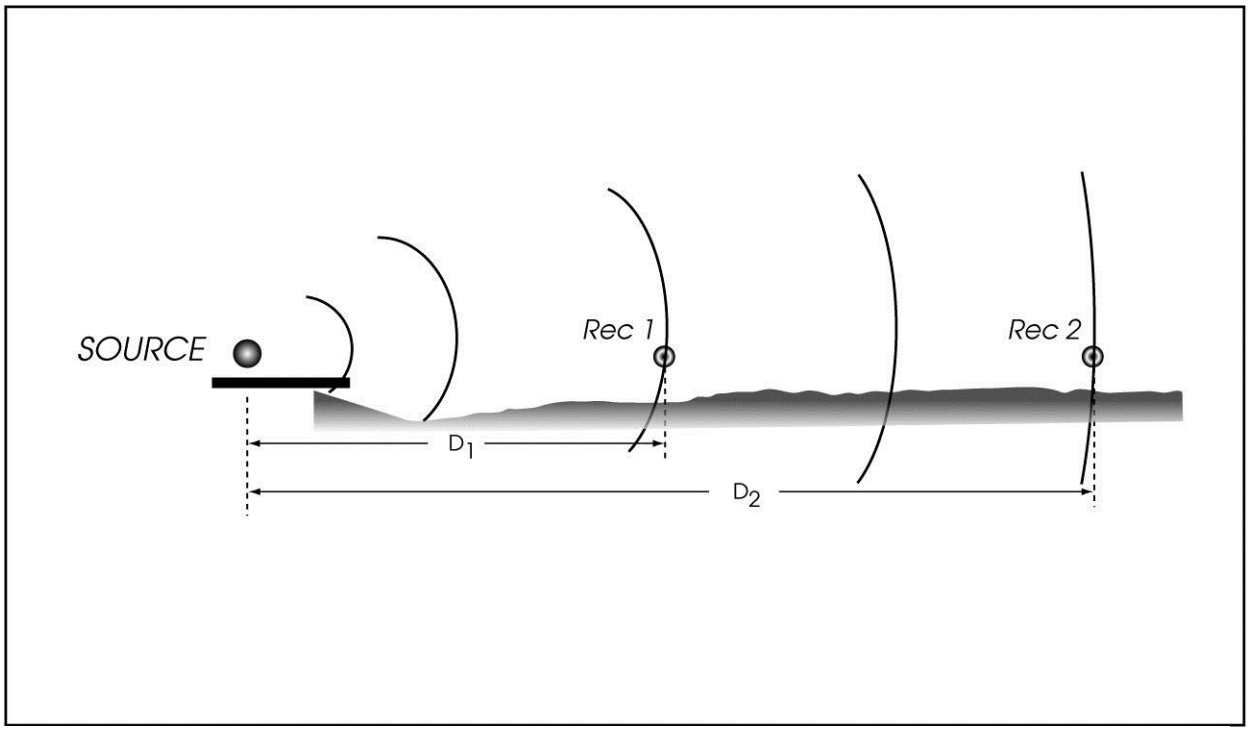

Figure 2-8. Change in Noise Level with Distance from Spherical Spreading

However, highway traffic noise is not a single, stationary point source. The movement of the vehicles makes the source of the sound appear to emanate from a line (line source) rather than a point when viewed over a time interval (Figure 2-9). This results in cylindrical spreading rather than spherical spreading. Because the change in surface area of a cylinder only increases by two times for each doubling of the radius instead of the four times associated with spheres, the change in sound level is 3 dBA/DD. The change in noise levels for a line source at any two different distances from cylindrical spreading is determined using the following equation:

$$dBA_2 = dBA_1 + 10\log_{10}(D_1/D_2) \quad \textbf{(2-14)}$$

Where:

dBA_1 = noise level at distance D_1 and conventionally the known noise level

dBA_2 = noise level at distance D_2 and conventionally the unknown noise level

Note

The expression $10\log_{10}(D_1/D_2)$ is negative when D_2 is more than D_1 and positive when D_1 is more than D_2. Therefore, the equation automatically accounts for the receiver being farther or closer with respect to the source—$\log_{10}$ of a number less than 1 gives a negative result, $\log_{10}$ of a number more than 1 is positive, and $\log_{10}(1) = 0$.

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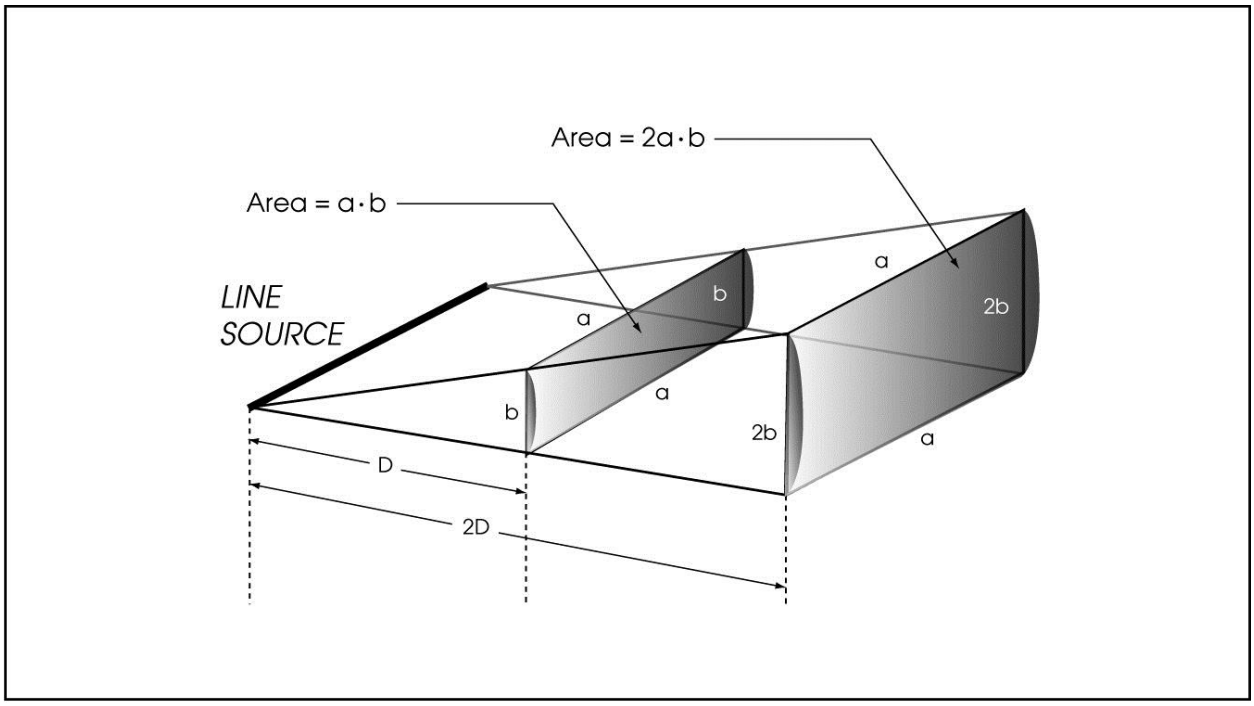

Figure 2-9. Line Source Propagation (Cylindrical Spreading)

2.1.4.2 Ground Absorption

Most often, the noise path between the highway and observer is very close to the ground. Noise attenuation from ground absorption and reflective wave cancellation adds to the attenuation from geometric spreading. Traditionally, this excess attenuation has been expressed in terms of decibels of attenuation per doubling of distance. This approximation is done for simplification only; for distances of less than 200 feet, the prediction results based on this scheme are sufficiently accurate. The sum of the geometric spreading attenuation and excess ground attenuation (if any) is referred to as the attenuation or dropoff rate. For distances of 200 feet or more, the approximation causes excessive inaccuracies in predictions. The amount of excess ground attenuation depends on the height of the noise path and characteristics of the intervening ground or site. In practice, excess ground attenuation may vary from 0 to 8–10 dBA/DD or more. In fact, it varies as the noise path height changes from the source to receiver and with vehicle type because the source heights are different. The complexity of terrain also influences the propagation of sound by potentially increasing the number of ground reflections.

The FHWA TNM is the model that is currently approved by FHWA for use in noise impact studies. The TNM has complex algorithms that directly calculate excess ground attenuation based on ground type and site geometry.

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2.1.4.3 Atmospheric Effects and Refraction

Research by Caltrans and others has shown that atmospheric conditions can have a profound effect on noise levels within 200 feet of a highway. Wind has shown to be the most important meteorological factor within approximately 500 feet, while vertical air temperature gradients are more important over longer distances. Other factors such as air temperature, humidity, and turbulence also have significant effects.

Wind

The effects of wind on noise are mostly confined to noise paths close to the ground because of the wind shear phenomenon. Wind shear is caused by the slowing of wind in the vicinity of a ground plane because of surface friction. As the surface roughness of the ground increases, so does the friction between the ground and the air moving over it. As the wind slows with decreasing heights, it creates a sound velocity gradient (because of differential movement of the medium) with respect to the ground. This velocity gradient tends to bend sound waves downward in the same direction of the wind and upward in the opposite direction. The process, called refraction, creates a noise shadow (reduction) upwind of the source and a noise concentration (increase) downwind of the source. Figure 2-10 shows the effects of wind on noise. Wind effects on noise levels along a highway depend very much on wind angle, receiver distance, and site characteristics. A 6-mph cross wind can increase noise levels at 250 feet by about 3 dBA downwind and reduce noise by about the same amount upwind. Present policies and standards ignore the effects of wind on noise levels. Unless wind conditions are specifically identified, noise levels are always assumed to be for zero wind. Noise analyses are also always made for zero-wind conditions.

Wind also has another effect on noise measurements. Wind "rumble" caused by air movement over a microphone of a sound level meter can contaminate noise measurements even if a wind screen is placed over the microphone.

Limited measurements performed by Caltrans in 1987 showed that wind speeds of about 11 mph produce noise levels of about 45 dBA, using a ½-inch microphone with a wind screen. This means that noise measurements below 55 dBA are contaminated by wind speeds of 11 mph or more. A noise level of 55 dBA is about at the low end of the range of noise levels routinely measured near highways for noise analysis. FHWA's *Measurement of Highway-Related Noise* (1996) recommends that highway noise measurements should not be made at wind speeds above 12 mph. An 11 mph criterion for maximum allowable wind speed for routine highway

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noise measurements seems reasonable and is therefore recommended. More information concerning wind/microphone contamination is provided in Section 3.

Wind Turbulence

Turbulence also has a scattering effect on noise levels, which is difficult to predict. It appears, however, that turbulence has the greatest effect on noise levels in the vicinity of the source.

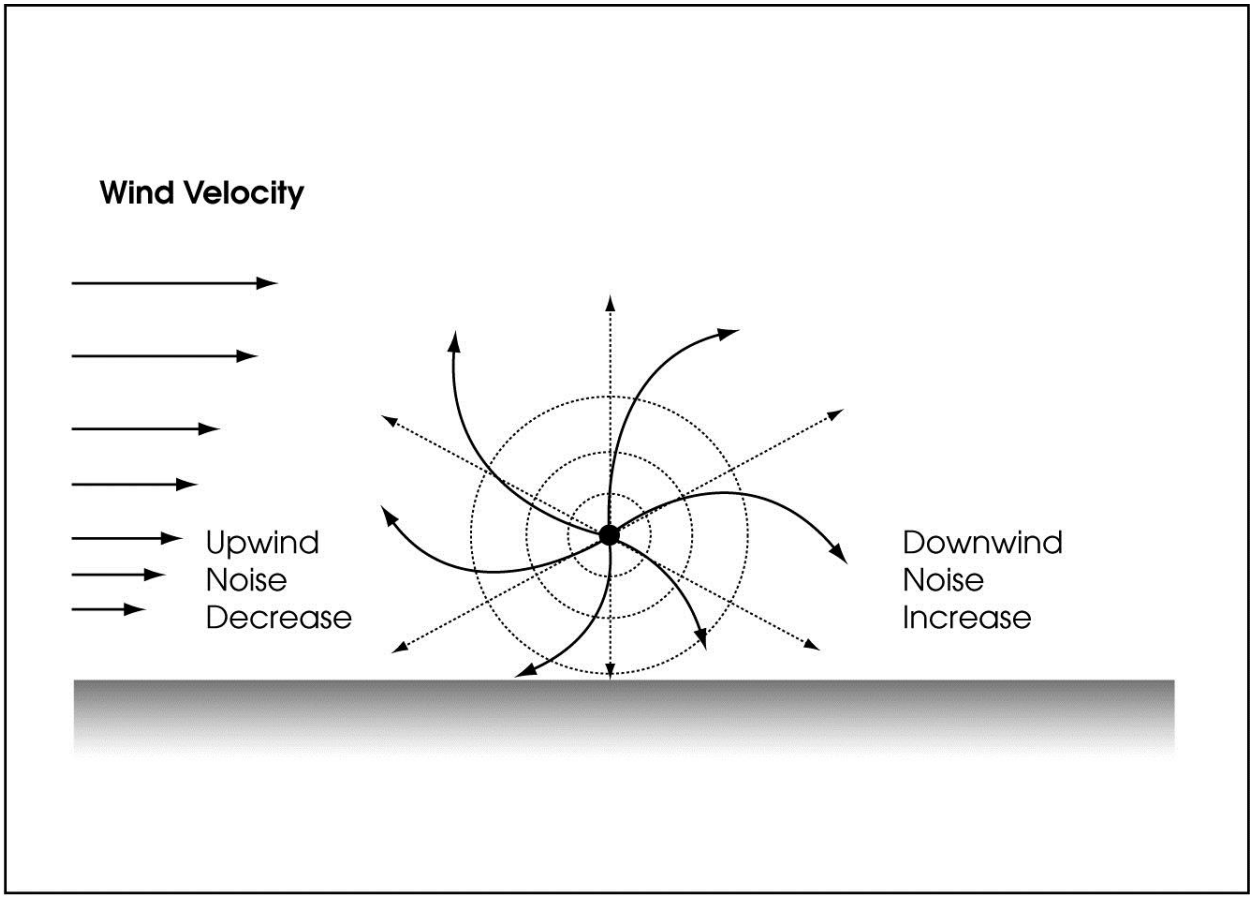

Figure 2-10. Wind Effects on Noise Levels

Temperature Gradients

Figure 2-11 shows the effects of temperature gradients on noise levels. Normally, air temperature decreases with height above the ground. This is called the normal lapse rate, which for dry air is about -5.5ºF per 1,000 feet. Because the speed of sound decreases as air temperature decreases, the resulting temperature gradient creates a sound velocity gradient with height. Slower speeds of sound higher above the ground tend to refract

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sound waves upward in the same manner as wind shear upwind from the source. The result is a decrease in noise. Under certain stable atmospheric conditions temperature profiles can become inverted (i.e., temperatures increase with height either from the ground up or at some altitude above the ground). This inversion results in speeds of sound that temporarily increase with altitude, causing noise refraction similar to that caused by wind shear downwind from a noise source. Also, once trapped within an elevated inversion layer, noise may be carried over long distances. Both ground and elevated temperature inversions have the effect of propagating noise with less than the usual attenuation rates and therefore increase noise. The effects of vertical temperature gradients are more important over longer distances.

Temperature and Humidity

Molecular absorption in air also reduces noise levels with distance. Although this process only accounts for about 1 dBA per 1,000 feet under average conditions of traffic noise in California, the process can cause significant longer-range effects. Air temperature and humidity affect molecular absorption differently depending on the frequency spectrum and can vary significantly over long distances in a complex manner.

Rain

Wet pavement results in an increase in tire noise and corresponding increase in frequencies of noise at the source. Wet pavement may increase vehicle noise emission levels relative to dry conditions in the range of 0 to 15 dBA (Sandberg and Ejsmont 2002). Because the propagation of noise is frequency-dependent, rain may also affect distance attenuation rates. However, traffic generally slows down during rain, decreasing noise levels and lowering frequencies. When wet, pavement types interact differently with tires than when they are dry. These factors make it very difficult to predict noise levels during rain. Therefore, no noise measurements or predictions should be made under rainy conditions. Noise abatement criteria (NAC) and standards in the FHWA noise regulation (23 CFR 772) are based on completely dry pavement.

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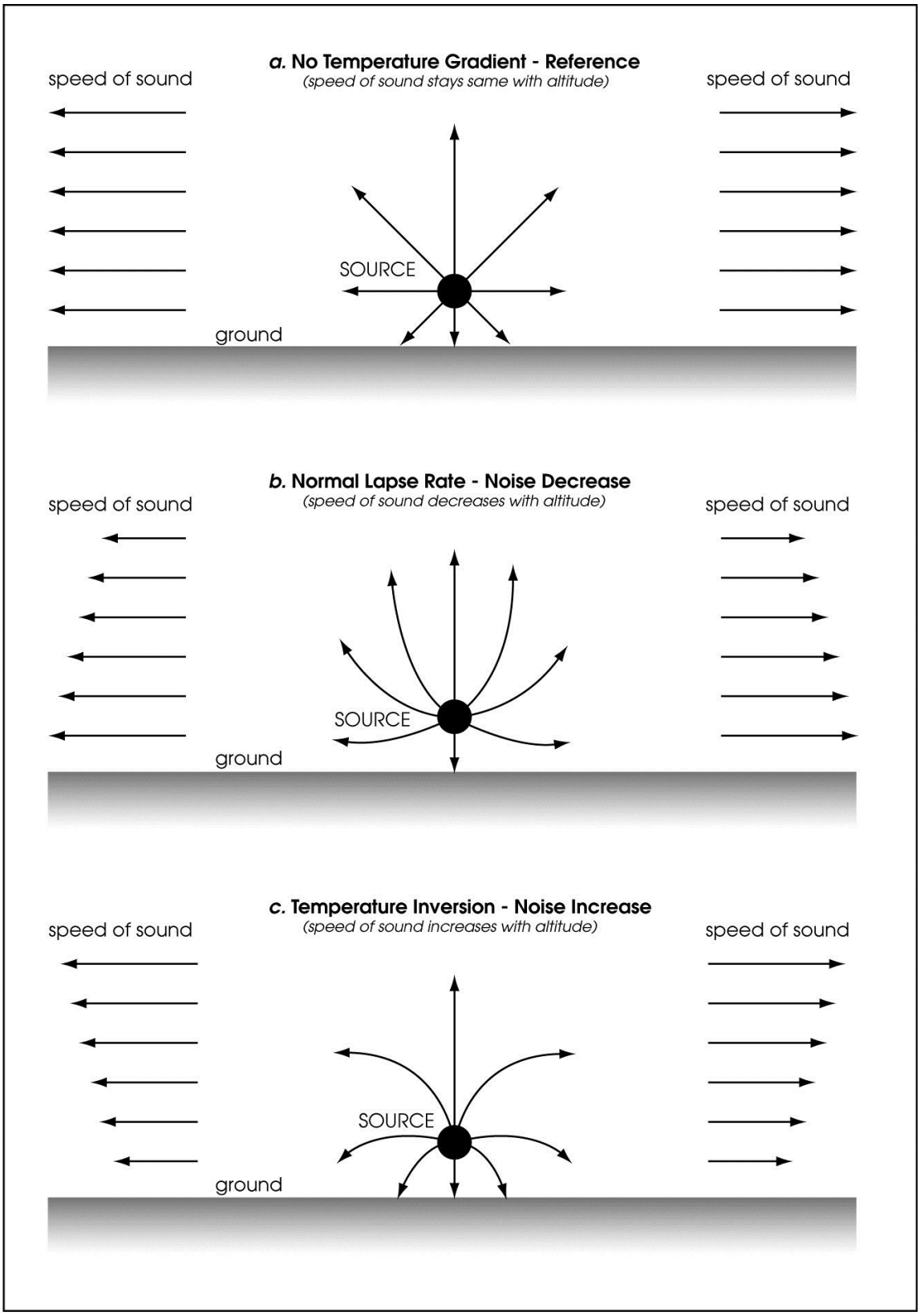

Figure 2-11. Effects of Temperature Gradients on Noise

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2.1.4.4 Shielding by Natural and Manmade Features, Noise Barriers, Diffraction, and Reflection

A large object in the path between a noise source and receiver can significantly attenuate noise levels at the receiver. The amount of attenuation provided by this shielding depends on the size of the object and frequencies of the noise levels. Natural terrain features such as hills and manmade features, such as buildings and walls, can significantly alter noise levels. Walls are often used specifically to reduce noise.

Trees and Vegetation

It is uncommon for trees and vegetation to result in a noticeable reduction in noise. A vegetative strip must be very dense and wide for there to be any meaningful shielding effect. A heavily vegetated ground surface may increase ground absorption which can increase attenuation over distance.

Landscaping

Caltrans research (California Department of Transportation 1995) has shown that ordinary landscaping along a highway accounts for less than 1 dBA of reduction. Claims of increases in noise from removal of vegetation along highways are mostly spurred by the sudden visibility of the traffic source. There is evidence of a psychological effect ("out of sight, out of mind") of vegetation on noise.

Buildings

Depending on site geometry, the first row of houses or buildings next to a highway may shield the successive rows. This often occurs where the facility is at-grade or depressed. The amount of noise reduction varies with building sizes, spacing of buildings, and site geometry. Generally, for an at-grade facility in an average residential area where the first row houses cover at least 40% of total area (i.e., no more than 60% spacing), the reduction provided by the first row is reasonably assumed to be 3 dBA, with 1.5 dBA for each additional row. For example, one may expect a 3-dBA noise reduction behind the first row, 4.5 dBA behind the second row, and 6 dBA behind the third row. For houses or buildings spaced tightly (covering about 65% to 90% of the area, with 10% to 35% open space), the first row provides about 5 dBA of reduction. Successive rows still reduce noise by 1.5 dBA per row. However, for the reason discussed in the preceding discussion, the limit is 10 dBA. For these assumptions to be true

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the first row of houses or buildings must be equal to or higher than the second row, which should be equal to or higher than the third row, etc.

Noise Barriers

Although any natural or manmade feature between source and receiver that reduces noise is technically a noise barrier, the term is generally reserved for a wall or berm specifically constructed for noise reduction. The acoustical design of noise barriers is addressed in Section 5. However, it is appropriate at this time to introduce the acoustical concepts associated with noise barriers. These principles apply loosely to any obstacle between the source and receiver.

As shown in Figure 2-12, when a noise barrier is inserted between a noise source and receiver, the direct noise path along the line of sight between the two is interrupted. Some of the acoustical energy will be transmitted through the barrier material and continue to the source, although at a reduced level. The amount of this reduction depends on the material's mass and rigidity, and is called the transmission loss (TL), which is expressed in decibels. Its mathematical expression is:

$$TL = 10\log_{10}(E_f/E_b) \quad \textbf{(2-15)}$$

Where:

E_f = relative noise energy immediately in front of barrier (source side)

E_b = relative noise energy immediately behind barrier (receiver side)

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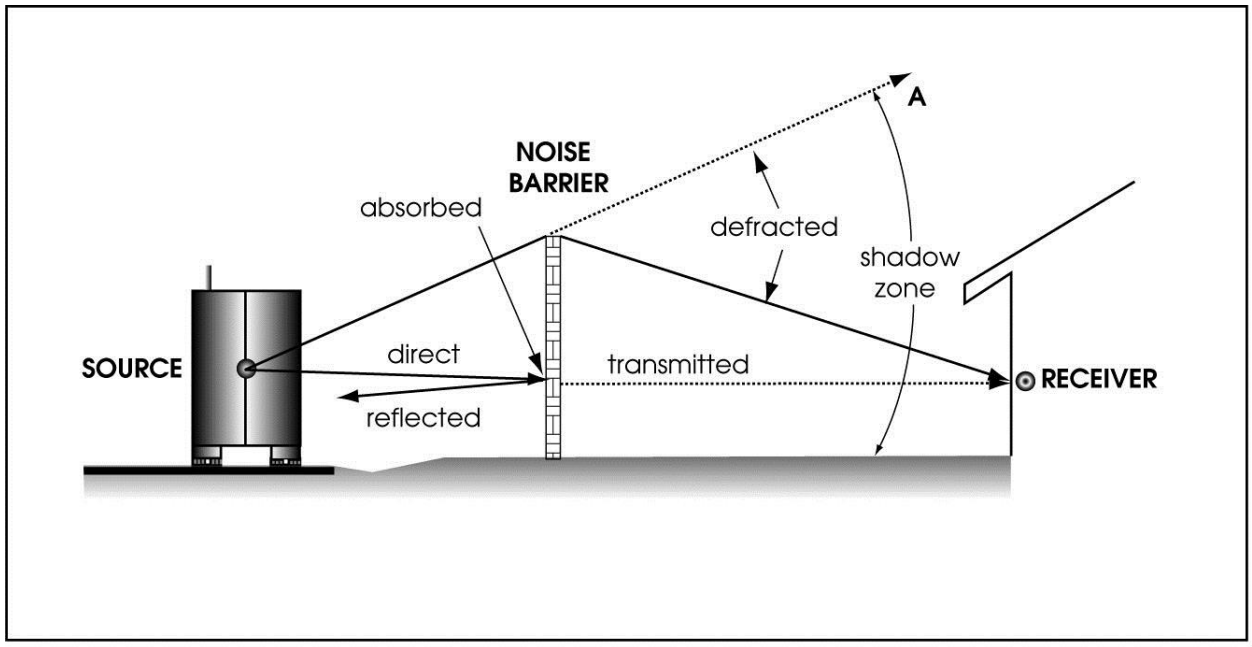

Figure 2-12. Alteration of Sound Paths after Inserting a Noise Barrier between Source and Receiver

Please note that E_f and E_b are relative energies (i.e., energies with reference to the energy of 0 dB [Section 2.1.3.4]). As relative energies, they may be expressed as any ratio (fractional or percentage) that represents their relationship. For example, if 1% of the noise energy striking a barrier is transmitted, TL = $10\log_{10}(100/1)$ = 20 dBA. Most noise barriers have TLs of 30 dBA or more. This means that only 0.1% of the noise energy is transmitted.

The remaining direct noise (usually close to 100%) is either partially or entirely absorbed by the noise barrier material (if sound absorptive) and/or partially or entirely reflected by it (if sound reflective). Whether the barrier is reflective or absorptive depends on its ability to absorb sound energy. A smooth, hard barrier surface, such as masonry or concrete, is considered almost perfectly reflective (i.e., almost all sound striking the barrier is reflected back toward the source and beyond). A barrier surface material that is porous, with many voids, is said to be absorptive (i.e., little or no sound is reflected back). The amount of energy absorbed by a barrier surface material is expressed as an absorption coefficient α, which has a value ranging from 0 (100% reflective) to 1 (100% absorptive). A perfect reflective barrier ($\alpha = 0$) will reflect back virtually all noise energy (assuming a transmission loss of 30 dBA or more) toward the opposite side of a highway. If the difference in path length between the direct and reflected noise paths to the opposite (unprotected) side of a highway is ignored, the maximum expected increase in noise will be 3 dBA.

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If one wishes to calculate the noise increase from a partially absorptive wall, Equation 2-15 may be used. E_f is the noise energy striking the barrier, but E_b becomes the energy reflected back. For example, a barrier material with an α of 0.6 absorbs 60% of the direct noise energy and reflects back 40%. To calculate the increase in noise on the opposite side of the highway in this situation, the energy loss from the transformation of the total noise striking the barrier to the reflected noise energy component is $10\log_{10}(100/40)= 4$ dBA. In other words, the energy loss of the reflection is 4 dBA. If the direct noise level of the source at a receiver on the opposite side of the highway is 65 dBA, the reflective component (ignoring the difference in distances traveled) will be 61 dBA. The total noise level at the receiver is the sum of 65 and 61 dBA, slightly less than 66.5 dBA. The reflected noise caused an increase of 1.5 dBA at the receiver.

The transmitted, absorbed, and reflected noise paths shown in Figure 2-12 are variations of the direct noise path. Of these three paths, only transmitted noise reaches the receiver behind the barrier. However, there is one more path—the diffracted path—that reaches the receiver. The diffracted path is actually the most important path. With the barrier in place, sound energy traveling along this path is diffracted downward toward the receiver.

In general, diffraction is characteristic of all wave phenomena, including light, water, and sound waves. It can best be described as the bending of waves around objects. The amount of diffraction depends on the wavelength and size of the object. Low frequency waves with long wavelengths approaching the size of the object are easily diffracted. Higher frequencies with short wavelengths in relation to the size of the object are not as easily diffracted. This explains why light, with its very short wavelengths, casts shadows with fairly sharp, well defined edges between light and dark. Sound waves also “cast a shadow” when they strike an object. However, because of their much longer wavelengths (by at least about six orders of magnitude) the noise shadows are not very well defined and amount to a noise reduction, not an absence of noise.

Because noise consists of many different frequencies that diffract by different amounts, it seems reasonable to expect that the greater the angle of diffraction, the more frequencies will be attenuated. In Figure 2-12, beginning with the top of the shadow zone and going down to the ground surface, the higher frequencies will be attenuated first, then the middle frequencies, and finally the lower ones. Please notice that the top of the shadow zone is defined by the extension of a straight line from the noise source (in this case represented at the noise centroid as a point source) to the top of the barrier. The diffraction angle is defined by the top of the shadow zone and the line from the top of the barrier to receiver. Therefore,

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the position of the source relative to the top of the barrier determines the extent of the shadow zone and the diffraction angle to the receiver. Similarly, the receiver location relative to the top of the barrier is also important in determining the diffraction angle.

From the previous discussion, three conclusions are clear. First, the diffraction phenomenon depends on three critical locations: source, top of barrier, and receiver. Second, for a given source, top of barrier, and receiver configuration, a barrier is more effective in attenuating higher frequencies than lower frequencies (Figure 2-13). Third, the greater the angle of diffraction, the greater the noise attenuation.

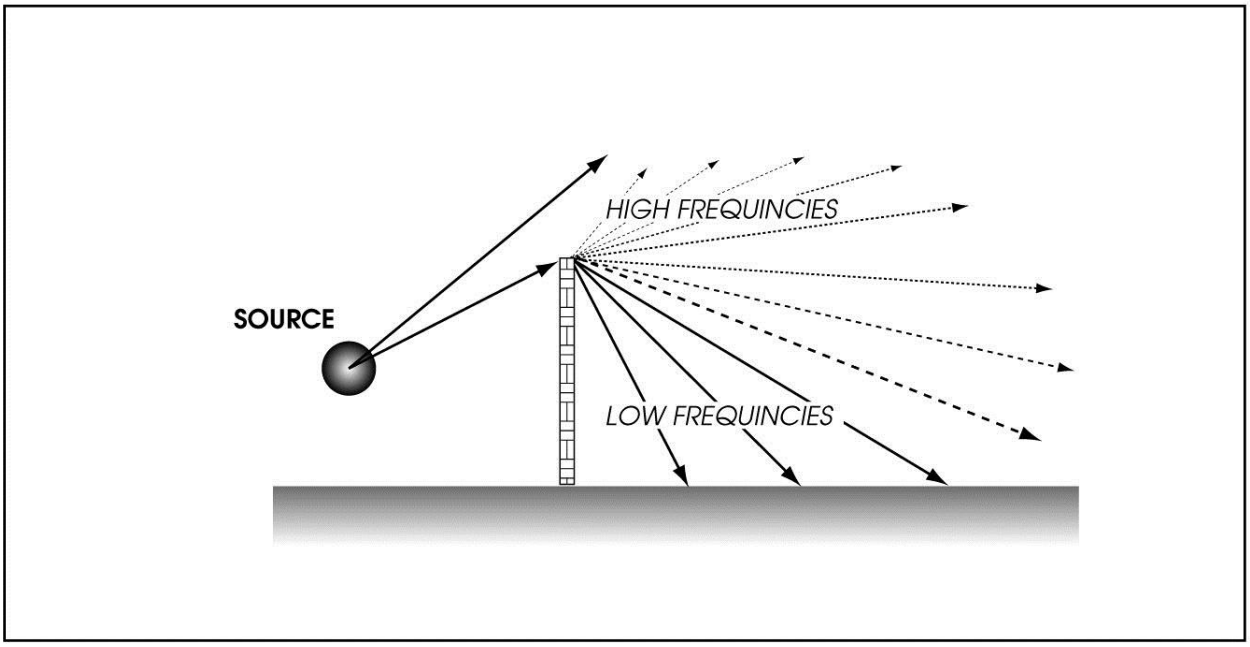

Figure 2-13. Diffraction of Sound Waves

The angle of diffraction is also related to the path length difference (δ) between the direct noise and diffracted noise. Figure 2-14 illustrates the concept of path length difference. A closer examination of this illustration reveals that as the diffraction angle becomes greater, so does δ. The path length difference is defined as $\delta = a + b - c$. If the horizontal distances from the source to receiver and the source to barrier, as well as the differences in elevation between the source, top of barrier, and receiver, are known, *a*, *b*, and *c* can readily be calculated. Assuming that the source in Figure 2-14 is a point source, *a*, *b*, and *c* are calculated as follows:

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$$a = \sqrt{[d_1^2 + (h_2 - h_1)^2]}$$

$$b = \sqrt{(d_2^2 + h_2^2)}$$

$$c = \sqrt{(d^2 + h_1^2)}$$

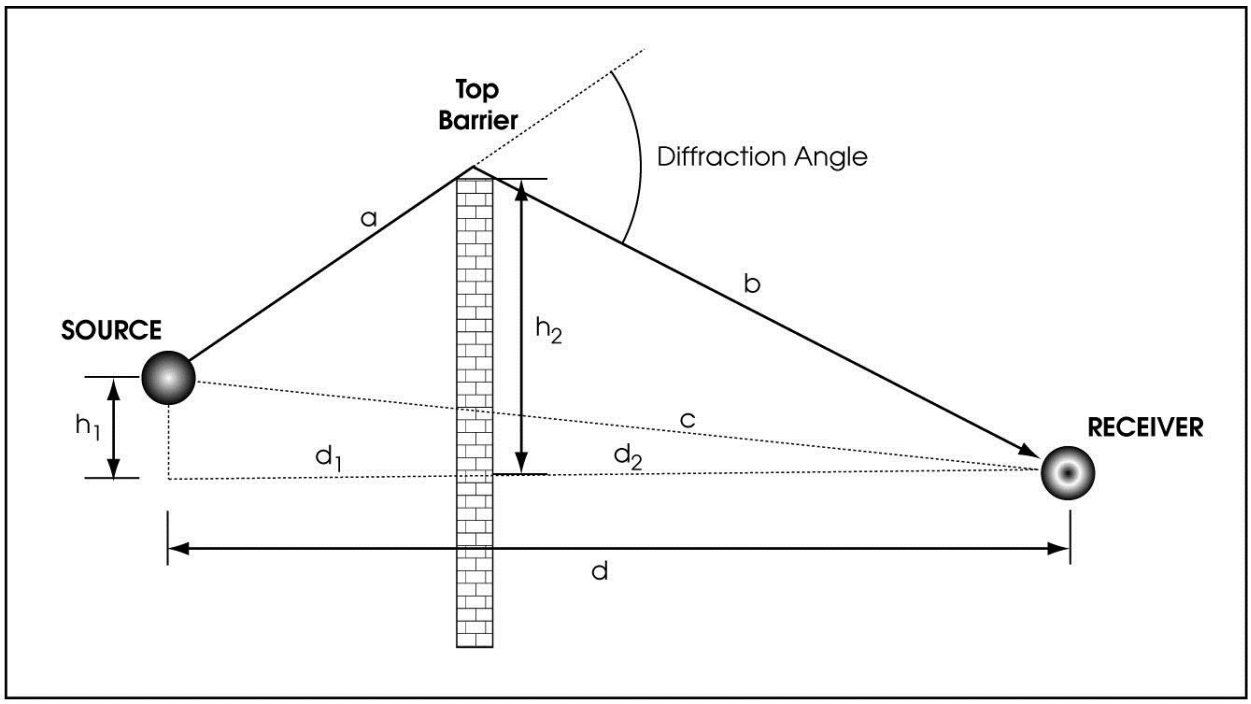

Figure 2-14. Path Length Difference between Direct and Diffracted Noise Paths

Highway noise prediction models use δ in barrier attenuation calculations. Section 5 addresses the subject in greater detail. However, it is appropriate to include the most basic relationship between δ and barrier attenuation through the Fresnel number (N_0). If the source is a line source (e.g., highway traffic) and the barrier is infinitely long, there is an infinite number of path length differences. The path length difference (δ_0) at the perpendicular line to the barrier is then of interest. Mathematically, N_0 is defined as follows:

$$N_0 = 2(\delta_0/\lambda) \quad \textbf{(2-16)}$$

Where:

N_0 = Fresnel number determined along the perpendicular line between source and receiver (i.e., barrier must be perpendicular to the direct noise path)

δ_0 = δ measured along perpendicular line to barrier

λ = wavelength of sound radiated by source

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According to Equation 2-3, $\lambda = c/f$. Therefore, Equation 2-16 may be rewritten as follows:

$$N_0 = 2(f\delta_0/c) \quad \textbf{(2-17)}$$

Where:

f = frequency of sound radiated by source

c = speed of sound

Please note that these equations relate δ_0 to N_0. If one increases, so does the other, along with barrier attenuation. Similarly, if frequency increases, so will N_0 and barrier attenuation. Figure 2-15 shows the barrier attenuation Δ_B for an infinitely long barrier as a function of 550 Hz. It has been found that the attenuation of the A-weighted SPL of typical traffic is almost identical to the sound attenuation of 55 Hz frequency band. (Federal Highway Administration 1978)

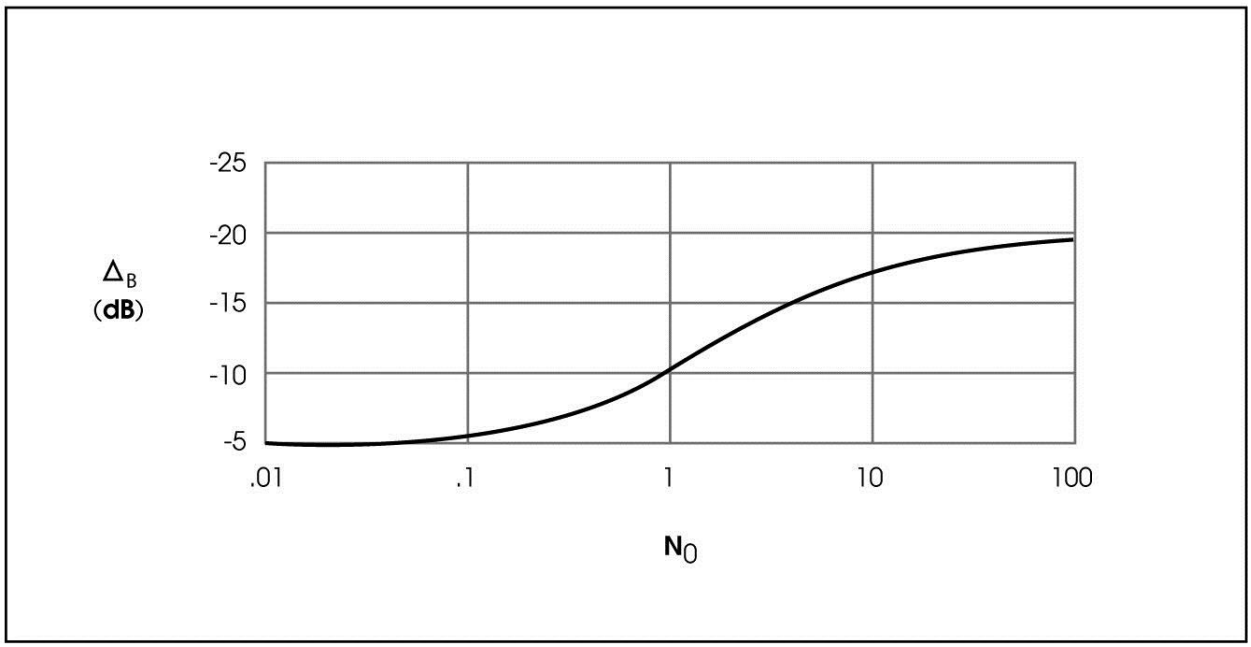

Figure 2-15. Barrier Attenuation (Δ_B) vs. Fresnel Number (N_0) for Infinitely Long Barriers

A barrier can be effective even when it does not completely block the line of sight between the source and the receiver. Figure 2-16 illustrates a special situation where the top of the barrier is just high enough to graze the direct noise path, or line of sight between the source and receiver. In this situation, a noise barrier provides about 5 dBA of attenuation.

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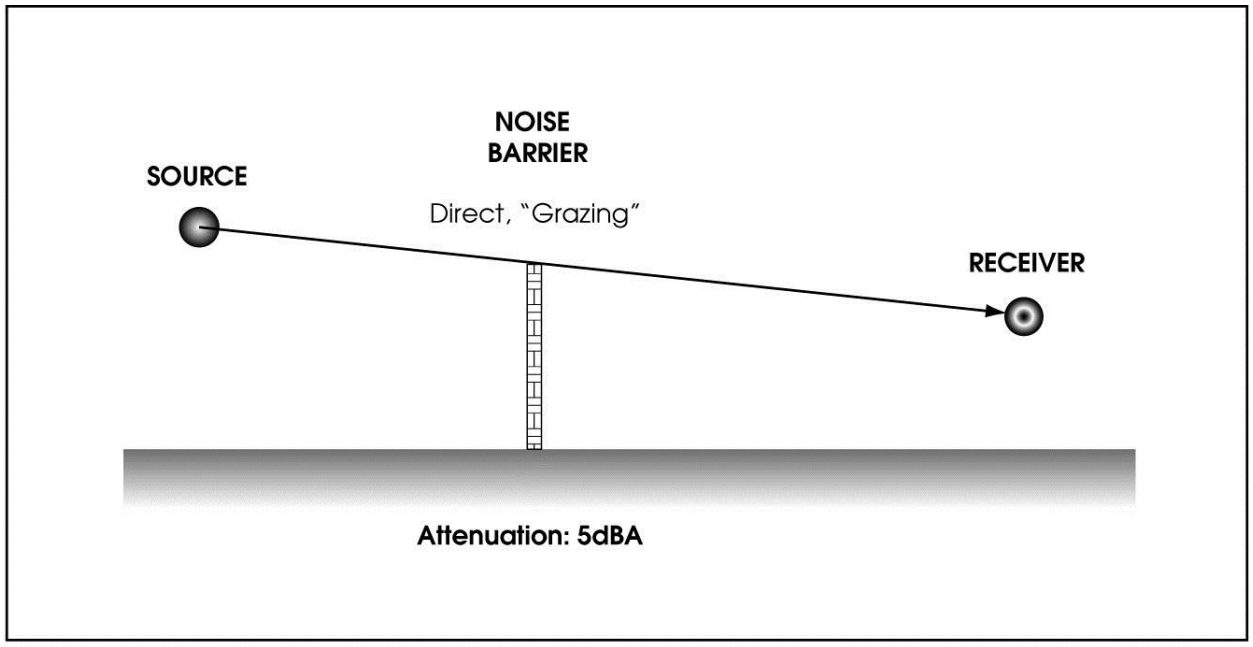

Figure 2-16. Direct Noise Path Grazing Top of Barrier, Resulting in 5 dBA of Attenuation

Another situation, in which the direct noise path is not interrupted but still close to the barrier, will provide some noise attenuation (Figure 2-17). Such negative diffraction (with an associated negative path length difference and Fresnel number) generally occurs when the direct noise path is within 5 feet above the top of the barrier for the average traffic source and receiver distances encountered in near-highway noise environments. The noise attenuation provided by this situation is between 0 and 5 dBA—5 dBA when the noise path approaches the grazing point, and near 0 dBA when it clears the top of the barrier by approximately 5 feet or more.

These principles of barriers apply loosely to terrain features (e.g., berms, low ridges, other significant manmade features). The principles are discussed in more detail in Section 5.

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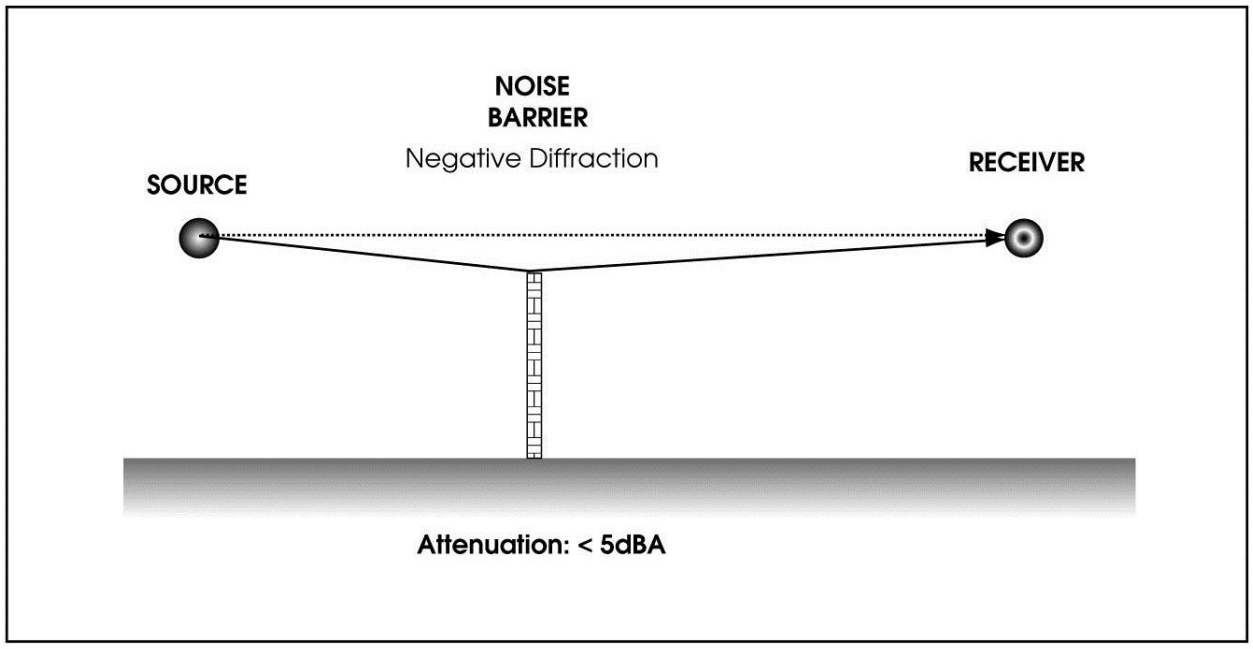

Figure 2-17. Negative Diffraction, Which Provides Some Noise Attenuation

2.2 Effects of Noise and Noise Descriptors

2.2.1 Human Reaction to Sound

People react to sound in a variety of ways. For example, rock music may be pleasant to some people, while for others it may be annoying, constitute a health hazard, or disrupt activities. Human tolerance to noise depends on a variety of acoustical characteristics of the source and environmental characteristics. These factors are briefly discussed below.

- **Noise Level, Variability in Level (Dynamic Range), Duration, Frequency Spectrums, and Time Patterns:** Exposures to very high noise levels can damage hearing. A high level is more objectionable than a low-level noise. For example, intermittent truck peak noise levels are more objectionable than the continuous level of fan noise. Humans have better hearing sensitivities in the high frequency region than the low. This is reflected in the A-scale (Section 2.1.3.6), which deemphasizes the low-frequency sounds. Studies indicate that annoyance or disturbance correlates with the A-scale.
- **Amount of Background Noise Present before Intruding Noise:** People tend to compare an intruding noise with existing background noise. If the new noise is readily identifiable or considerably louder

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than the background or ambient, it usually becomes objectionable. One example is an aircraft flying over a residential area.

- **Nature of Work or Living Activity Exposed to Noise Source:** Highway traffic noise might not be disturbing to workers in a factory or office, but it might be annoying or objectionable to people sleeping at home or studying in a library. An automobile horn at 2:00 a.m. is more disturbing than the same noise in traffic at 5:00 p.m.

2.2.1.1 Human Response to Changes in Noise Levels

Under controlled conditions in an acoustics laboratory, the trained healthy human ear is able to discern changes in sound levels of 1 dBA when exposed to steady single-frequency (pure tone) signals in the mid-frequency range. Outside such controlled conditions, the trained ear can detect changes of 2 dBA in normal environmental noise. It is generally accepted that the average healthy ear, however, can barely perceive a noise level change of 3 dBA. If changes to the character (i.e., frequency content) of a sound occur, level changes less than 3 dBA may be noticeable. Individuals who are exposed to continuous traffic noise may also be able to notice small changes in noise levels (i.e., less than 3 dBA).

Earlier, the concept of A-weighting and the reasons for describing noise in terms of dBA were discussed. The human response curve of frequencies in the audible range is simply not linear (i.e., humans do not hear all frequencies equally well).

It appears that the human perception of loudness is also not linear, either in terms of decibels or in terms of acoustical energy. As discussed, there is a mathematical relationship between decibels and relative energy. For example, if one source produces a noise level of 70 dBA, two of the same sources produce 73 dBA, three will produce about 75 dBA, and 10 will produce 80 dBA.

Human perception is complicated by the fact that it has no simple correlation with acoustical energy. Two noise sources do not sound twice as loud as one noise source. Based on studies conducted over the years some approximate relationships between changes in acoustical energy and corresponding human reaction have been charted. Table 2-10 shows the relationship between changes in acoustical energy, dBA, and human perception. The table shows the relationship between changes in dBA (ΔdBA), relative energy with respect to a reference of a ΔdBA of 0 (no change), and average human perception. The factor change in relative energy relates to the change in acoustic energy.

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Table 2-10. Relationship between Noise Level Change, Factor Change in Relative Energy, and Perceived Change

Noise Level Change, (dBA)	Change in Relative Energy ($10^{\pm\Delta dBA/10}$)	Perceived Change	
		Perceived Change in Percentage ($[2^{\pm\Delta dBA/10}-1] * 100\%$)	Descriptive Change in Perception
+40	10,000		16 times as loud
+30	1,000		Eight times as loud
+20	100	+300%	Four times as loud
+15	31.6	+183%	
+10	10	+100%	Two times as loud
+9	7.9	+87%	
+8	6.3	+74%	
+7	5.0	+62%	
+6	4.0	+52%	
+5	3.16	+41%	Readily perceptible increase
+4	2.5	+32%	
+3	2.0	+23%	Barely perceptible increase
0	1	0%	Reference (no change)
-3	0.5	-19%	Barely perceptible reduction
-4	0.4	-24%	
-5	0.316	-29%	Readily perceptible reduction
-6	0.25	-34%	
-7	0.20	-38%	
-8	0.16	-43%	
-9	0.13	-46%	
-10	0.10	-50%	One-half as loud
-15	0.0316	-65%	
-20	0.01	-75%	One-quarter as loud
-30	0.001		One-eighth as loud
-40	0.0001		One-sixteenth as loud

Section 2.1.3.3 discusses that the rms value of the sound pressure ratio squared (P_1/P_2) is proportional to the energy content of sound waves (acoustic energy). Human perception is displayed in two columns: percentage and descriptive. The percentage of perceived change is based on the mathematical approximation that the factor change of human perception relates to ΔdBA as follows:

$$\text{Factor Change in Perceived Noise Levels} = 2^{\pm\Delta dBA/10} \quad \textbf{(2-18)}$$

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According to this equation, the average human ear perceives a 10-dBA decrease in noise levels as half of the original level ($2^{\pm\Delta dBA/10} = 2^{-10/10} = 0.5$). By subtracting 1 and multiplying by 100, the result will be in terms of a percentage change in perception, where a positive (+) change represents an increase and a negative (-) change a decrease. The descriptive perception column indicates how the percentage change is typically perceived.

2.2.2 Describing Noise

Noise in our daily environment fluctuates over time. Some fluctuations are minor, and some are substantial. Some occur in regular patterns, and others are random. Some noise levels fluctuate rapidly, and others slowly. Some noise levels vary widely, and others are relatively constant. To describe noise levels, one needs to choose the proper noise descriptor or statistic.

2.2.2.1 Time Patterns

Figure 2-18 is a graphical representation of how noise can have different time patterns depending on the source. Shown are noise levels vs. time patterns of four different sources: a fan (a), pile driver (b), single vehicle passby (c), and highway traffic (d).

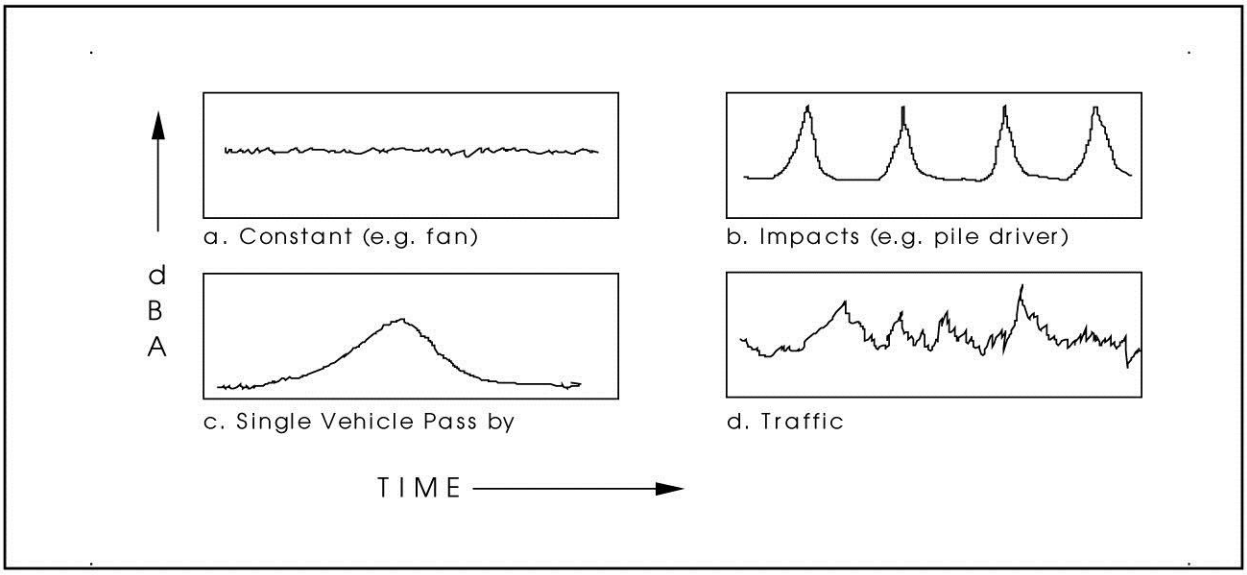

Figure 2-18. Different Noise Level vs. Time Patterns

The simplest noise level time pattern is constant noise, which is essentially a straight, level line. Such a pattern is characteristic of stationary fans,

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compressors, pumps, and air conditioners. At each instant, the noise level is about the same for a fixed observer. A single measurement taken at random would suffice to describe the noise level at a specific distance. The minimum and maximum noise levels would be nearly the same as the average noise level.

Other noise levels vs. time patterns are more complicated. For example, to describe the pile driving noise, noise samples need to include the instantaneous peaks, or maximum noise levels. In our environment, there are a range of noises of many different patterns in addition to the ones shown in Figure 2-18. The levels may be extremely short in duration, such as a single gunshot (transient noise); intermittent, such as the pile driver; or continuous, such as the fan. Traffic noise along major highways tends to lie somewhere between intermittent and continuous. It is characterized by the somewhat random distribution of vehicles, each of which emits a pattern such as shown for a single vehicle passby.

2.2.2.2 Noise Descriptors

The proper noise descriptor to use in any given situation depends on the nature of the noise source. For example a high amplitude short duration event such as gunshot requires a different descriptor than a constant relatively low amplitude noise source such as traffic. The proper descriptor depends on the spatial distribution of noise sources, duration of the noise event, amount of fluctuation, and time patterns.

Dozens of descriptors and scales have been devised over the years to quantify community noise, aircraft flyovers, traffic noise, industrial noise, speech interference, etc. The descriptors shown in Table 2-11 are those encountered most often in traffic, community, and environmental noise. There are many more descriptors not discussed here. The word “Level,” abbreviated *L*, is frequently used whenever sound is expressed in decibels relative to the reference pressure. Therefore, all the descriptors shown in Table 2-11 have *L* as part of the term.

All Caltrans highway traffic noise analysis should be done in terms of worst noise hour $L_{eq}(h)$ as required under 23 CFR 772. If a noise analysis requires other descriptors to satisfy city or county requirements, see Section 2.2.3 for a discussion of descriptor conversions.

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Table 2-11. Common Noise Descriptors

Noise Descriptor	Definition
Maximum noise level (L_{max})	The highest instantaneous noise level during a specified time period. This descriptor is sometimes referred to as "peak (noise) level." The use of term "peak level" should be discouraged because it may be interpreted as a non-rms noise signal (see Section 2.1.3.3 for difference between peak and rms).
Statistical descriptor (L_x)	The noise level exceeded *X* % of a specified time period. The value of *X* is commonly 10 (e.g., L_{10}). Other values such as 50 and 90 are used also.
Equivalent noise level (L_{eq}). Routinely used by Caltrans and FHWA to address the worst noise hour (L_{eq}[h]).	The equivalent steady-state noise level in a stated period of time that would contain the same acoustic energy as the time-varying noise level during the same period
Day-night noise level (L_{dn}). Used commonly for describing community noise levels.	A 24-hour L_{eq} with a "penalty" of 10 dBA added during the night hours (10 p.m. to 7 a.m.) because this time is normally used for sleep
Community noise equivalent level (CNEL). A common community noise descriptor, also used for airport noise.	Same as L_{dn} with an additional penalty of 4.77 dBA (or 10log3), for the hours 7 p.m. to 10 p.m., which are usually reserved for relaxation, television, reading, and conversation
Sound exposure level. Used mainly for aircraft noise, it enables comparing noise created by a loud but fast overflight with that of a quieter but slow overflight.	The acoustical energy during a single noise event, such as an aircraft overflight, compressed into a period of 1 second, expressed in decibels

2.2.2.3 Calculating Noise Descriptors

The following formulae and examples may be used to calculate various noise descriptors from instantaneous noise vs. time data.

Statistical Descriptor

L_x, a statistical descriptor, signifies the noise level that is exceeded *X* % of the time. This descriptor was formerly used in highway noise, before L_{eq}. The most common value of *X* was 10, denoting the level that is exceeded 10% of the time. Therefore, the L_{10} descriptor is used as an example to represent the L_x family of calculations. The following instantaneous noise samples (Table 2-12) shown as a frequency distribution (dBA vs. number of occurrences) serve to illustrate the L_{10} calculation.

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Fifty samples were taken at 10-second intervals. To determine L_{10}, identify the five highest values (10% of 50) and then count down five values from the top. The "boundary" of the top 10% is 76 dBA. Therefore, L_{10} lies at 76 dBA. L_{50} would be at 66 dBA (25 occurrences from the top).

Table 2-12. Noise Samples for L_{10} Calculation

Noise Level (dBA)	Occurrences (Sampling Interval of 10 Seconds) (Each *X* Is One Occurrence)							Total Occurrences
80								0
79								0
78	X							1
77	X							1
76	X	X	X					3
75	X	X						2
74	X	X						2
73	X	X						2
72								0
71	X	X	X					3
70	X							1
69	X	X						2
68	X	X	X	X	X			5
67	X	X						2
66	X	X	X	X				4
65	X	X	X	X	X	X	X	7
64	X	X	X	X	X			5
63	X	X	X					3
62	X	X	X					3
61	X	X						2
60	X	X						2
Total samples								**50**

Equivalent Noise Level

L_{eq} is an energy average noise level. L_{eq} is also called an energy-mean noise level. The instant noise levels over a certain time period are energy-averaged by first converting all dBA values to relative energy values. Next, these values are added and the total divided by the number of values. The result is average (relative) energy. The final step is to convert the average energy value back to a decibel level. Equation 2-12 showed the method of adding the energy values. This equation can be expanded to yield L_{eq}:

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$$L_{eq} = 10\log_{10}[(10^{SPL_1/10} + 10^{SPL_2/10} + \ldots 10^{SPL_n/10})/N] \quad \textbf{(2-19)}$$

Where:

SPL_1, SPL_2, SPL_n = first, second, and *n*th noise level

N = number of noise level samples

Example

Calculate L_{eq} of the following noise instantaneous samples, taken at 10-second intervals:

- 10:00:10: 60 dBA
- 10:00:20: 64 dBA
- 10:00:30: 66 dBA
- 10:00:40: 63 dBA
- 10:00:50: 62 dBA
- 10:01:00: 65 dBA

Using Equation 2-19:

$L_{eq} = 10\log_{10}[(10^{60/10}+10^{64/10}+10^{66/10}+10^{63/10}+10^{62/10}+10^{65/10})/6] =$
$10\log_{10}(14235391.3/6) = 63.8$ dBA

Usually, longer time periods are preferred. Using the sampling data in Table 2-12, the following equation can be used to add the dBA levels for each set of equal noise levels:

$$SPL_{Total} = SPL_1 + 10\log_{10}(N) \quad \textbf{(2-20)}$$

Where:

SPL_1 = SPL of one source

N = number of identical noise levels to be added (in this case, number of occurrences of each noise level)

Next, the following equation can be used to add the subtotals:

$$SPL_{Total} = 10\log_{10}(10^{SPL_1/10} + 10^{SPL_2/10} + \ldots 10^{SPL_n/10}) \quad \textbf{(2-21)}$$

Finally, this amount must be energy-averaged to compute L_{eq}. This may be accomplished using the following equation:

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$$L_{eq} = 10\log_{10}(10^{SPL_{Total}/10}/N) \quad \textbf{(2-22)}$$

Where:
N = total number of samples (in this case, 50)

The calculation procedures are shown in Table 2-13.

Table 2-13. Noise Samples for L_{eq} Calculation

Noise Level (dBA)	Occurrences (N) (from Table 2-12)	Total Noise Levels [dBA + $10\log_{10}(N)$]
80	0	
79	0	
78	1	78
77	1	77
76	3	80.8
75	2	78
74	2	77
73	2	76
72	0	
71	3	75.8
70	1	70
69	2	72
68	5	75
67	2	70
66	4	72
65	7	73.5
64	5	71
63	3	67.8
62	3	66.8
61	2	64
60	2	63
Total	**50**	**87.5**
$L_{eq} = 10\log_{10}[(10^{8.75})/50] = 70.5$ dBA		

Day-Night Noise Level

L_{dn} is actually a 24-hour L_{eq}, or the energy-averaged result of 24 1-hour L_{eq}s, except that the nighttime hours (10 p.m. to 6 a.m.) are assessed a 10-dBA penalty. This penalty attempts to account for the fact that nighttime noise levels are potentially more disturbing than equal daytime noise levels. Mathematically, L_{dn} is expressed as follows:

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$$L_{dn} = 10\log_{10}\left[\left(\frac{1}{24}\right)\sum_{i=1}^{24} 10^{L_{eq}(h)_i + W_i/10}\right] \quad \textbf{(2-23)}$$

Where:

$W_i = 0$ for day hours (7 a.m. to 10 p.m.)

$W_i = 10$ for night hours (10 p.m. to 7 a.m.)

$L_{eq}(h)_i = L_{eq}$ for *i*th hour

To calculate L_{dn} accurately, one must have 24 successive hourly L_{eq} values, representing one typical day. The hourly values between 10 p.m. and 7 a.m. (nine hourly values) must first be weighted by adding 10 dBA. An example is shown in Table 2-14.

The energy average calculated from the nine weighted and 15 unweighted hourly L_{eq} values is the L_{dn}. Once the hourly data is properly weighted, the L_{dn} can be calculated as an L_{eq} (in this case, a weighted 24-hour L_{eq}). Equation 2-19 can be used with the weighted data. The resulting L_{dn} is 65 dBA.

Table 2-14. Noise Samples for L_{dn} Calculations

Begin Hour	$L_{eq}(h)$ (dBA)	Weight (dBA)	Weighted Noise (dBA)
Midnight	54	+10	64
1 a.m.	52	+10	62
2 a.m.	52	+10	62
3 a.m.	50	+10	60
4 a.m.	53	+10	63
5 a.m.	57	+10	67
6 a.m.	62	+10	72
7 a.m.	65	0	65
8 a.m.	63	0	63
9 a.m.	64	0	64
10 a.m.	66	0	66
11 a.m.	66	0	66
Noon	65	0	65
1 p.m.	65	0	65
2 p.m.	63	0	63
3 p.m.	65	0	65
4 p.m.	65	0	65
5 p.m.	63	0	63
6 p.m.	64	0	64
7 p.m.	62	0	62
8 p.m.	60	0	60

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Begin Hour	$L_{eq}(h)$ (dBA)	Weight (dBA)	Weighted Noise (dBA)
9 p.m.	58	0	58
10 p.m.	57	+10	67
11 p.m.	55	+10	65

Community Noise Equivalent Level

CNEL is the same as L_{dn} except for an additional weighting of almost 5 dBA for the evening hours between 7 p.m. and 10 p.m. The equation is essentially the same as Equation 2-23, with an additional definition of $W_i = 10\log_{10}(3)$, which is 4.77. Calculations for CNEL are similar to L_{dn}. The result is normally about 0.5 dBA higher than L_{dn} using the same 24-hour data. The equation for the CNEL is as follows:

$$\text{CNEL} = 10\log_{10}\left[\left(\frac{1}{24}\right)\sum_{i=1}^{24} 10^{L_{eq}(h)_i + W_i/100}\right] \quad \textbf{(2-24)}$$

Where:

$W_i = 0$ for day hours (7 a.m. to 7 p.m.)

$W_i = 10\log_{10}(3) = 4.77$ for evening hours (7 p.m. to 10 p.m.)

$W_i = 10$ for night hours (10 p.m. to 7 a.m.)

$L_{eq}(h)_i = L_{eq}$ for the *i*th hour

The 24-hour data used in the L_{dn} example yields a CNEL of 65.4 dBA, compared with an L_{dn} of 65.0 dBA.

Sound Exposure Level

The sound exposure level (SEL) is useful in comparing the acoustical energy of different events involving different source characteristics. For example, the overflight of a slow propeller-driven plane may not be as loud as a jet aircraft. However, the duration of the noise is longer than the duration of the noise from the jet aircraft overflight. SEL makes a noise comparison of both events possible because it combines the effects of time and level. For example, the L_{eq} of a steady noise level will remain unchanged over time. It will be the same whether calculated for a time period of 1 second or 1,000 seconds. The SEL of a steady noise level, however, will keep increasing because all the acoustical energy within a given time period is included in the reference time period of 1 second. Because both values are energy-weighted, they are directly related to each other by time, as shown in the following equations:

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$$SEL = L_{eq}(T) + 10\log_{10}(T) \quad \textbf{(2-25)}$$

$$L_{eq}(T) = SEL + 10\log_{10}(1/T) = SEL - 10\log_{10}(T) \quad \textbf{(2-26)}$$

Where:

T = duration of noise level in seconds

Example

L_{eq} of a 65-second aircraft overflight is 70 dBA. What is the SEL?

$SEL = L_{eq}(65) + 10\log_{10}(65) = 70 + 18.1 = 88.1$ dBA

A time period of 1 hour (T = 3,600 seconds) is commonly used for the L_{eq} descriptor when it is applied to criteria in policies and standards. The SEL value accumulated over the 1-hour period can be converted to $L_{eq}(h)$ as follows. $L_{eq}(h) = SEL - 10\log_{10}(3{,}600)$, or $88.1 - 35.6 = 52.5$ dBA for the example above. Because a conversion from SEL to $L_{eq}(h)$ always involves subtraction of the constant 35.6 and the following relationships between SEL and $L_{eq}(h)$ always hold true:

$$L_{eq}(h) = SEL - 35.6 \quad \textbf{(2-27)}$$

$$SEL = L_{eq}(h) + 35.6 \quad \textbf{(2-28)}$$

These relationships have many practical applications when one is adding a mixture of SELs and $L_{eq}(h)$s. For example, one wants to calculate the existing worst hour noise level in $L_{eq}(h)$ at a receiver A from the following data.

- Highway noise = 63 dBA, $L_{eq}(h)$
- Two train passbys with SELs of 89 dBA each
- Five aircraft overflights averaging SELs of 93 dBA each

First, all SELs are added:

$$\text{Total SEL} = 10\log_{10}[2(10^{89/10}) + 5(10^{93/10})] = 100.6 \text{ dBA}$$

Next, the SEL is expanded to 1 hour using Equation 2-28:

$$L_{eq}(h) = 100.6 - 35.6 = 65 \text{ dBA}$$

Finally, the $L_{eq}(h)$ of the highway is added:

$$\text{Worst hour noise level at receiver A} = 10\log_{10}(10^{63/10} + 10^{65/10}) = 67.1 \text{ dBA}$$

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2.2.3 Conversion between Noise Descriptors

Although Caltrans exclusively uses L_{eq}, there are times that comparisons need to be made with local noise standards, most of which are in terms of L_{dn} or CNEL. If 24-hour traffic and noise data are available, these descriptors can be calculated accurately. However, this information is often not available. The methodologies in this section allow a reasonably accurate conversion of the worst hourly noise level to L_{dn} or CNEL (and vice versa).

Before these conversions are discussed, it should be noted that although these conversions are reasonably accurate, they are only approximate for various reasons. First is the assumption that 24 hourly traffic mixes remain constant and that traffic speeds do not change. Second, the method assumes that the peak hour traffic coincides with the worst-hour L_{eq}, which is often not true. Nevertheless, the methods of conversion discussed may be used if only average daily traffic (ADT) volumes are known and a reasonable estimate can be made of the percentage of peak hour traffic volume of the ADT. Another requirement is a reasonable estimate of the day and night traffic volume split for L_{dn} and day, evening, and night split for CNEL.

The previous section discussed that L_{dn} is defined as an energy-averaged 24-hour L_{eq} with a nighttime penalty of 10 dBA assessed to noise levels between 10 p.m. and 7 a.m. If traffic volumes, speeds, and mixes were to remain constant throughout the entire 24 hours and there were no nighttime penalty, there would be no peak hour and each hourly L_{eq} would equal the 24-hour L_{eq}. Hourly traffic volumes would then be 100/24, or 4.17% of ADT. Peak hour corrections would not be necessary in this case. (Let this be the reference condition.)

To convert peak hour L_{eq} to L_{dn}, at least two corrections must be made to the reference condition. First, one must make a correction for peak hour traffic volumes expressed as a percentage of ADT. Second, one must make a correction for the nighttime penalty of 10 dBA. For CNELs, a third correction needs to be made for the evening hour penalty. For this one must know what fractions of the ADT occur during the day and at night. Depending on the accuracy desired and information available, other corrections can be made for different day/night traffic mixes and speeds; these are not discussed in this section.

The first correction for peak hour can be expressed as:

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$$10\log_{10}\frac{4.17}{P}$$

Where:

P = peak hour volume as percent of ADT

The second correction for nighttime penalty of 10 dBA is:

$$10\log_{10}(D + 10N)$$

Where:

D = day fraction of ADT

N = night fraction of ADT

D + N = 1

The following equations are used to convert from peak hour L_{eq} to L_{dn}, and vice versa, respectively:

$$L_{dn} = L_{eq}(h)_{pk} + 10\log_{10}\frac{4.17}{P} + 10\log_{10}(D + 10N) \quad \textbf{(2-29)}$$

$$L_{eq}(h)_{pk} = L_{dn} - 10\log_{10}\frac{4.17}{P} - 10\log_{10}(D + 10N) \quad \textbf{(2-30)}$$

Where:

$L_{eq}(h)_{pk}$ = peak hour L_{eq}

P = peak hour volume % of ADT

D = daytime fraction of ADT

N = nighttime fraction of ADT

D + N = 1

Example

Peak hour L_{eq} at a receiver near a freeway is 65.0 dBA. Peak hour traffic is 10% of ADT. Daytime traffic volume is 85% of ADT, and nighttime traffic volume is 15% of ADT. Assume that the day and nighttime heavy truck percentages are equal and traffic speeds do not vary significantly. What is the estimated L_{dn} at the receiver?

$$L_{dn} = 65.0 + 10\log_{10}\frac{4.17}{10} + 10\log_{10}(0.85 + 1.50) = 65.0 + (-3.8) + 3.70 = 64.9 \text{ dBA}$$

Please note that in this example, which is a fairly typical case, L_{dn} is approximately equal to $L_{eq}(h)_{pk}$. The general rule is that L_{dn} is within about 2 dBA of $L_{eq}(h)_{pk}$ under normal traffic conditions.

The following equations are used to convert from peak hour L_{eq} to CNEL, and L_{dn} to peak hour L_{eq}, respectively:

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$$CNEL = L_{eq}(h)_{pk} + 10\log_{10}\frac{4.17}{P} + 10\log_{10}(d + 4.77e + 10N) \quad \textbf{(2-31)}$$

$$L_{eq}(h)_{pk} = CNEL - 10\log_{10}\frac{4.17}{P} - 10\log_{10}(d + 4.77e + 10N) \quad \textbf{(2-32)}$$

Where:

The variables *d* and *e* are further divisions of *D* shown in L_{dn} to account for day and evening hours. Please note that $d + e = D$ (shown in Equations 2-31 and 2-32). The factor 4.77 comes from $10\log_{10}(3)$, which is the designated penalty for evening hours in the definition of CNEL. Although an evening hour penalty of 5 dBA is often used to calculate CNEL, the correct value is $10\log_{10}(3)$. The difference between using 4.77 and 5 is usually negligible.

Example

Using the data for the previous L_{dn} example and adding a further division of *D* into $d = 0.80$ and $e = 0.05$, the CNEL result using Equation 2-31 is 65.2 dBA, 0.3 dBA more than L_{dn}.

From Equations 2-31 and 2-32, the following equations can be derived in terms of CNEL and L_{dn}:

$$CNEL = L_{dn} + [10\log_{10}(d + 4.77e + 10N) - 10\log_{10}(d + e + 10N)] \quad \textbf{(2-33)}$$

$$L_{dn} = CNEL - [10\log_{10}(d + 4.77e + 10N) - 10\log_{10}(d + e + 10N)] \quad \textbf{(2-34)}$$

Example

Using the same example for which L_{dn} was 64.9 dBA, the CNEL in Equation 2-33 yields 65.2 dBA. Please note that CNEL is always larger than L_{dn}.

The values in Table 2-15 can also be used in Equations 2-29 and 2-30. Please notice that the peak hour percentage term of the equation always yields a negative value, while the weighted day/night split always yields a positive value. The difference between the two is the difference between $L_{eq}(h)_{pk}$ and L_{dn}.

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Table 2-15. L_{eq}/L_{dn} Conversion Factors

Peak Hour, %	$10\log_{10}(4.17/P)$	Day	Night	$10\log_{10}(D+10N)$
5	-0.8	0.98	0.02	+0.7
6	-1.6	0.95	0.05	+1.6
7	-2.3	0.93	0.07	+2.1
8	-2.8	0.90	0.10	+2.8
9	-3.3	0.88	0.12	+3.2
10	-3.8	0.85	0.15	+3.7
11	-4.2	0.83	0.17	+4.0
12	-4.6	0.80	0.20	+4.5
13	-4.9	0.78	0.22	+4.7
14	-5.3	0.75	0.25	+5.1
15	-5.6	0.73	0.27	+5.4
17	-6.1	0.70	0.30	+5.7
20	-6.8	0.68	0.32	+5.9
		0.65	0.35	+6.2
		0.63	0.37	+6.4
		0.60	0.40	+6.6

Figure 2-19 illustrates the difference between $L_{eq}(h)_{pk}$ and L_{dn}. For example, if P is 10% and $D/N = 0.85/0.15$, $L_{dn} \approx L_{eq}(h)$.

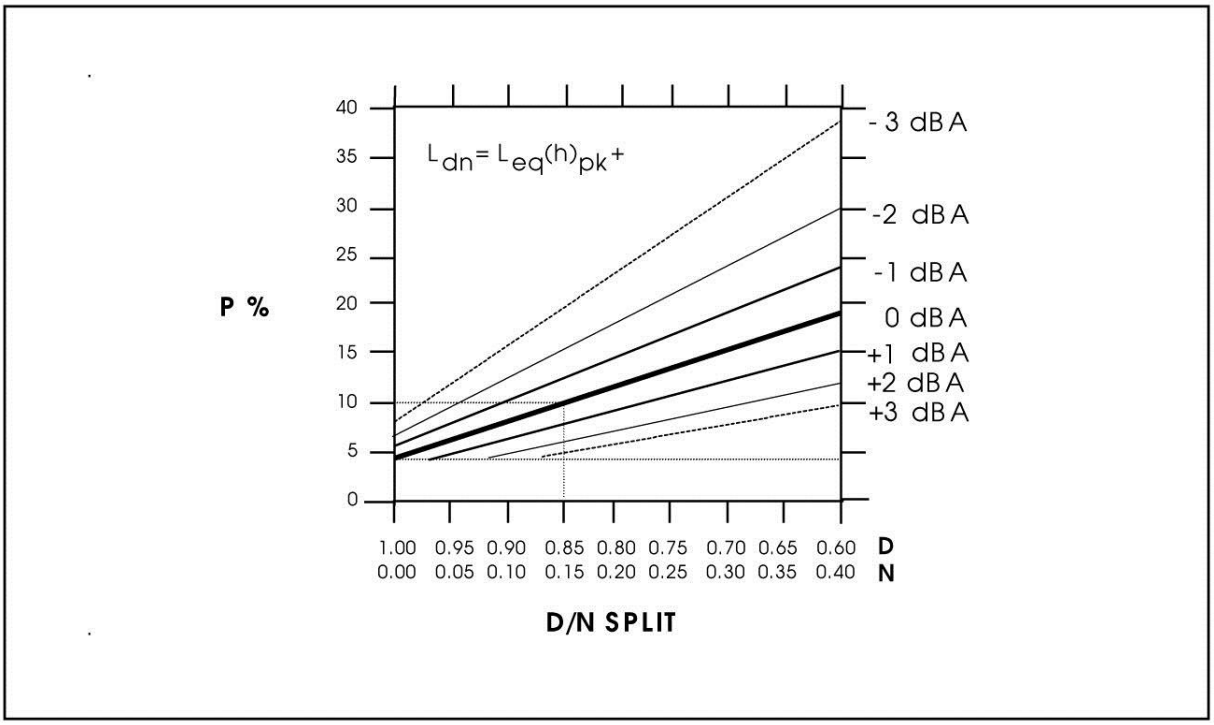

Figure 2-19. Relationship between L_{dn} and $L_{eq}(h)_{pk}$

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If CNEL is desired, the L_{dn} to CNEL corrections (Δ) in Table 2-16 may be used. Please note that this table is only calculated for a common day/night volume spilt of 0.85/0.15. Because of the many possible combinations, other tables are not shown. For other D/N splits, use Equation 2-31 or 2-32 to calculate CNEL. This table is intended to be used when only an L_{dn} is given and CNEL is desired.

Table 2-16. L_{dn}/CNEL Corrections (Δ) (Must Be Added to L_{dn} to Obtain CNEL)

D = 0.85		Δ
D	E	(CNEL = L_{dn} + Δ)
0.80	0.05	0.3
0.79	0.06	0.4
0.78	0.07	0.5
0.77	0.08	0.5
0.76	0.09	0.6
0.75	0.10	0.7
0.74	0.11	0.7
0.73	0.12	0.8
0.72	0.13	0.8
0.71	0.14	0.9
0.70	0.15	0.9

D = percentage of traffic in hours 7:00 a.m. to 10:00 p.m.
E = percentage of traffic in hours 7:00 p.m. to 10:00 p.m.
d = percentage of traffic in hours 7:00 a.m. to 7:00 p.m.
D = d + E.

The values shown assume a fixed nighttime fractional traffic contribution of 0.15 (D/N split of 0.85/0.15 for L_{dn}). The remaining daytime traffic contribution of 0.85 is further subdivided into day (*d*) and evening (*E*) hours. In each instance, *d* + E = 0.85.

2.2.4 Negative Effects on Humans

The most obvious negative effects of noise are physical damage to hearing. Other obvious effects are the interference of noise with certain activities, such as sleeping and conversation. Less obvious are the stress effects of noise. A brief discussion of each of the topics follows.

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2.2.4.1 Hearing Damage

A person exposed to high noise levels can suffer hearing damage, either gradual or traumatic. These are described as follows.

- **Gradual:** Sustained exposure to moderately high noise levels over a period of time can cause gradual hearing loss. It starts out as a temporary hearing loss, such as immediately after a loud rock concert. The hearing usually restores itself within a few hours after exposure, although not quite to its pre-exposure level. This is also called a temporary threshold shift. Although the permanent deterioration may be negligible, it will become significant after many repetitions of the exposure. At that time, it is considered permanent hearing damage. The primary cause of permanent hearing damage is daily exposure to industrial noise. Transportation noise levels experienced by communities and the general public are normally not high enough to produce hearing damage.
- **Traumatic:** Short, sudden exposure to an extremely high noise level, such as a gunshot or explosion at very close range, can cause a traumatic hearing loss, which is very sudden and can be permanent.

Hearing damage is preventable by reducing the exposure to loud noise. This can be done by quieting the source, shielding the receiver with a barrier, or having the receiver wear proper ear protection. Occupational exposure to noise is controlled at the Federal Level by OSHA and at the state level by the state level by the California Division of Safety and Health. The maximum allowable noise exposure over an 8 hours period is a level of 90 dBA. For each halving of the exposure time, the maximum noise level is allowed to increase 5 dBA. Therefore, the maximum allowable noise exposure (100%) is 90 dBA for 8 hours, 95 dBA for 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 30 minutes, and 115 dBA for 15 minutes. Dosimeters, worn by workers in noisy environments, can measure noise during the workday in percentages of the maximum daily exposure.

2.2.4.2 Interference with Activities

Activities most affected by noise include rest, relaxation, recreation, study, and communications. Although most interruptions by noise can be considered annoying, some may be considered dangerous, such as the inability to hear warning signals or verbal warnings in noisy industrial situations or situations involving workers next to a noisy freeway. Figure 2-20 gives an estimate of the speech communication that is possible at various noise levels and distances.

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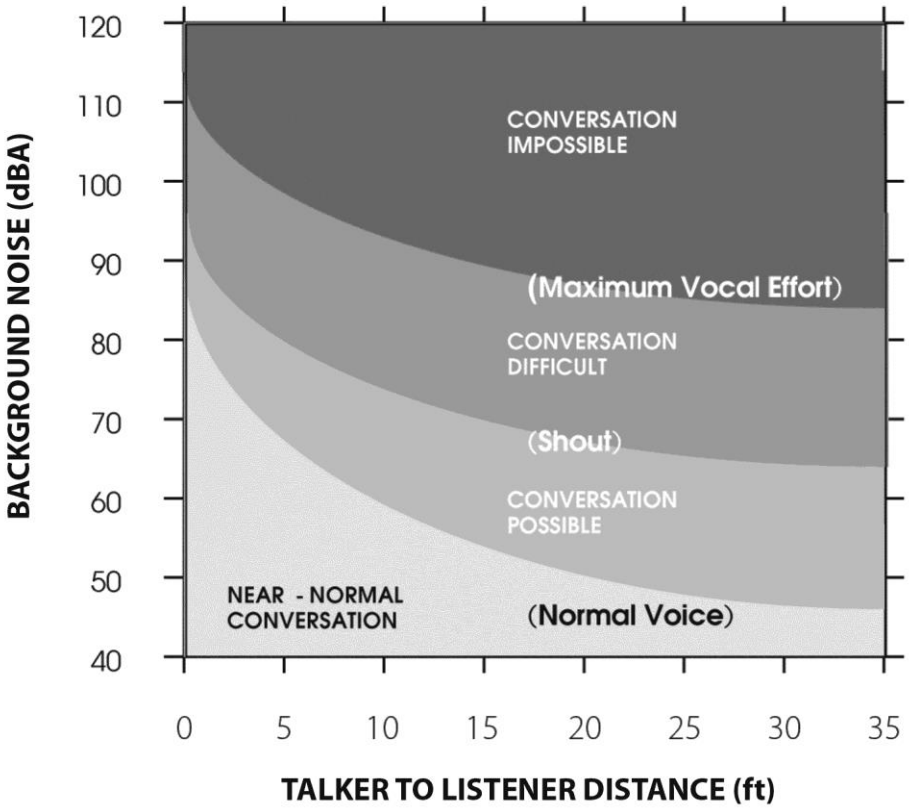

Figure 2-20. Interference of Conversation from Background Noise

For example, if the talker-to-listener distance is about 20 feet, normal conversation can be conducted with the background level at about 50 dBA. If the background level is increased to 60 dBA, the talker must either raise his or her voice or decrease the distance to the listener to about 10 feet.

2.2.4.3 Stress-Related Diseases

There is ample evidence that noise can cause stress in humans and may be responsible for a host of stress-related diseases, such as hypertension, anxiety, and heart disease. Although noise is probably not the sole culprit in these diseases, it can be a contributor. The degree to which noise contributes to stress-related diseases depends on noise frequencies, their

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bandwidths, noise levels, and time patterns. In general, higher frequencies, pure tones, and fluctuating noise levels tend to be more stressful than lower frequencies, broadband, and constant-level noise.

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Section 3

Measurements and Instrumentation

Noise measurements play an important role in noise analysis and acoustical design of noise attenuation for transportation projects. This section addresses recommendations on why, where, when, and how noise measurements should be taken. A brief discussion on available instrumentation is also included. Because of the variety of sound instrumentation, coverage of equipment setup and operational procedures is discussed only at a general level. For additional detail, manufacturers' manuals should be consulted.

The noise analyst should be aware of both the importance and limitations of noise measurements. As with all field work, quality noise measurements are relatively expensive, requiring time, personnel, and equipment. Therefore, the noise analyst should carefully plan the location, time, duration, and number of repetitions of noise measurements before actually taking the measurements. Efforts should be made during the measurements to document location, traffic levels, weather, and other pertinent factors discussed in this section.

The contents of this section represent Caltrans measurement procedures and are consistent with methods described in FHWA's *Measurement of Highway-Related Noise* (1996a).

3.1 Purposes of Noise Measurements

There are five major purposes for measuring transportation noise.

- Determine existing ambient and background noise levels.
- Calibrate noise prediction models.
- Monitor construction noise levels for compliance with standard specifications, special provisions, and local ordinances.
- Evaluate the effectiveness of abatement measures such as noise barriers.
- Perform special studies and research.

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Ambient and background noise and model calibration measurements are routinely performed by the Caltrans districts. Construction noise monitoring is also conducted frequently by the districts. Some districts conduct before-and-after noise abatement measurements. Special studies and noise research measurements are done rarely by the districts and are often contracted to consultants with Caltrans oversight.

Where, when, and how noise measurements are performed depends on the purpose of the measurements. The following sections discuss the reasons for the measurements, what they include, and how the results are typically used.

3.1.1 Ambient and Background Noise Levels

Ambient noise levels are all-encompassing noise levels at a given place and time, usually a composite of sounds from all sources near and far, including specific noise sources of interest. Typically, ambient noise levels include highway and community noise levels. Ambient noise levels are measured for the following reasons.

- To assess highway traffic noise impacts for new highway construction or reconstruction projects. Existing ambient noise levels provide a baseline for comparison to predicted future noise levels. The measurements are also used to describe the current noise environment in the area of the proposed project. This information is reported in appropriate environmental documents. Generally, the noise resulting from natural and mechanical sources and human activity considered usually to be present should be included in the measurements.
- To investigate citizens' traffic or construction noise complaints. Noise measurements are usually reported via memorandum to the interested party, with recommendations for further actions or reasons that further actions are not justified.

Background noise is considered to be the total noise in a specific region without the presence of noise sources of interest. Typically, this would be the noise generated within the community without the highway and is usually measured at acoustically representative locations away from the highway where highway noise does not contribute to the total noise level. Background noise levels are routinely measured to determine the feasibility of noise abatement and to ensure that noise reduction goals can be achieved. Noise abatement cannot reduce noise levels below background levels. Section 5.1.6 discusses the importance of background noise levels.

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Depending on the situation, noise sources measured may typically include highway traffic, community activity, surface street traffic, trains, and sometimes airplanes (when project is near an airport).

3.1.2 Model Validation/Calibration

Noise measurements near highways or other transportation corridors are routinely used to validate and, if necessary, calibrate the project-specific TNM model by comparing calculated noise levels with actual (measured) noise levels. The calculated levels are modeled results obtained from traffic counts and other parameters recorded during the noise measurements. The difference between calculated and measured noise levels may then be applied to calculated future noise levels, assuming site conditions will not change significantly, or modeled existing noise levels (see Sections 4.3.3 and 4.4). Model calibration can only be performed on projects involving reconstruction of existing highways.

3.1.3 Construction Noise Levels

Construction noise measurements are frequently conducted by districts to check the contractor's compliance with the standard specifications, special provisions, and local ordinances.

3.1.4 Performance of Abatement Measures

Before-and-after abatement measurements can be used to evaluate the performance of noise barriers, building insulation, or other abatement options. The measurements provide a check on the design and construction procedures of the abatement. Although these measurements are occasionally performed by some districts, they are not part of a routine program.

3.1.5 Special Studies and Research

These measurements are usually done by Caltrans headquarters staff and consultants. They may involve district assistance and generally involve noise research projects. Setups are usually complex and include substantial equipment and personnel positioned at many locations for simultaneous noise measurement. The studies generally require more sophisticated equipment and setups than routine noise studies.

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3.2 Measurement Locations

The selection of measurement locations requires considerable planning and foresight by the noise analyst. A fine balance must be achieved between sufficient quality locations and the cost in person hours. Good engineering judgment must be exercised in site selection; experience makes this task easier.

Many tools are available in the search for quality noise measurement sites. Preliminary design maps, cross sections, aerial photographs, and field survey data are all helpful sources of information. However, noise measurement sites should only be selected after a thorough field review of the project area.

3.2.1 General Site Recommendations

Some general site requirements common to all outside noise measurement sites are listed below (more detailed considerations are discussed in Section 3.2.2).

- Sites must be clear of major obstructions between the source and receiver unless these are representative of the area of interest. Small reflecting surfaces should be more than 10 feet from the microphone positions. Large reflecting surfaces should be avoided unless they are the subject of study.
- Sites must be free of noise contamination by sources other than sources of interest. Avoid sites located near sources such as barking dogs, lawnmowers, pool pumps, and air conditioners unless it is the express intent of the analyst to measure these sources.
- Sites must be acoustically representative of areas and conditions of interest. They must either be located at or represent locations of human use.
- Sites must not be exposed to prevailing meteorological conditions that are beyond the constraints discussed in this section. For example, in areas with prevailing high wind speeds, sites in open fields should be avoided.

3.2.2 Measurement Site Selection

For the purpose of this document, a distinction will be made between receivers and noise measurement sites. Receivers are all locations or sites of interest in the noise study area. Noise measurement sites are locations

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where noise levels are measured. Unless an extremely rare situation exists in which a noise measurement site is used for a specialized purpose, all noise measurement sites may be considered receivers. However, not all receivers are noise measurement sites. Additional information on receivers and noise measurement sites can be found in Section 4.3.

For describing existing noise levels at selected receivers, measured noise levels are normally preferred. Restricted access or adverse site conditions may force the selection of noise measurement sites at locations that are physically different from but acoustically equivalent to the intended receivers. In some cases, measurements are not feasible. In such cases, the existing noise levels must be modeled. This can only be accomplished along an existing facility, where traffic data can be collected.

In general, there will be more modeled receivers than noise measurement sites. It is far less expensive to take noise measurements at selected, representative receivers and then model the results for the remaining receivers. Nevertheless, there needs to be an adequate overlap of measurement sites and modeled receivers for model calibration and verification.

Factors that should be considered when selecting noise measurement sites are described in the next three sections.

3.2.2.1 Site Selection by Purpose of Measurement

Noise measurement sites should be selected according to the purpose of the measurement. For example, if the objective is to determine noise impacts of a highway project, sites should be selected in areas that will be exposed to the highest noise levels generated by the highway after completion of the project. The sites should also represent areas of human use. Conversely, if the objective is to measure background community noise levels, the sites should be located in areas that represent the community without influence from the highway. These measurements are often necessary for acoustical noise barrier design and to document pre-project noise levels at distant receivers. Past controversies concerning reported increases in noise levels at distant receivers attributed to noise barriers could have been readily resolved if sufficient background noise measurements had been obtained prior to the project being built. (Refer to Section 3.1.1 for more information on background noise levels).

Classroom noise measurements (Street and Highways Code Section 216) or receivers lacking outside human use require both inside and outside noise measurements in rooms with worst noise exposures from the highway. Measurements should generally be made at a point in a room,

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hall, or auditorium where people would be affected by infiltrating noise from the sources of interest. These points are typically desks, chairs, or beds near windows. Several sensitive points may need to be tested, and the results averaged. No measurements should be made within 3 to 4 feet of a wall. It is also important to take measurements in the room in its typical furnished condition. If windows are normally open, measurements should be taken with windows open and closed. Devices such as fans, ventilation, clocks, appliances, and telephones should be turned off. People should vacate the room or be extremely quiet.

Model calibration measurements usually require sites to be near the highway, preferably at receivers or acoustical equivalents to the receivers (see Section 4.4 for additional details). Sites for construction noise monitoring are dictated by standard specifications, special provisions, and local ordinances, which detail maximum allowable noise levels at a reference distance (e.g., L_{max} of 86 dBA at 50 feet) and other requirements.

Before-and-after measurements for evaluations of noise barriers and other abatement options, as well as measurements for special studies or research, are non-routine and require a detailed experimental design. Coordination with Caltrans Headquarters staff is advisable.

3.2.2.2 Site Selection by Acoustical Equivalence

Noise measurement sites should be representative of the areas of interest. Representativeness in this case means *acoustical equivalence*. The concept of acoustical equivalence incorporates equivalences in noise sources, distances from these sources, topography, and other pertinent parameters.

The area under study may need to be divided into sub-areas in which acoustical equivalence can generally be maintained. Sub-area boundaries must be estimated by one or more of the previously mentioned acoustical parameters. Also, in cases where measurements are being taken for more than one purpose, separate sub-areas may be defined by each purpose. The areas of interest may vary in size. For example, noise abatement for a school may cover only the school itself, while a noise study for a large freeway project may range from a large area to many sub-areas.

The number of measurement sites selected within each area or sub-area under study depends on the area's size, number of receivers, and remaining variations in acoustical parameters. If sub-areas are carefully selected, the number of measurement sites can be minimized. The minimum number of sites recommended for each area or sub-area is two.

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Figure 3-1 shows an example of receiver and noise measurement site selections for an at-grade freeway widening and noise barrier project. Alternate noise measurement sites to be used if the selected receivers are not accessible or otherwise not suitable for noise measurement locations are shown also. Only sites near the freeway are shown. Background noise measurement sites would typically be off the map, farther from the freeway. Actual site selection would depend on field reviews and more information not shown on the map.

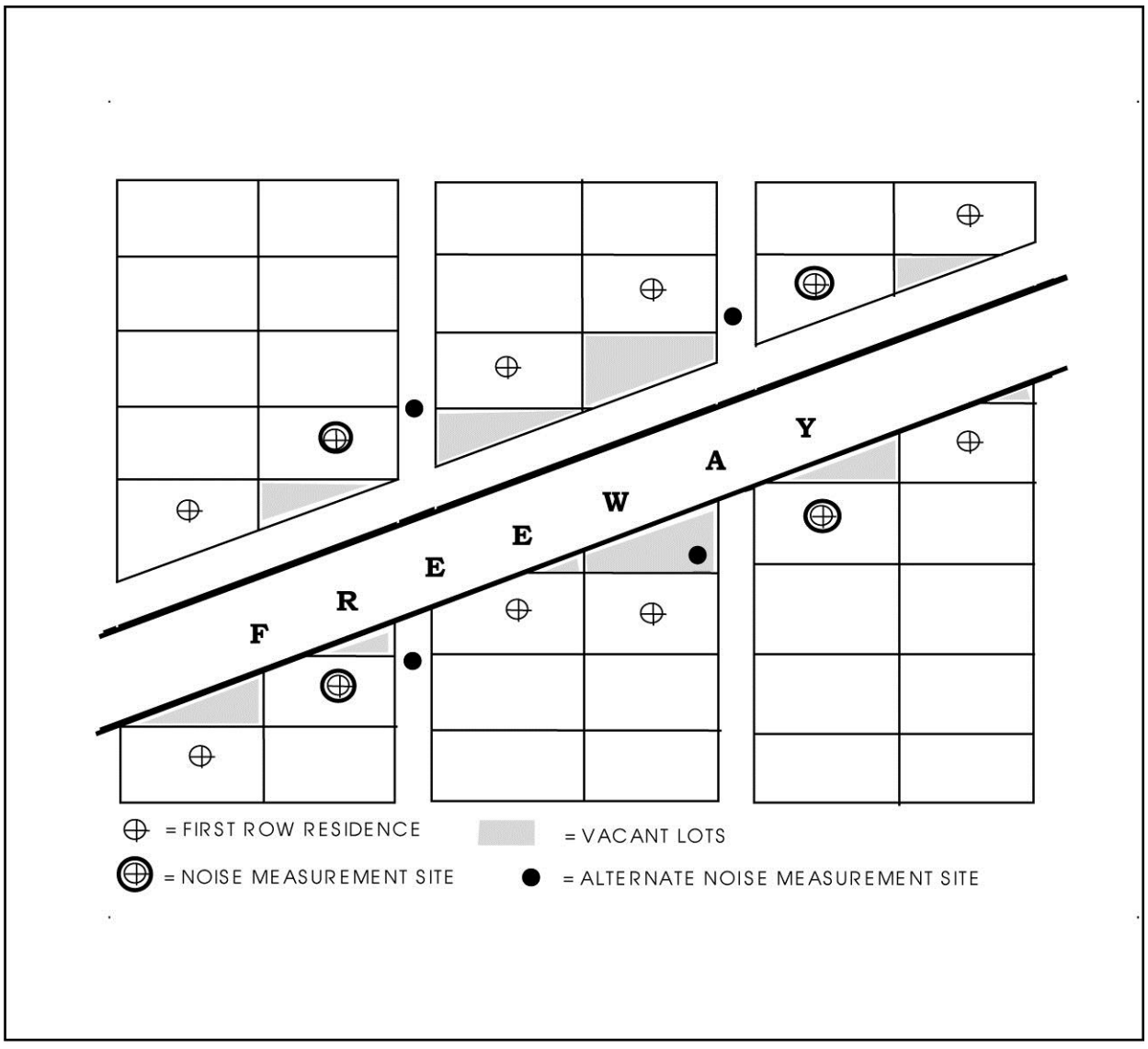

Figure 3-1. Typical Measurement Site Locations

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3.2.2.3 Site Selection by Geometry

In addition to being an important consideration in determining acoustical equivalence, topography (site geometry) plays an important role in determining locations of worst exposure to highway noise. Receivers located farther from a highway may be exposed to higher noise levels, depending on the geometry of a site. One typical example is a highway on a high embankment, where the first-tier receivers may be partially shielded by the top of the fill. Unshielded second- or third-tier receivers may then be exposed to higher noise levels even though they are farther from the source. This concept is shown in Figure 3-2. Another common situation involves a receiver close to the source, shielded by the top of a highway embankment, and an unshielded receiver farther from the source. The attenuation provided by the embankment is often more than the distance effect, resulting in higher noise levels at the farther receiver.

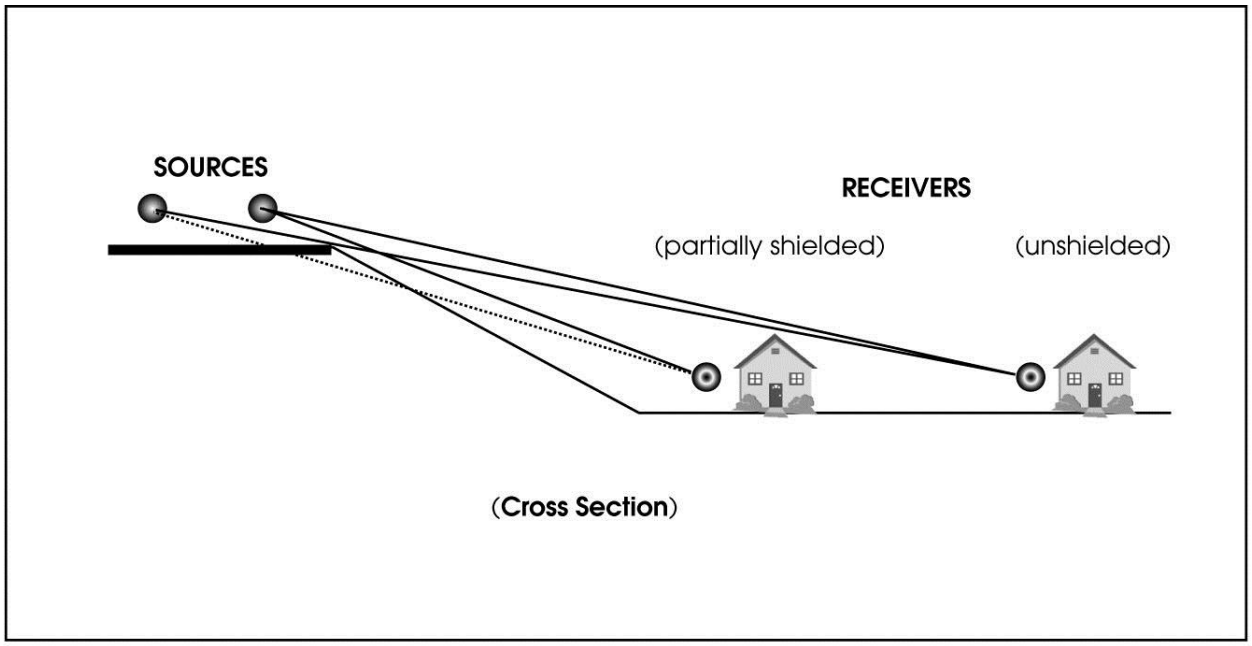

Figure 3-2. Typical Noise Measurement Site Locations

Figure 3-3 illustrates another example of the effects of site geometry on the selection of highest noise exposure. The unshielded Receiver 1 shows a higher noise level than Receiver 2 even though the latter is closer to the freeway. Other examples can be generated in which the nature of terrain and natural or artificial obstructions cause noise levels at receivers closer to the source to be lower than those farther away. This concept is an important consideration in impact analysis, where interest usually focuses on the noisiest locations.

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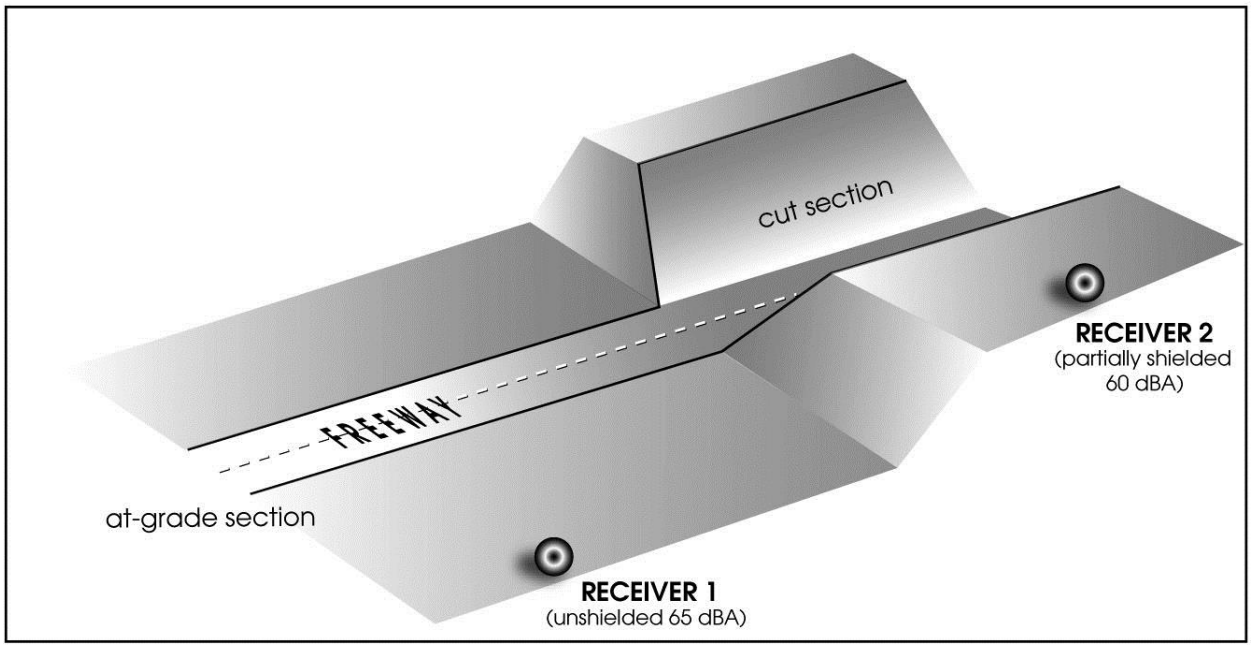

Figure 3-3. Receiver Partially Shielded by Top of Cut vs. Unshielded Receiver

3.3 Measuring Times, Duration, and Number of Repetitions

3.3.1 Measuring Times

23 CFR 772 requires that traffic characteristics that yield the worst hourly traffic noise impact on a regular basis be used for predicting noise levels and assessing noise impacts. Therefore, if the purpose of the noise measurements is to determine a future noise impact by comparing predicted noise with measured noise, the measurements must reflect the highest existing hourly noise level that occurs regularly. In some cases, weekly or seasonal variations need to be considered. In recreational areas, weekend traffic may be higher than on weekdays and may be heavily influenced by season, depending on the type of recreation. Measurements made for retrofit noise barrier projects also require noise measurements during the highest traffic noise hour.

The noise impact analysis for classrooms, under the provisions of the Streets and Highways Code Section 216, requires noise measurements to be made "at appropriate times during regular school hours" and sets an indoor noise limit of 52 dBA, $L_{eq}(h)$, from freeway sources. Therefore, noise measurements for schools qualifying for school noise abatement under Section 216 need to be made during the noisiest traffic hour during

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school hours. Noise from school children often exceeds traffic noise levels. To avoid contaminated measurements, it is often necessary to vacate classrooms for the duration of the measurements or to take measurements during vacation breaks.

Noise measurements for model calibration do not need to be made during the worst noise hour, but it is desirable to have about the same estimated traffic mix (e.g., heavy truck percentages of the total volume) and speeds as during the noisiest hour. Accurate traffic counts and meteorological observations (see Section 3.6) must be made during these measurements.

Noise monitoring for background community noise levels should be done during the expected time of the highest noise level from the highway even though the measurements are taken at sites far enough removed from an existing highway that they will not be contaminated by it. This should be done because the background levels will later be added to predicted near-highway noise levels.

Noise monitoring for investigating citizen complaints may need to be done at a time to which the parties mutually agree. Frequently, these measurements are taken before or after normal working hours, as dictated by the nature of the complaint.

Construction monitoring is performed during operation of the equipment to be monitored. This may require night work on some construction projects.

Unless other times are of specific interest, before-and-after noise abatement (e.g., noise barrier) measurements to verify noise abatement performance should be done during the noisiest hour. Noise barriers are designed for noisiest hour traffic characteristics, which probably include highest truck percentages, and to minimize contamination by background noise. Traffic should be counted during these measurements. If before-and-after traffic conditions differ, measurements should be normalized or adjusted to the same conditions of traffic (see Section 3.3.1.2).

The nature of special studies and research projects dictates the appropriate times for those measurements.

3.3.1.1 Noisiest Hour for Highway Traffic

The peak traffic hour is generally not the noisiest hour. During rush hour traffic, vehicle speeds and heavy truck volumes are often low. Free-flowing traffic conditions just before or after rush hour often yield higher noise levels. Preliminary noise measurements at various times of the day

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are sometimes necessary to determine the noisiest hour. If accurate traffic counts and speeds for various time periods are available, the noisiest hour may be determined by using TNM. Experience based on previous studies may also be valuable in determining the noisiest hour for a particular facility.

3.3.1.2 Adjusting Other-Than-Noisiest Hour

For the sake of efficiency, highway traffic noise measurements are often not made when the highest hourly traffic noise levels occur. These measurements may be adjusted upward to noisiest hour levels by using TNM. To make the adjustments, traffic must be counted and speeds determined simultaneously with the noise measurements. The following procedure must be followed.

1. During each measurement, take noise measurements and count traffic simultaneously. Although lane-by-lane traffic counts yield the most accurate results, it is usually sufficient to count traffic by direction (e.g., east- and westbound). Separate vehicles into the five vehicle groups used by the model (autos, medium trucks, heavy trucks, buses, and motorcycles). Obtain average traffic speeds (both directions). These may be obtained by radar or driving a test vehicle through the project area at the prevailing traffic speed.
2. Expand vehicle counts for the measurement period to hourly values (e.g., if the measurement period was 15 minutes, multiply the vehicles counted in each group by 4). Section 3.3.2 discusses duration of measurement as a function of hourly vehicle volumes.
3. Enter the hourly traffic volumes and speeds from steps 1 and 2 into TNM. Also include the proper roadway and receiver geometry and site parameters. Run the model.
4. Enter the traffic volumes and speeds associated with the noisiest hour and the same roadway and receiver geometry and site parameters as used in step 3. Run the model.
5. Subtract results of step 3 from step 4. The step 4 results should always be larger than step 3.
6. Add the differences obtained in step 5 to the noise measurements of step 1.

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Example

Measured noise level in step 1, L_{eq} = 66 dBA

Calculated for step 1 conditions (step 3) = 67 dBA

Calculated for noisiest hour (step 4) = 69 dBA

Difference (step 5) = 2 dBA

Measured noise level adjusted to noisiest hour (step 6) = 66 + 2 = 68 dBA

If 24-hour monitoring equipment is available, a histogram of 24 hourly noise measurements may be developed for an existing freeway. This information may then be used to adjust an off-peak hour noise level at any location along the freeway to a noisiest hour noise level. However, steps must be taken to reduce the chance of noise contamination from non-traffic sources. If hourly noise relationships are in agreement between the two monitors, there is reasonable assurance that neither was contaminated. There is, however, no assurance that regional contamination such as frequent aircraft flyovers did not take place. As such, measurements with remote noise monitoring equipment must be approached with extreme caution and only with at least some familiarity of nearby noise sources.

3.3.2 Measurement Duration

A noise measurement representing an hourly L_{eq} does not need to last the entire hour. As long as noise levels do not change significantly, a shorter time period will usually be sufficient to represent the entire hour of interest. The recommended length of measurements depends on how much the noise levels fluctuate—the higher the fluctuations, the longer the measurement must be. Vehicle spacing and differences in vehicle types are responsible for fluctuating noise levels. These fluctuations decline as traffic densities increase. Highway noise also becomes more constant as the distance from the highway increases because the rate of distance change between a moving vehicle and a receiver diminishes. The durations in Table 3-1 are recommended for highway traffic noise measurements as a function of number of vehicles per hour (vph) per lane.

Table 3-1. Suggested Measurement Durations

Traffic Volume	Vehicles per Hour per Lane	Duration (Minutes)
High	>1,000	10
Medium	500–1,000	15–20
Low	<500	20–30

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Most sound level meters automatically integrate and digitally display cumulative L_{eq}. Near the beginning of each measurement period, the displays fluctuate considerably. However, after more data are collected, they tend to stabilize. The time necessary to stabilize depends on the amount of noise fluctuation. A measurement may be terminated when the range of the fluctuation in displayed L_{eq} is less than 0.5 dBA. However, measurements can be lengthened if necessary.

3.3.3 Number of Measurement Repetitions

Noise measurements taken at a specific site tend to vary. The most common causes of these variations are listed below.

- Change in traffic volumes, speeds, and/or mixes.
- Contamination from non-traffic noise sources, such as barking dogs, aircraft, nearby construction, and landscaping and road maintenance activities.
- Change in weather (e.g., wind speed, wind direction, temperature, and humidity).
- Changes in site conditions.
- Instrument, operator, or calibration error.
- Malfunctioning instruments.

Because of these potential variables and errors that may occur during a measurement, it is strongly recommended that a time-averaged measurement (e.g., the L_{eq} descriptor) be repeated at least once at each site. This procedure will reduce the chances of undetected errors. There are exceptions to this recommendation, however. Whenever three or more noise measurements are made in the same general area, simultaneously or in relatively rapid succession, one measurement at each site may be sufficient if the sites are acoustically equivalent (see Section 3.2.2.2). However, to determine whether a measurement at a particular site is acceptable, the measurement should be compared to those at the other sites and subjected to the same criteria for repeat measurements discussed later in this section.

The recommended minimum of two measurements should be taken independently (using two different setups and separate calibrations). However, the operator is not precluded from taking more than one measurement per setup and calibration. In fact, if time permits, multiple measurements during each setup are encouraged to improve accuracy. To

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save time concurrent measurements may be made at a single position with two separate instrument setups.

Repeat measurements should be compared with the original measurements under the same conditions of traffic, meteorology, and site. Noise contamination, instrument malfunction, operator error, or any other anomalies in the measurements can then readily be detected. To ensure that conditions are the same for all measurements, traffic counts and some basic meteorological measurements should be made during the noise measurements (see Sections 3.3.4 and 3.6). If the repeat measurements are not in reasonable agreement with the original measurements, additional measurement repetitions are recommended. For routine measurements, such as determining ambient noise levels or calibrating noise prediction models, the above-recommended minimum of two measurements normalized for differences in traffic mix and volumes should agree within 2 dBA. If more than one measurement is taken per setup, the mean noise levels for the two setups should agree within 2 dBA. Repetitive measurements for each setup should then be within about 1 dBA of the mean noise level of the setup.

The above criteria have been set empirically from many years of field experience with a variety of sound level meters approved for transportation noise measurements (American National Institute of Standards [ANSI] S1.4 1983, Types 1 and 2). Some examples illustrating these criteria are listed below and were purposely selected to show the extreme allowable limits. Usually, better agreement between setups and within setups can be expected. Examples 1 to 3 assume that all meteorological conditions, traffic conditions, and site conditions are the same throughout all measurements.

Example 1

Measurement 1

Setup 1: 74.5 dBA, L_{eq}

Setup 2: 76.5 dBA, L_{eq}

Mean: 75.5 dBA, L_{eq}

Conclusion: Measurements are acceptable because they agree by 2 dBA.

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Example 2

Measurement 1

Setup 1: 69 dBA, L_{eq}

Setup 2: 71 dBA, L_{eq}

Measurement 2

Setup 1: 67 dBA, L_{eq}

Setup 2: 69 dBA, L_{eq}

Mean

Setup 1: 68 dBA, L_{eq}

Setup 2: 70 dBA, L_{eq}

Overall: 69 dBA, L_{eq}

Conclusion: Measurements are acceptable because they agree by 2 dBA and measurements within each setup are within about 1 dBA of the setups' mean.

Example 3

Measurement 1

Setup 1: 61.6 dBA, L_{eq}

Setup 2: 58.6 dBA, L_{eq}

Measurement 2

Setup 1: 59.6 dBA, L_{eq}

Setup 2: –

Mean

Setup 1: 60.6 dBA, L_{eq}

Setup 2: 58.6 dBA, L_{eq}

Overall Mean: 59.9 dBA, L_{eq} (round to 60)

Conclusion: Measurements are acceptable.

Examples 1 to 3 indicate that as long as the agreement criteria between the two setups and within each setup are met, all measurements can be averaged together. Examples 4 and 5 illustrate the process if the setups do not agree by 2 dBA.

Example 4

Measurement 1

Setup 1: 65.3 dBA, L_{eq}

Setup 2: 68.0 dBA, L_{eq}

Conclusion: Measurements are not acceptable; difference of more than 2 dBA).

After the second measurement, a decision should be made to either take another measurement during Setup 2 or break the setup and take a measurement for a new Setup 3. Either method will be acceptable,

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although if the decision is to take another measurement during Setup 2, and the agreement criteria still cannot be met, it is recommended to break Setup 2 and perform additional measurements with Setup 3. If agreement is reached between Setups 2 and 3, Setup 1 should be eliminated, as illustrated in Example 5:

Example 5

Measurement 1

Setup 1: 65.3 dBA, L_{eq}

Setup 2: 68.0 dBA, L_{eq}

Setup 3: 69.0 dBA, L_{eq}

Measurement 2

Setup 1: –

Setup 2: 68.5 dBA, L_{eq}

Setup 3: –

Mean

Setups 2 and 3: 68.5 dBA, L_{eq}

Conclusion: Setup 2 and 3 measurements are acceptable.

If Setup 3 measurement would have agreed with both Setups 1 and 2 (e.g., 67.0 instead of 69.0), another decision would have to be made, such as one of the following.

- Use Setups 1 and 3.
- Use Setups 2 and 3.
- Use the average of all three setups (all measurements).

The safest approach would be to use the average of all measurements unless there would be a good reason to eliminate one setup.

These examples illustrate some extreme cases; many other combinations are possible. Most measurements will show better agreement. The examples are intended to show how the recommended criteria may be applied in general. The analyst may need to rely more on individual judgment and experience in more complicated situations.

In some cases, more accuracy is required than the criteria allow. These cases apply mostly to special studies or research. However, they may also be applied to a few key noise measurement sites on a large project for the purpose of accurate model calibration. In these cases, a 95% confidence interval for the mean of several measurements (using a minimum of two setups) can be calculated. The 95% confidence interval should be specified to be no more than about 1 dBA. Table 3-2 shows the maximum allowable standard deviations (S_{max}) as a function of the number of

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samples (measurements). Although the table is calculated for up to 10 measurements, the criterion can be met by five or fewer measurements in most cases. A scientific calculator with statistical functions is essential when making calculations in the field.

Table 3-2. Maximum Allowable Standard Deviations for a 95% Confidence Interval for Mean Measurement of about 1 dBA

Number of Measurements	Maximum Allowable Standard Deviations
2	0.11
3	0.40
4	0.63
5	0.81
6	0.95
7	1.08
8	1.20
9	1.30
10	1.40

Example
Measurement 1
Setup 1: 67.8 dBA, L_{eq}
Setup 2: 68.7 dBA, L_{eq}
Measurement 2
Setup 1: 66.9 dBA, L_{eq}
Setup 2: 67.9 dBA, L_{eq}
Measurement 3
Setup 1: –
Setup 2: 67.8 dBA, L_{eq}
Standard Deviation (Maximum)
Setups 1 and 2: 0.73 (0.63)
Setups 1 to 3: 0.64 (0.81)
Mean
Setups 1 to 3: 67.8 dBA, L_{eq} (round to 68)
Conclusion: Use Setups 1 to 3 (five measurements).

The preceding examples assume that the previously mentioned site, traffic, and meteorological conditions remain the same during all measurements. Site conditions and contamination from other noise sources can be controlled by careful site selection. Noise contamination from intermittent

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sources can further be controlled by pausing the instruments during the contamination or by marking and editing recorded data.

Operator error and instrument malfunction usually cause larger errors that are easily detected. Instrument error is a function of equipment brand, type, and calibration. Instrument records of calibration, repair, performance, manufacturers' manuals, and accuracy standards (discussed later in Section 3.7) will give a good estimate of instrument error.

The next section addresses a method of normalizing noise measurements made under different traffic conditions. Meteorological limits for comparisons of noise measurements will be discussed in Section 3.6.

3.3.4 Normalizing Measurements for Differences in Traffic Mixes and Volumes

Before applying the criteria discussed in Section 3.3.3, repeated measurements must be adjusted for differences in traffic mix and volume. The effects of traffic differences can be calculated by the noise prediction models and compared with the actual differences in the measurements. However, a simple method to normalize measurements for differences in traffic mixes and volumes has been developed for optional use in the field.

This method involves field calculations that with practice can be carried out in a few minutes with a log function calculator as demonstrated in the discussion below. The repeated measurements are field-adjusted for the same traffic conditions as the first measurement. The adjusted (normalized) measurements may then be compared directly according to the criteria in Section 3.3.3.

The obvious advantage of using this method is that it may eliminate the need to return to the same site at a later date if repetition criteria are not met. However, as with most simplified methods, there are certain limitations to the use of this procedure. The method should not be used in the following cases.

- Average traffic speeds are not the same for each measurement. This is difficult to verify, but under free-flow conditions at a specific location, speeds generally will be constant.
- Truck speeds are significantly different (more than 5 mph) from auto speeds or truck percentages are significantly different (more than doubled).
- Speeds cannot be determined within 5 mph.

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- The ratio of distances from the receiver to the centerline of the far (directional) lane group and the receiver to the centerline of the near (directional) lane group is more than 2:1. For most eight-lane urban freeways, this means that the receiver should not be closer than 45 feet from the edge of the traveled way.
- The directional split of traffic is different by more than 20% for each vehicle group between measurements. For example, if the directional split between heavy trucks during the first measurement is 60/40 and 80/20 or 40/60 during the next measurement, the method would be valid. However, a second split of 85/15 or 35/65 means that the method would be inaccurate. This criterion is usually met.

The method uses the concept of equivalent vehicles (V_E), which equates medium and heavy trucks to an acoustically equivalent number of autos. Based on the TNM Reference Energy Mean Emission Levels (REMELs) (Federal Highway Administration 1996b), one heavy truck traveling at 55 mph makes as much noise as approximately 10 autos cruising at the same speed. A medium truck at 55 mph is acoustically equivalent to approximately four autos passing at the same speed. These relationships are speed-dependent and the same for the maximum noise level (L_{max}) and time-averaged noise levels (L_{eq}).

The relationships do not consider source heights and may not be used if the path from the source to the measurement site is intercepted by a barrier or natural terrain feature. Table 3-3 shows V_E for speeds from35 to 70 mph in 5-mph increments, based on the FHWA TNM REMELs for baseline conditions.

Table 3-3. Equivalent Vehicles Based on Federal Highway Administration Traffic Noise Model Reference Energy Mean Emission Levels

	Equivalent Vehicles		
Speed (mph)	1 Heavy Truck	1 Medium Truck	1 Automobile
35	19.1	7.1	1
40	15.1	5.8	1
45	12.9	5.0	1
50	11.5	4.5	1
55	10.4	4.1	1
60	9.6	3.7	1
65	8.9	3.5	1
70	8.3	3.2	1

Note: Based on FHWA TNM REMELs and vehicle definitions in Federal Highway Administration 1996a and 1996b (also see Section 4.5.2).

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The following is an example of calculating V_E using Table 3-3.

Given

In 15 minutes, the following traffic was counted: 76 heavy trucks, 34 medium trucks, and 789 autos. Average traffic speed was 55 mph.

Solution

76 heavy trucks = 76 x 10.4 = 790 V_E

34 medium trucks = 34 x 4.1 = 139 V_E

789 autos = 789 x 1 = 789 V_E

Total = 1,718 V_E

To normalize a noise measurement for one traffic count to another noise measurement for a different traffic count, the following procedure should be followed:

1. $L_{eq}(1)$ is the first noise measurement, which is used as the reference measurement. Convert the traffic count for $L_{eq}(1)$ to V_E, which is designated $V_E(1)$.
2. $L_{eq}(2)$ is the second noise measurement, which is to be normalized. Convert the traffic count for $L_{eq}(2)$ to $V_E = V_E(2)$.
3. *c* is the correction to be applied to $L_{eq}(2)$ for normalization to the traffic of $L_{eq}(1)$. The equation to compute *c* is $10\log_{10}[V_E(1)/V_E(2)]$. Note that *c* may be negative or positive.
4. $L_{eq}(2N)$ is the normalized $L_{eq}(2)$. The equation to compute $L_{eq}(2N)$ is $L_{eq}(2) + c$.
5. $L_{eq}(2N)$ may be directly compared to $L_{eq}(1)$ in the field to determine whether the agreement criteria discussed in Section 3.3.3 are met. If more than two measurements are made, the same procedure can be used for subsequent measurements. The same reference measurement must be used throughout the procedure.

Following is an example for determining in the field whether three 15-minute measurements for different traffic conditions meet the agreement criteria in Section 3.3.3 (for convenience the measurements have been numbered consecutively regardless of setup):

Given

		15-Minute L_{eq}					
Measurement	Setup	dBA	Heavy Trucks	Medium Trucks	Autos	Speed (mph)	Equivalent Vehicles (V_E)
1	1	74.4	100	50	1,275	55	2,520
2	1	75.5	150	100	850	55	2,820
3	2	74.0	60	30	1,700	55	2,447

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Correction Calculations (Using Table 3-3)

Correction c for $L_{eq}(2) = 10\log_{10}\left(\frac{V_E(1)}{V_E(2)}\right) = 10\log_{10}\left(\frac{2{,}520}{2{,}820}\right) = -0.5$

$L_{eq}(2N) = L_{eq}(2) + c = 75.5 - 0.5 = 75.0$ dBA

Correction c for $L_{eq}(3) = 10\log_{10}\left(\frac{2{,}520}{2{,}447}\right) = 0.2$

$L_{eq}(3N) = 74.0 + 0.2 = 74.1$ dBA

Normalized Data Using Table 3-3

Measurement	Setup	Normalized L_{eq} (dBA)
1	1	74.4
2	1	75.0
3	2	74.1

Further examination indicates that the agreement criteria of Section 3.3.3 are met, and no further measurements are necessary. Please note that the normalized data are only used to determine agreement between measurements. The actual measurements and traffic counts may be used in later calculations as follows.

Average Energy of Measurements

74.5 dBA (report as 75 dBA)

Average 15-Minute Traffic Counts

Mean Heavy Trucks $= \left(\frac{100 + 150 + 60}{3}\right) = 103.3$

Mean Medium Trucks $= \left(\frac{50 + 100 + 30}{3}\right) = 60.0$

Mean Autos $= \left(\frac{1275 + 850 + 1700}{3}\right) = 1{,}275.0$

Expand Average 15-Minute Traffic Counts to 1 Hour

Mean Heavy Trucks = 103.3 x 4 = 413

Mean Medium Trucks = 60.0 x 4 = 240

Mean Autos = 1,275.0 x 4 = 5,100

The expanded average traffic counts may be used in the prediction model to calculate the noise level. The result may be compared to the energy-averaged measurement. Section 4.4 explains how this comparison may be used for "calibrating" the prediction model.

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An alternative more detailed approach to normalization is contained in American Association of State Highway and Transportation Officials (AASHTO) Draft Standard TP 99-12 (American Association of State Highway and Transportation Officials 2011).

3.3.5 Classroom Noise Measurements

These measurements meet the requirements of the California Streets and Highways Code Section 216 which is discussed in the Protocol. Under these provisions:

> [t]he noise level produced by traffic on, or by construction of, a state freeway shall be measured in the classrooms, libraries, multipurpose rooms, and spaces used for pupil personnel services of a public or private elementary or secondary school if the rooms or spaces are being used for the purpose for which they were constructed and they were constructed under any of the following circumstances: …

Section 216 lists all of these circumstances and should be consulted to determine applicability of these measurements. For convenience, the rooms mentioned above will be referred to as "classrooms" in this section.

Determining a project's traffic noise impacts on classroom interiors under Section 216 requires taking noise measurements inside the classroom. Please note that Section 216 requires that all measurements "be made at appropriate times during regular school hours and shall not include noise from other sources that exceed the maximum permitted by law." The noise of vehicles that exceed the maximum allowable level in the California Vehicle Code (L_{max} of 90 dBA at 50 feet for vehicles traveling more than 45 mph) should be excluded. Because this is difficult, however, the requirement is ignored. It is customary to take outside and inside noise levels to determine building insertion loss. This information is useful when noise abatement is necessary.

If the project involves a reconstruction of an existing freeway, simultaneous traffic noise measurements may be taken inside and outside the classroom. Microphones should be placed as shown in Figures 3-4 and 3-5.

Figure 3-4 shows the preferred setup where microphone 1 (Mic. 1) should be placed outside the classroom at approximately the same distance from the freeway as the center of the classroom. Care must be taken to place the microphone far enough away from the building to avoid significant shielding by the corner of the building. This can be accomplished by maintaining at least a 70º angle between a perpendicular line to the

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freeway and a line to the corner of the building. Mic. 2 should be placed in the center of the classroom.

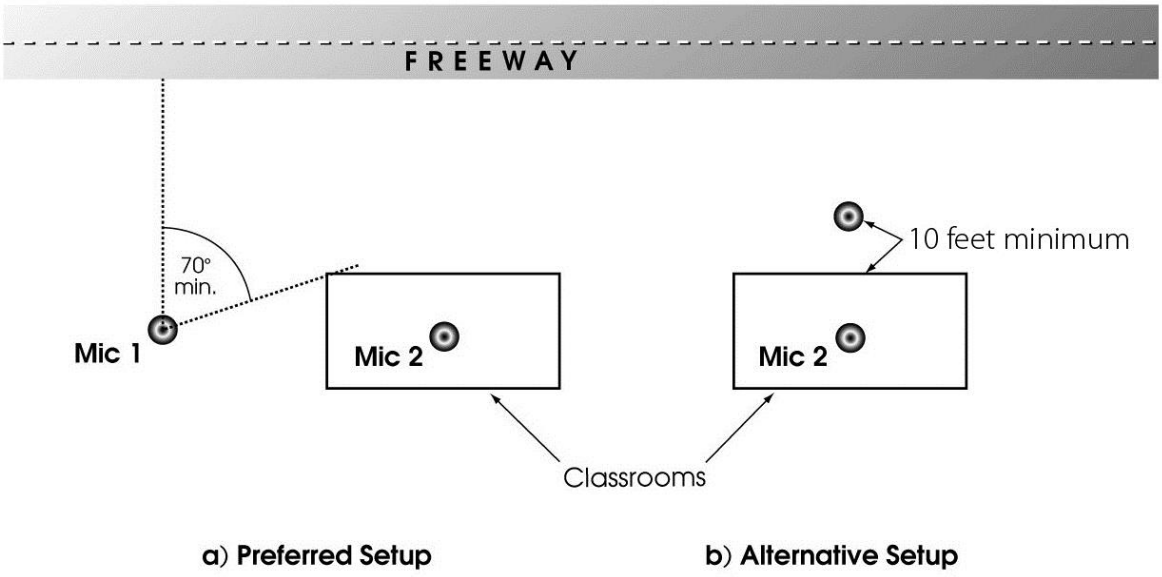

Figure 3-4. Classroom Noise Measurements (Reconstruction of Existing Freeway)

Figure 3-5 shows an alternate setup to be used if the setup shown in Figure 3-4 is not possible. Mic. 1 should be positioned at least 10 feet from the building to avoid noise reflections from the building. The disadvantage of this setup is that Mic. 1 and Mic. 2 are not equal distances from the freeway. If Mic. 1 is 200 feet or more from the freeway, the effects of unequal distances can usually be ignored. Assuming a 33-by-33-foot classroom, the error would be 0.5 dBA or less. Between 65 and 200 feet, a distance reduction of 1 dBA would have to be applied to Mic. 1 to normalize Mic. 1 to Mic. 2. If the distance from Mic. 1 to the freeway is less than 65 feet, a larger adjustment will be necessary. TNM may be used to calculate the adjustments.

If the classrooms are not air-conditioned and rely on open windows or doors for ventilation, simultaneous measurements should be made with doors and windows open and closed. The noise insertion loss provided by the building under these conditions is useful for predicting inside classroom noise levels and for choosing noise abatement options if needed. For instance, if a classroom interior is not expected to meet the inside classroom noise criterion with the windows and doors open, but will meet the criterion with them closed, noise abatement considered may include adding air conditioning.

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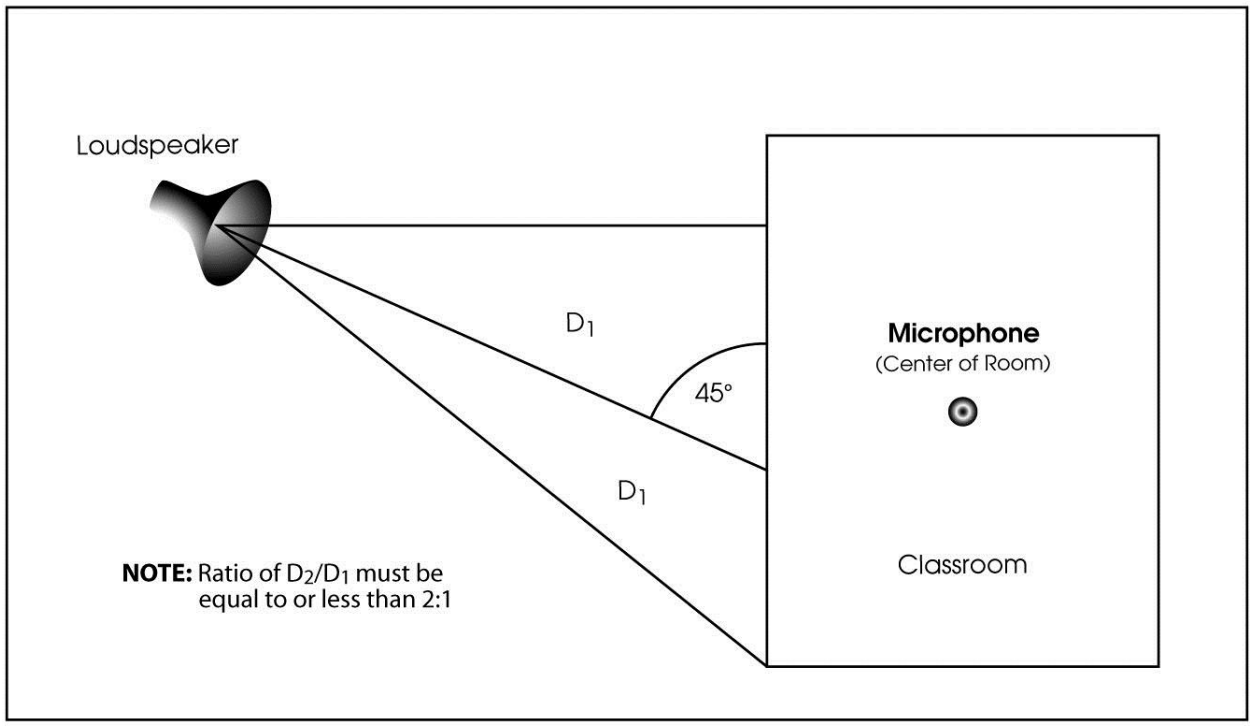
If the project is on a new alignment or construction noise will be the dominant noise source, there is no existing traffic source that can be used to measure building attenuation. In that case, it is appropriate to use an artificial noise source to quantify building insertion loss (Figure 3-5).

Acceptable choices of an artificial source would be traffic noise audio recordings or an electronically generated noise spectrum that approximates typical traffic noise. This spectrum should be linear, from 31.5 to 500 Hz, and decrease at 6 dB per octave from 500 to 4,000 Hz. Amplification should be sufficient to produce A-weighted sound levels at least 10 dBA greater than background noise levels at exterior and interior microphone locations. A commercial-quality loudspeaker should be used with directional characteristics such that a 2,000-Hz signal measured at 45º from perpendicular to the face of the speaker is no more than 6 dB less than the level measured at the same distance on the perpendicular axis. The sound level output must be kept constant for inside and outside measurements.



Source)

The loudspeaker is a point source. To account for all the possible angles of incidence provided by a line source and to avoid reflections from the building face, the speaker should be positioned as shown in Figure 3-5 for the indoor noise measurements.

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Placing the speaker and microphone so that there is a direct line of sight between them through an open door or window should be avoided. If possible, additional measurements at 15º, 30º, and 60º should be taken and the results averaged. If only one angle is used, it should be 45º.

Once the indoor measurements are completed, outdoor measurements must be taken. For the outdoor noise measurements, the distance between the speaker to the outdoor microphone should be the same as the distance between the speaker and the indoor microphone. The sound level output of the artificial source must be the same for both indoor and outdoor measurements. The difference between the measured outdoor sound level and the indoor sound level indicates the sound level reduction provided by the building shell.

Section 7.4 discusses methods for evaluating interior noise for Activity Category D land use facilities (schools, hospitals, libraries, etc.). Under the 2011 revision to 23 CFR 772 interior noise abatement for residences is no longer a federally fundable form of noise abatement.

3.4 Instrumentation

The instruments used for measuring or recording noise include a range of manufacturers, models, types, accessories, degrees of accuracy, prices, and levels of sophistication. It is not the intent of this section to discuss all details of noise instruments or to endorse certain manufacturers. Informative catalogs are available from all major manufacturers to help in deciding what equipment to purchase, and sales representatives are usually very helpful in demonstrating the equipment. Once purchased, user manuals will be useful, ready references for specific operating procedures. It is strongly recommended that Caltrans Headquarters staff be consulted before purchasing noise instrumentation.

This section will address general features common to most instruments. The categories discussed are sound level meters, recording devices, frequency analyzers, acoustical calibrators, and meteorological and other non-noise-related equipment.

3.4.1 Sound Level Meters

ANSI has established requirements for sound level meter accuracy in standard ANSI S1.4-1983 (Revision of S1.4-1973) and ANSI S1.4N-1985 Amendment to ANSI S1.4-1983. The standard defines three basic types of sound level meters.

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- Type 0: Laboratory Standard (primarily designed for laboratory use).
- Type 1: Precision (field use).
- Type 2: General Purpose (field use).

The expected total allowable error for a Type 1 sound level meter in the field is about 1.5 dB; for a Type 2 sound level meter in the field, the allowable error is about 2.3 dB. These expected values of total allowable errors apply to an instrument selected at random. These errors may be reduced for a specific instrument through careful calibration and adjustment.

For each sound level meter type, the standard requires three frequency weightings (A, B, and C) and two response settings (slow and fast). In addition, the standard permits other optional features in a sound level meter, such as impulse and peak measuring capabilities and wide ranges for the display of sound levels. All sound level meters used by Caltrans or its contractors shall be of any type described above (Types 0, 1, 2, with A-weighting). The type must be marked on the meter by the manufacturer. Although sound level meters are available in a variety of configurations, they all have the following general components.

- **Microphone System (Microphone and Preamplifier):** The microphone converts air pressure fluctuations into an electrical signal that is measured by instrumentation such as the sound level meter or a third-octave band spectrum analyzer. Most microphones can be detached from the body of the meter and connected to an extension cable. To satisfy a Type 0 or 1 requirement, the microphone may need to be separated from the meter body.

  Microphones come in various diameters. The 0.5-inch-diameter microphone is used most commonly. The air condenser microphone (most common) consists of a membrane and back plate separated by an air gap. The width of the air gap fluctuates as the membrane vibrates in a sound field, thereby changing the capacitance. Microphones of sound level meters complying with the type standards are omni-directional, have a flat frequency response, and are sensitive over a wide range of frequencies.

  A compatible preamplifier, usually manufactured as part of the microphone system, should always be used. A preamplifier provides high-input impedance and constant low-noise amplification over a wide frequency range. Depending on the type of microphone, a preamplifier may also provide a polarization voltage to the microphone.

- **Wind Screen:** A spherically or cylindrically shaped screen, generally made of open-celled polyurethane. When placed over the microphone,

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it reduces wind noise (see Section 3.6). The wind screen should always be used, even in absence of wind, because it helps to protect the microphone against dust or mishaps.

- **Root Mean Square Detector:** Converts peak-to-peak signals to a rms signal. This measure is derived by squaring the signal at each instant, obtaining the average (mean) of the squared values, and taking the square root of this average.
- **Amplifier:** Amplifies the electrical signal.
- **Frequency Weighting Filters (A to C):** These filters are required by ANSI S1.4-1983 and ANSI S1.4-1985. The A-weighting is used internationally for environmental noise measurements (including transportation noise).
- **Slow or Fast Response Switch:** Refers to time-averaging characteristics of the sound level meter. On the slow setting, the averaging of sound levels takes place over 1-second increments. On the fast setting, the averaging time is 0.125 second. On a real-time display (digital or analog), the sound level fluctuations are easier to read on the slow setting. The fast setting, however, gives a better resolution of instantaneous sound levels.
- **Range Setting:** Allows setting of the correct range of sound levels to be measured.
- **Digital Display:** Displays instantaneous noise levels or integrated averages. Digital displays often have multi-function switches that allow the user to view various noise descriptors such as L_{eq} and L_{max}.
- **Battery Check Switch:** Allows user to check battery voltage.
- **Output:** For various recording devices.
- **Power On/Off Switch**.

Many sound level meters also have pause switches to interrupt data sampling, preset time switches that allow sampling over a predesignated time period, reset switches for starting a new sampling period, and other features.

3.4.2 Data Recording and Analysis

Professional sound level meters typically can log measured sound levels in the form of the various sound level descriptors including those described in Table 2-12. These logged values can then be downloaded to a computer for analysis using a computer spreadsheet or other analysis software.

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Professional sound level meters will typically have an audio output that can be connected to an external audio recorder for recording the audio signal from the meter. Handheld solid state digital audio recorders are typically used as an external recording device. Recorders should be high-quality professional recorders with flat frequency response and high signal-to-noise ratios. Once the signal is recorded a digital signal analyzer can then be used to analyze the recorded signal using octave, one-third octave, or narrow band signal analysis equipment. Digital signal analyzers can be dedicated stand-alone units, computer software programs, or built into the sound level meter. Some sound level meters also have the ability to directly capture digital audio recordings.

3.4.3 Acoustical Calibrators

Acoustical calibrators are used to calibrate the sound level meter/recorder system in the field. The calibrator fits over the top of the microphone. Care must be taken that the microphone is properly seated in the calibrator cavity. When activated, the calibrator emits an audio signal at a reference frequency and decibel level. Most calibrators have a reference level of 94 dB or 114 dB at 1,000 Hz. Modern sound level meters generally maintain calibration within about ±0.2 dB. If field calibration values fall outside this deviation, the meter should be checked and calibrated by a laboratory accredited to perform calibrations on specified instruments.

Acoustical calibrators and sound level meters should be periodically certified for proper calibration by an appropriate certified acoustic lab.

3.4.4 Meteorological and Other Non-Noise-Related Equipment

Basic meteorological data including wind speed, wind direction, temperature, and relative humidity should be collected concurrently with most noise measurements.

An anemometer is an instrument used to measure wind speed. For general-purpose measurements at relatively close distances to a noise source, i.e., within about 100 feet, a hand-held, wind-cup anemometer and an empirically observed estimation of wind direction are sufficient to document wind conditions. For all types of measurements, the anemometer should be located at a relatively exposed position and at an elevation approximately equal to that of the highest receiver position.

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Other recommended equipment includes a radar gun to measure traffic speeds, tape measures, survey levels (or hand levels), and rods to survey the site and document microphone positions with reference to landmarks, as well as watches or stopwatches to time the measurements. Portable radios or cell phones may be helpful to maintain contact with traffic counting personnel and other field personnel. Traffic count logging equipment is also very useful. Traffic can be counted and classified in real time in the field or recorded with a video camera for subsequent counting and classification.

3.5 Noise Measurement Procedures

This section addresses general procedures for routine noise measurements. Manufacturers' manuals should be consulted for operating each specific instrument. The following procedures are common to all routine Caltrans noise measurements.

3.5.1 Instrumentation Setup

The sound level meter microphone should be placed 5 feet above the ground and at least 10 feet from reflecting surfaces such as buildings, walls, parked vehicles, and billboards. Operators should be careful not to shield the microphone with their bodies during the measurements. Other obstructions between microphone and noise source should be avoided unless they are representative of the region of interest.

If the microphone is not separated from the sound level meter body, the sound level meter should be supported on a tripod. If the microphone is separated, it should be placed on a tripod or other stand.

When meteorological equipment is set up, thermometers should be in the shade, and the anemometer should have good exposure to representative winds.

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3.5.2 Field Calibration

Acoustical calibrators are described under Section 3.4.3. Some calibrators provide a choice of several frequency settings. If the calibrator offers these choices, 1,000 Hz should be used for calibration. The sound level meter/recorder system can then be adjusted to this level. The procedures in manufacturers' user manuals should be followed.

The sound level meter/recorder system should be calibrated before and after each setup. If several measurements are made during the same setup, calibration may also be checked between measurements. For routine measurements, if the reading differs by less than 0.5 dB from the reference level (C_R) indicated on the calibrator, the sound level meter/recorder system does not need to be adjusted. If the reading deviates by 0.5 dB or more, or if measurements are part of a special study in which extreme accuracy is required, the sound level meter/recorder system should be adjusted within 0.1 dB of the reference level.

If the final calibration (C_F) of the acoustic instrumentation differs from the initial calibration (C_I) by 1 dB or more, all data measured with the system between the calibrations should be discarded and repeated. The instrumentation and connections should be checked thoroughly before repeating the measurements. If the final calibration is less than 1 dB from the initial calibration, all data measured with that system between the calibrations should be adjusted as follows:

$$\text{Data Adjustment} = C_R - [(C_I + C_F\}/2)] \qquad \textbf{(3-1)}$$

Example

C_R = 94.2 dB

C_I = 94.4 dB

C_F = 94.6 dB

Data Adjustment = 94.2 – [(94.4 + 94.6)/2] = -0.3 dB

All data measured in between the two calibrations should be reduced by 0.3 dB (e.g., a measurement of 66.7 dBA would become 66.4 dBA). For routine measurements, it is customary to round off and report the final adjusted value to the nearest decibel; for example, 66.4 dBA would be reported as 66 dBA, and 66.5 dBA would be reported as 67 dBA.

The field calibration procedure is described below.

1. Adequate start-up of instruments should be allowed before calibration (at least 1 minute or as specified in the manufacturer's manual). The

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analyst should check that all proper connections have been made and that batteries are fresh or adequately charged.

2. The calibrator should be placed carefully over the microphone and properly seated. Touching the calibrator during calibration should be avoided.
3. If necessary make calibration adjustments as indicated in the manufacturer's user manual.

3.5.3 Measurements

Following calibration of equipment, a wind screen should be placed over the microphone. The frequency weighting should be set on "A." The proper response setting should be set at "fast" or "slow." "Slow" is typically used for traffic noise measurements. The desired sampling time, sampling interval, and noise descriptor should be selected.

During the noise measurements, any noise contamination, such as barking dogs, local traffic, lawnmowers, train passbys and aircraft, should be noted. If the sound level meter is equipped with a "pause" or "standby" switch or button, the measurement should be temporarily interrupted until the noise contamination ceases. Notes on the start time and duration of the contaminating event should be taken.

Talking during measurements should be avoided. Curious bystanders will often ask the operator about the monitoring. A possible way to avoid talking near the microphone is to stand 25 to 50 feet from it, which is far enough not to contaminate the measurement but close enough to watch the setup.

If highway noise measurements are taken, traffic should be counted simultaneously with the noise measurements. At a minimum, directional traffic should be counted separately. Traffic counts by lane are best but often not practical because they are too labor-intensive. Traffic should be divided into heavy trucks, medium trucks, autos, buses, and motorcycles as defined in TNM. Definitions of these vehicle types are addressed in Section 4. Average speeds for each vehicle group and direction should be estimated using a radar gun (if available) or test runs with a vehicle in the flow of traffic during the noise measurements.

Wind speed and direction, temperature, humidity, and sky conditions (i.e., clear, partly cloudy, overcast, fog, or haze) should be observed and documented.

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After the last measurement of the setup, the equipment should be recalibrated before power is turned off. Also, if the power is interrupted during or between measurements, the instruments need to be recalibrated before additional measurements are taken. The procedure for calibration and necessary data adjustment was discussed in Section 3.5.2.

3.5.4 Documentation

Measurement data should be carefully recorded. If the data are read from a display and hand-copied on a form, the readings should be checked and confirmed by another person if possible. It is recommended that blank data logging and collection forms be printed in advance for noise data, meteorological data, traffic counts, and site data. The forms can easily be designed for various types of measurements or specific studies using word processing or spreadsheet software. Specifically, the following items should be documented:

- **Noise Measurement Sites:** A sketch should be made showing the microphone location in relation to natural or artificial landmarks. Distances should be shown to the nearest foot to such features as building corners, trees, street signs, curbs, and fences. Enough detail should be included on the sketch to enable anyone to reoccupy, at a later date, the three-dimensional (including height above ground) position of the microphone within 1 foot horizontally and 0.5 foot vertically. Accurate three-dimensional relationships between source and site should be shown. Cross sections should be obtained from accurate maps or field surveys. Sites should be located on maps showing all receivers used in the noise analysis. Global positioning system (GPS) coordinates should be noted at each position. Photo documentation is also recommended. Many digital cameras and smart phones are capable of taking pictures that are automatically geo-tagged. The district, county, route number, and post mile of the site should be included.
- **Noise Measurements:** All instruments used for the noise measurements should be recorded, including manufacturer, model number, and serial number. Also important are the calibrator make, model, serial number, reference level, frequency, and last calibration date. Names of instrument operators and persons recording the data should be shown. Pre- and post-calibration data should be shown. Site number, date, time, length of measurement, noise descriptor, pertinent settings on the sound level meter/recorder system, and noise data should be recorded. Remarks, notes of contamination, or anything that might have a possible effect on the measurement results should be included.

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- **Meteorological Conditions:** Prevailing wind direction and speed during the noise measurements, temperature, relative humidity, and sky conditions should be noted. Approximate height, and location of measurements should be indicated. Date, time, site number, and name of observer should be shown also.
- **Traffic Counts:** The number of vehicles broken down by classification should be shown. It is important to indicate the location of traffic counts, number of lanes or lane groups counted, direction, length of time, time, district, county, route, post mile, names of personnel, and counts and speeds.

Care must be taken so that enough information to make necessary cross references between noise measurements, traffic counts, weather, and site information can be made later if necessary.

3.6 Meteorological Constraints on Noise Measurements

Meteorological conditions can affect noise measurements in several ways. At an ambient noise level of 40 to 45 dBA, wind speeds of more than 11 mph may begin to contaminate noise measurements with a rumbling noise because of frictional forces on a microphone covered with a wind screen. Without the screen, the effect would be present at a much lower wind speed.

Extremes in temperature and relative humidity affect critical components of sound level meters. For example, during conditions of high humidity, water condensation can form on the vibrating microphone membrane, causing a “popping” sound that can contaminate noise measurements.

Rain or snow on highway pavement can alter the levels and the frequencies of tire and pavement noise, causing it to vary in unpredictable ways from levels on dry pavements, on which vehicle noise source characteristics are based. Pavement should be dry when taking measurements. Refraction caused by wind shear or temperature gradients near the ground surface will also alter noise levels. The effects of refraction are discussed in Section 2.1.4.3. When noise levels are compared to determine the effects of a transportation project on the noise environment or to evaluate the effectiveness of a noise abatement measure, the before and after noise levels should be conducted under equivalent meteorological conditions.

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The following sections include listings of meteorological constraints on noise measurements and equivalent meteorological conditions.

3.6.1 Meteorological Criteria

Noise measurements should not be made when one or more of the following meteorological conditions exist.

- Wind speeds are more than 11 mph for routine highway noise measurements.
- Manufacturers' recommendations for acceptable temperature and humidity ranges for instrument operation are exceeded. Typically, these ranges are from 14 to 122°F for temperature and 5 to 90% for relative humidity. Heavy fog conditions usually exceed 90% relative humidity.
- There are rain, snow, or wet pavement conditions. All reported highway noise levels are assumed valid for dry pavements only.

3.6.2 Equivalent Meteorological Conditions

Wind can significantly alter noise levels. Wind effects are caused by refraction (bending) of the noise rays because of wind shear near the ground. Noise rays are bent upward upwind and downward downwind from the source, resulting in a noise decrease upwind and increase downwind from a source.

Studies by Caltrans and others have shown that this wind effect can affect noise measurements significantly even at relatively close distances to noise sources. Section 3.3.3 indicates that to compare noise measurements for agreement, all site, traffic, and meteorological conditions must be the same.

Noise measurement comparisons can therefore only be made for similar meteorological conditions. ANSI S12.8 - 1998 "Methods for Determination of Insertion Loss of Outdoor Noise Barriers" recommends that meteorological equivalence be based on wind, temperature, and cloud cover. The following criteria are recommended for atmospheric equivalence average wind velocities from the source position to the receiver position. In the case of highway noise, the wind component of interest is perpendicular to the highway. The standards recommended by ANSI may be used to define meteorological equivalency for the purposes of comparing noise levels for agreement with Section 3.3.3 or any time before and after noise measurements are performed on noise barriers.

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3.6.2.1 Equivalent Wind Conditions

Wind conditions are equivalent for noise measurements if the following conditions exist.

- The wind class (Table 3-4) remains unchanged.
- The vector components of the average wind velocity from the source to receiver (perpendicular to the highway) do not differ by more than a certain limit.

This limit depends on the accuracy desired and the distance from the source to receiver. To keep the measurement accuracy due to atmospheric wind conditions to within about 1 dB, this limit should be 2.2 mph for distances less than 230 feet. If it is desired to keep this accuracy within about 0.5 dB for the same distance, the measurements to be compared should each be repeated at least four times. The 2.2 mph limit does not apply to the "calm" condition. By convention, the perpendicular wind component blowing from the highway to receiver (microphone position) is positive, while the same component blowing from the receiver to highway is negative.

Table 3-4. Classes of Wind Conditions

Wind Class	Vector Component of Wind Velocity, mph
Upwind	-2.2 to -11
Calm	-2.2 to +2.2
Downwind	+2.2 to +11

For example, two measurements may be compared when their respective wind components are 0 and -2.2 mph, -2.2 and -4.4mph, or -5.5 and -7.7 mph, but not when their respective components are 1.1 mph and 3.3 mph, because of the change in wind class. For the purposes of comparison with the results from the FHWA TNM, which has no provisions for wind inputs and therefore predicts noise levels for calm (no wind) conditions, the perpendicular wind component needs to be between -2.2 and +2.2 mph.

Please note that the actual wind velocity (direction and speed) needs to be resolved into two components, with directions parallel and perpendicular to the highway. Then, only the perpendicular component is considered (as long as the actual wind speed does not exceed 11 mph, any wind velocity may be resolved in this manner). The component of wind velocity for a given set of acoustical measurements should be determined as follows.

- Monitoring wind velocity (speed and direction) throughout any period of acoustical measurements.

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- Noting the average speed and direction.
- Computing from these averages the vector component of wind velocity from the source to receiver (perpendicular to the highway).

3.6.2.2 Equivalent Temperature and Cloud Cover

Measurements to be compared (e.g., before or after noise barrier measurements or repeat measurements) should be made for the same class of cloud cover, as determined from Table 3-5, and with the average air temperatures within 25°F of each other.

Table 3-5. Cloud Cover Classes

Class	Description
1	Heavily overcast.
2	Lightly overcast, either with continuous sun or sun obscured intermittently by clouds 20 to 80% of the time.
3	Sunny, with sun essentially unobscured by clouds at least 80% of the time.
4	Clear night, with less than 50% cloud cover.
5	Overcast night, with 50% or more cloud cover.

3.6.2.3 Equivalent Humidity

Although there are no strict guidelines for equivalence of humidity, an attempt should be made to pair measurements for similar conditions of humidity. For example, comparisons of measurements made under extremely dry conditions (e.g., less than 25%) with those made during humid conditions (e.g., more than 75%) should be avoided.

3.7 Quality Assurance

All sound level meters and acoustical calibrators should be periodically calibrated by the manufacturer, or by a laboratory accredited to perform calibrations on specified instruments. All calibrations should be traceable to the National Institute of Standards and Technology (NIST) in Washington, DC. For legal purposes instrument manuals and calibration and repair records should be kept on file in the office of the responsible party (e.g., District office, headquarters environmental unit). Historical data on the instrument performance may be useful in determining the reliability and accuracy of the equipment.

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Section 4

Detailed Analysis for Traffic Noise Impacts

This section discusses the procedure for conducting a detailed analysis of traffic noise impacts. These procedures comply with analysis requirements of 23 CFR 772 and are consistent with standard acoustical practices.

4.1 Gathering Information

The first step in a technical noise analysis is to determine the level of detail necessary for the study, which depends on the size and nature of the project. Generally, as the size of the project, the complexity of terrain, and the population density increase, so does the amount of information and level of effort needed for an adequate noise analysis.

For the analysis, it is necessary to obtain adequate information and mapping showing project alternatives and their spatial relationships to potentially noise-sensitive areas. A "no build" alternative should be included. Early in the project, final design details usually are not available, and additional analyses may need to be performed as more details are introduced. Topographical information may also be limited in early stages of project design. Field reviews, recent aerial photographs, and online geographic data may be necessary to augment information shown on preliminary maps. Design-year traffic information for all project alternatives is also required for the analysis. Traffic count data for all state highways is available for downloading from the Caltrans website at:

http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm

4.2 Identifying Existing and Future Land Use and Applicable Noise Abatement Criteria

Existing and reasonably expected future activities on all lands that may be affected by noise from the highway must be identified (see the Protocol for details on how various land use types are addressed). Existing

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activities, developed lands, and undeveloped lands which have been permitted for development that may be affected by noise from the highway must be identified. Land development is considered to be permitted on the date that the land use (subdivision, residences, schools, churches, hospitals, libraries, etc.) has received all final discretionary approvals from the local agency with jurisdiction, generally the date that the building permit or vesting tentative map is issued. This information is essential to determine which NAC apply for determining traffic noise impacts. The NAC are shown in Table 4-1.

Table 4-1. Activity Categories and Noise Abatement Criteria (23 CFR 772)

Activity Category	Activity $L_{eq}[h]$[a]	Evaluation Location	Description of Activities
A	57	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B[b]	67	Exterior	Residential.
C[b]	67	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E	72	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties, or activities not included in Activity Categories A–D or F.
F			Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G			Undeveloped lands that are not permitted for development of a specific use.

[a] The $L_{eq}(h)$ activity criteria values are for impact determination only and are not design standards for noise abatement measures. All values are A-weighted decibels (dBA).

[b] Includes undeveloped lands permitted for this activity category.

23 CFR 772 requires that a minimum of one receiver be placed in all areas within a project area that are associated with Activity Categories A, B, C, D, and G. Undeveloped Activity Category

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G areas are included because FHWA wants to provide a record of predicted future noise levels to local agencies so that these noise levels can be considered in future land use planning.

If there are no exterior use areas at an Activity Category E use it is not necessary to include a receiver in that area. Similarly, it is not necessary to include a receiver at an Activity Category F use. Receivers are not required for these areas because these uses are already developed and it is not necessary to inform local planning agencies about future noise levels in these areas.

4.3 Determining Existing Noise Levels

Existing noise levels may be determined at discrete locations in the project area by actual noise measurement (see Section 3) or using the TNM (see Section 4.5.1). The latter is usually the case. This section discusses how to select these locations, the methods used to determine existing noise levels, and how to "calibrate" the noise prediction model with measurements where appropriate.

4.3.1 Selecting Noise Receivers and Noise Measurement Sites

For the purposes of noise analysis, a noise receiver is any location included in the noise analysis. A noise measurement site is a location where noise measurements are taken to determine existing noise levels, and verify or calibrate the noise prediction model. Receivers and noise measurement sites may or may not coincide. Normally, there are more receivers than noise measurement sites. It is far less expensive to model (calculate) noise levels for receivers than to take noise measurements in the field. If the project involves the reconstruction of an existing facility, existing noise levels are measured at representative receivers and compared with modeled results for the conditions observed during the measurement. The difference between modeled and measured results may then be applied to the results for modeled future conditions. This process, called model calibration, is fully described in Section 4.4.

4.3.1.1 Receptors and Receivers

In the context of a 23 CFR 772 analysis the term *receptor* means a single dwelling unit or the equivalent of a single dwelling unit. A *receiver* is a single point in a noise model that can represent one receptor or multiple receptors. Within the identified land use activity categories adjacent to the project, there are typically numerous noise receptors that need to be

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analyzed for future noise impacts or benefits from noise abatement under consideration. It is not reasonable or possible to examine these factors at all receptors. Therefore, modeling receivers should be carefully selected to accurately represent one or more receptor locations. Some general recommendations for selecting receivers are listed below.

- Although noise impacts must be evaluated at all developed land uses, receiver locations should focus on areas of frequent human use (defined in the Protocol glossary).
- The TNM has been validated at distances within 500 feet of the highway. Receptors that are located beyond 500 feet from the project area do not need to be considered for analysis unless there is a reasonable expectation that noise impacts would extend beyond that boundary. This may require engineering judgment and supplemental noise measurements to determine impacts.
- Generally select receivers in locations that are receiving or are expected to receive the highest noise levels over the period covered by the analysis. Because in most cases impacts will be at receivers closest to the highway, most receivers should be in the first row of residences relative to the project alternative. Some common exceptions include the following.
  - Projects where realignment would move the noise sources toward receptors other than those adjacent to the existing alignment.
  - Projects involving geometry where the first row of homes is partially shielded and second-row homes actually may receive higher noise levels (e.g., roadways on high embankments).
  - Areas near the ends of proposed barriers where second- or third-row receptor sites may be needed to better define the barrier limits.
  - Projects that involve widening where additional right-of-way requirements may clear the first row of residences and turn the second row into the first.
- A noise measurement site should coincide with a modeling receiver whenever possible. However, this often may not be the case. The selected receiver location may not be a good or accessible location for setting up a sound level meter. In that case, a noise measurement site that is acoustically representative of the receiver should be selected in a more accessible location.
- Other noise-sensitive locations, such as libraries, churches, hospitals, and schools, should be included.
- Receivers that are acoustically equivalent of the area of concern should be chosen. The concept of acoustical equivalence incorporates equivalencies in noise sources (traffic), highway cross sections,

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distance from the highway, topography of intervening terrain, shielding, and other pertinent factors. The region under study may need to be subdivided into subregions in which acoustical equivalence generally can be maintained. One or more of the previously mentioned acoustical factors should dictate boundaries of each subregion. The size of subregions may vary depending on the scope of the project.

- A minimum of two receivers should be selected for each acoustically equivalent region or subregion. The actual number necessary to define noise impacts depends not only on the type of project, but also on such influences as complexity of the highway profile and variability of the surrounding terrain. A highway with a straight grade or very shallow vertical curves in a relatively flat area with tract-type residential development that parallels the highway may need only a few receivers to adequately define the noise impacts. However, a project involving a major freeway that includes interchanges, cuts and fills in an area of rolling terrain, and non-tract mixed residential and commercial development is likely to need more receivers.
- Receivers are placed 5 feet above the ground elevation, unless dictated by unusual circumstances, special studies, or other requirements. Exceptions would include placing a receiver 5 feet above a wooden deck of a house situated on a steep slope, instead of 5 feet above the ground. Similar situations might be encountered where residential living areas are built above garages, where second-story levels would be more logical receiver locations.
- Noise should be evaluated at second-story elevations or at higher elevations in the case of multistory buildings when there are exterior areas of frequent human use at the higher elevations that could benefit from noise reduction. Examples include large patios or decks that are the primary outdoor use area in an apartment complex. Clearly, it will not be feasible or reasonable to construct a wall that protects a receiver location several stories above a freeway. There may, however, be situations where an upper story of a building is at the same elevation as the highway (i.e., the highway is on a fill section). In this case, it may be both feasible and reasonable to build a wall to reduce noise at the upper stories.
- To determine the number of benefited receptors (defined in the Protocol glossary), it is usually necessary to include receivers in the first, second, and third rows of residences (or beyond in some cases) in the noise analysis.

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4.3.1.2 Noise Measurement Sites

The selection of noise measurement locations requires planning and foresight by the noise analyst. A fine balance should be achieved between a sufficient number of quality locations and the cost and availability of resources. Preliminary design maps, cross sections, aerial photographs, and field survey data are all helpful sources of information for selecting noise measurement sites, but the sites should be selected only after a thorough field review of the project area. Some recommended site characteristics common to all outside noise measurement sites are listed below.

- Sites should be clear of major obstructions. Reflecting surfaces such as walls of residences should be more than 10 feet from the microphone positions.
- Sites should be free of noise contamination by sources other than those of interest. Sites located near barking dogs, lawn mowers, pool pumps, air conditioners, etc. should be avoided unless it is the express intent to measure noise from these sources.
- Sites should be acoustically representative of areas and conditions of interest. They should either be located at or represent locations of frequent human use.

In addition to these general requirements, the selection of noise measurement sites is governed by the same general guidelines as those for selection of receivers in Section 4.3.1.1. Of particular importance is the concept of acoustical equivalence for representativeness of the area of concern. More detailed considerations are discussed in Section 3.2.

4.3.2 Measuring Existing Noise Levels

When possible, existing noise levels should be determined by field measurements. As with all field work, quality noise measurements are relatively expensive, requiring time, personnel and equipment. The noise analyst should carefully plan the locations, times, duration, and number of repetitions of the measurements before taking the measurements. Meteorological and other environmental conditions can significantly affect noise measurements. Particular attention should be given to the meteorological and environmental constraints described in the Section 3.6.

In the noise analysis for a project, the noise measurements are used to determine existing ambient and background noise levels, and to calibrate the noise prediction model when appropriate. Section 3 provides details of noise measurement methods.

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4.3.3 Modeling Existing Noise Levels

Noise levels near existing facilities can also be determined by modeling. Although measurements are preferred, adverse environmental conditions, construction, unavailability of good measurement sites, or lack of time may make it necessary to calculate existing noise levels using TNM. However, this can only be done in areas where a defined highway source exists with minimal influence from traffic on other roads in the area or other contaminating noise sources.

Often, a combination of measurements and modeling at various receivers is used to determine existing noise levels. In addition to the measurement sites, additional receivers are modeled to establish better resolution of existing noise levels. Measurements are used in a process called model validation and calibration, which is discussed in the following section. This process can be applied to the additional modeled receivers for determining existing noise levels at a greater resolution. Model validation and calibration ensure that existing noise levels at the measured and modeled receptors are in reasonable agreement.

4.4 Validating/Calibrating the Prediction Model

The main purpose of modeling is to predict future noise levels. The computer model (TNM) and procedures used to predict future noise levels are discussed in Section 4.5. However, as mentioned in Section 4.3, TNM also can be used for modeling existing noise levels where measurements are not possible or undesirable because of lack of access or local environmental conditions. In both cases, the model should be validated with measurements and calibrated if necessary. This section, which discusses the model validation/calibration procedures that rely on measurements and modeling, should be used with Section 4.5. However, for convenience, all information needed except for running the model is contained in this section.

TNM cannot account for all the variables present in the real world. It uses relatively simple algorithms to approximate physical processes that are complex in nature. TNM for projects involving existing roadways should always be validated for accuracy by comparing measured sound levels to modeled sound levels using traffic data collected during the measurement. If modeled sound levels do not match measured sound levels within ±3 dB the model parameters should be reviewed and adjusted if necessary to ensure that they accurately represent actual site conditions. If the measurements and model results are still not in agreement, the model should be calibrated.

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This section discusses the model calibration process. Section 4.4.1 addresses model calibrations that are routinely performed by Caltrans. The procedures for these are straightforward but rely on sound judgment and place a heavy burden on quality noise measurements.

4.4.1 Routine Model Calibration

4.4.1.1 Introduction

The purpose of model calibration is to fine-tune the prediction model to actual site conditions that are not adequately accounted for by the model. In general, model calibrations are recommended if the site conditions, highway alignment, and profile in the design year relative to existing conditions are not expected to change significantly.

Model calibration is defined as the process of adjusting calculated future noise levels by algebraically adding a calibration constant derived from the difference between measured and calculated noise levels at representative sites. The difference—calibration constant, K-constant, or *K*—is defined as measured noise level *M* minus calculated noise level *C*, or $K = M - C$. Please note that *K* is positive when *M* is greater than *C*, and *K* is negative when *M* is less than *C*. In this section, a distinction will be made between calculated and predicted noise levels as follows:

- Calculated noise levels (existing or future) are the results of the model.
- Predicted noise levels are adjusted or calibrated calculated values.

4.4.1.2 Limitations

Highways constructed along new alignments and profiles do not lend themselves to model calibration. The site before project construction does not include the new highway. Ambient noise levels are generated by typical community noise sources, such as lawn mowers, air conditioners, and barking dogs, which cannot be modeled with TNM.

Highway reconstruction projects that significantly alter alignments and profiles of an existing highway are also poor candidates for model calibration. However, predictions of future noise levels for simple highway widening projects, design of retrofit noise barriers, or other improvements that do not significantly change highway alignment or profile are good candidates for model calibration as long as other site conditions do not change.

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4.4.1.3 Pertinent Site Conditions

To determine whether the model can be calibrated successfully, the site conditions that are allowed to change between the present and the expected life of the project should be examined first. For this purpose, site conditions should be divided into two groups:

- **Group 1:** Site conditions that can be accounted for by the model, which include the following.
  - Traffic mix, speeds, and volumes.
  - Noise dropoff rates, terrain conditions, ground types, and distances.
  - Opaque barriers (noise transmission through barrier material may be ignored [i.e., high transmission loss]).
  - Roadway and barrier segment adjustments.
  - Receptor locations.
  - Grade corrections.
  - Pavement type.

  Note that FHWA policy requires the use of the "average" pavement type for design year traffic noise predictions. Alternative pavement types such as dense-graded asphaltic concrete (DGAC), Portland cement concrete (PCC), and open-graded asphaltic concrete (OGAC) can be used in the model validation process if actual existing pavements are one of these types of alternative pavements.
- **Group 2:** Site conditions that cannot be accounted for by the model and therefore are ignored, although they affect the local noise environment. These include the following.
  - Non-typical vehicle noise populations such as farm equipment, recreational vehicles, or vehicles with studded snow tires or aggressive tread (i.e., designed for mud and snow conditions).
  - Transparent shielding (noise transmission through material is significant [i.e., low transmission loss], and such materials include wood fences with shrinkage gaps [noise leaks] and areas of heavy brush or trees).
  - Reflections off nearby buildings and structures.
  - Meteorological conditions.

For the purposes of model validation and calibration, Group 1 site conditions are allowed to change somewhat. The degree to which conditions can change is a judgment call and is discussed further in

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Section 4.4.1.5. Group 2 site conditions, however, are not allowed to change. These conditions affect noise levels to an unknown extent but are ignored by the model. As long as they remain constant during the entire analysis period, they may be corrected for with *K*. If they change at some point in the future, however, *K* also must change by an unknown amount, and model calibration becomes invalid.

Some cautions and challenges associated with Groups 1 and 2 site conditions are discussed in Section 4.4.1.5. First, however, the calibration procedures will be explained.

4.4.1.4 Procedures

The actual mechanics of model calibration are fairly straightforward.

1. Select locations along the existing highway that are representative of the area of interest.
2. Take noise measurements at these locations and count traffic, preferably during the peak noise hour. If this is not possible, select any other time during which traffic mix and speeds (not necessarily volumes) are roughly similar to the noisiest time. This may be estimated. Typically, this condition occurs during daytime whenever traffic is free-flowing.
3. Calculate the noise levels with the prediction model using the traffic counts (expanded to 1 hour), site geometry, and any other pertinent existing features.
4. Compare measured and calculated noise levels. If these values differ by more than 3 dB check traffic data and model parameters to ensure they represent actual site conditions. If the values continue to differ by more than 3 dB then calibrate the model using the difference. The difference, *K*, is determined as follows:

$$K = \text{Measured} - \text{Calculated, or } K = M - C \quad \textbf{(4-1)}$$

Add K to the future calculated noise levels to obtain predicted noise levels *P*:

$$P = C + K \quad \textbf{(4-2)}$$

The following illustrates the mechanics of the calibration procedure with some typical values.

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Example

Existing Noise Levels (L_{eq}[h], dBA)	Future Noise Levels (L_{eq}[h], dBA)
73 (C_1)	75 (C_2)
70 (M)	? (P_1)

$K = M - C_1 = 70 - 73 = -3$ dBA

$P_1 = C_2 + K = 75 + (-3) = 72$ dBA

The predicted future noise level is 72 dBA. In essence, although the model calculated the future noise level to be 75 dBA, it is expected that the actual future noise level will be 72 dBA, possibly because of the inability of the model to account for existing obstacles or other site features that attenuate noise.

4.4.1.5 Cautions and Challenges

Section 4.4.1.3 indicated that Group 1 conditions (those conditions that can be accounted for in the model) are allowed to vary. Experience has shown that significant changes in traffic volumes, speeds, and mix, as well as shielding by barriers more than 6 feet high and segment adjustments within the range normally encountered, can be accounted for adequately by the model. The main problem areas in Group 1 site conditions pertaining to model calibrations are differences in source-to-receiver distances and low barriers.

First, distances should be considered. No model can satisfy all conditions encountered in the real world. Therefore, *K* tends to be at least somewhat distance-dependent. This has two major implications for the calibration process.

- Source-to-receiver distances, their relative heights, and the groundcover between them should not change significantly during the analysis period. Slight changes in distances (e.g., from widening projects) or even slight changes in profile or receiver height are permissible. Also, the differences between ground effects before and after construction of a noise barrier appear to be adequate in the model.
- Receivers need to be selected for several representative distances to include the effects of propagation inaccuracies in *K*. Each receiver may have a different *K*. The user must decide on their radius of influence and whether to group some *K*'s together (if they are close enough). This is clearly a matter of judgment based on experience.

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The second Group 1 challenge relates to attenuation from low ground features or barriers. Although it is Caltrans' policy to build barriers that are at least 6 feet high, it is possible that the existing condition includes a low rise in terrain, a hinge point, or a low barrier. Because these features will result in some degree of attenuation, it is important to include these low ground features or barriers in the model if calibration is going to be conducted. Meteorology is one of the major challenges in Group 2 site conditions. The effects of wind speed and direction or temperature inversions on noise levels at a receiver can be substantial, even at relatively short distances from a highway. (Refer to Section 2.1.4.3 for more details on these effects.) Because the prediction model does not take weather into consideration, noise measurements should be taken under calm wind conditions. Strong temperature inversion conditions should be avoided as well. Temperature inversion conditions can occur during warm summer and fall months with cool morning conditions. Section 3.6 discussed the criteria for identifying calm winds. Any attempt to calibrate the model for a prevailing wind condition is only valid for that condition. Noise standards, however, are not linked to weather.

Finally, noise contamination from other sources not considered by the model cannot be corrected by model calibration, as illustrated in the following hypothetical case. In this case, at a calibration site, the existing measured noise level is 68 dBA. This freeway noise level is contaminated by nearby surface streets and other neighborhood noises and the freeway contribution and background noise cannot be separated from the measurement. It is not known that the freeway traffic and background noise contribute 65 dBA each, for a total of 68 dBA. The existing noise level from the freeway was calculated to be 65 dBA, which happens to agree with the actual freeway contribution. There is no reason to believe that the background noise will change in the future. Therefore, the model is incorrectly calibrated. The calculated future noise level is 70 dBA. However, the predicted future level must be determined. This problem is outlined below.

Existing Noise Levels	**Future Noise Levels**
Freeway: 65 dBA (unknown)	Freeway: 70 dBA (unknown)
Background: 65 dBA (unknown)	Background: 65 dBA (unknown)
Total: 68 dBA (measured)	Total: 71 dBA (actual)
Freeway: 65 dBA (calculated)	Freeway: 70 dBA (calculated)
K = M – C = 68 – 65 = 3	Freeway: ? dBA (predicted)

Predicted Freeway

$$P = C + K = 70 + 3 = 73 \text{ dBA}$$

(Compared with 71 dBA actual)

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In this situation, the calibration process caused an overprediction of 2 dBA, although the background remained the same during the analysis period. Therefore, background noise high enough to contaminate the noise measurements cannot be considered a Group 1 or 2 site condition. In short, it represents a site condition that precludes the use of model calibration.

Noise measurement sites should be carefully selected to eliminate as many Group 2 site conditions as possible and to avoid any contamination. Contamination occurs when the sound level of an undesired noise source is within 10 dBA of the noise source of interest. A quick check for contamination can be performed by viewing the instantaneous sound level on a sound level meter. If the meter responds at all to fluctuations of the undesired source, the noise level likely will be contaminated.

4.4.1.6 Tolerances

Model accuracy is usually sufficient when the difference between measured and model sound levels is less than 3 dB. Because of the inherent uncertainties in the measurements and calibration procedures, model calibration should not be attempted when calculated and measured noise levels agree within 1 dBA. If there is great confidence in the accuracy and representativeness of the measurements, calibration may be attempted when calculated noise levels are within 2 dBA of the measured values. Differences of 3 to 4 dBA may routinely be calibrated unless the validity of the measurements is in serious doubt. Differences of 5 dBA or more should be approached with caution. The analyst should retake measurements, look for obvious causes for the differences (e.g., weather, pavement conditions, obstructions, reflections), check traffic and other model input parameters (and remember to expand traffic counted during the noise measurement to 1 hour), and confirm that the traffic speeds are accurate. If differences of 5 dBA or more still exist after confirming the measurements and input parameters, the decision about whether to calibrate the model should be made after determining whether any of the responsible Group 2 site conditions will change during the project life.

4.4.1.7 Common Dilemmas

The following hypothetical cases present some common dilemmas the noise analyst may need to resolve when selecting model calibration sites. In one case, a receiver was selected in a backyard abutting a freeway right-of-way. The only obstacle between the receiver and the freeway is a 6-foot-high wood fence running parallel to the freeway. The fence boards are standard ½ - by 6-inch boards with shrinkage gaps between them. The

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question is whether this receiver should be used for model calibration measurements.

There is no clear-cut answer. If the fence is new and expected to remain in good condition for about the next 20 years and no noise barrier is planned, this probably would be a good representative location to measure existing noise levels and predict model-calibrated future noise levels for all the backyards bordering the right-of-way.

In another case, the predicted (calibrated) noise level at this receiver is high enough to qualify for a noise wall. Before the wall is constructed, the existing fence provides transparent shielding, a Group 2 site condition. After the wall is constructed, however, any effect from the fence will be eliminated, regardless of whether the fence remains (i.e., the effects of a Group 2 site condition change). In this case, the location would be a bad choice for model calibration.

In many cases, it is uncertain whether noise levels are high enough to justify noise barriers until the noise is measured. There are also no assurances of the longevity of wooden backyard fences. In the preceding case (and for wooden privacy fences in general), it is good policy to pick for calibration purposes locations on the freeway side of the fence or on a side street that dead-ends at the freeway right-of-way. Similar situations may exist in areas of heavy shrubs or dense woods.

Shielding by a solid barrier such as by a masonry block wall of at least 6 feet in height, can be adequately addressed by the model and does not represent a problem in the calibration process.

4.5 Predicting Future Noise Levels

After determining the existing noise levels, future noise levels are predicted for all project alternatives under study for the analysis period. This information is needed to determine whether any of the alternatives are predicted to result in traffic noise impacts. The traffic noise prediction procedures are specified in 23 CFR 772. FHWA requires that all new project noise studies be evaluated using the federally approved TNM. An exception to this requirement may occur for a reevaluation noise study of a project that was originally analyzed using an earlier noise model. Any decision to use an earlier noise model should be reviewed and approved by Caltrans headquarters noise staff. Refer to the 2009 version of TeNS for a detailed discussion of previous noise models.

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4.5.1 FHWA TNM Overview

The FHWA TNM was released on March 30, 1998. FHWA mandated that all new federal-aid highway projects that begin after January 15, 2006, be evaluated using TNM. TNM Version 2.5 is the current version as of the publishing of this document. *Federal Highway Administration Traffic Noise Model* and *FHWA TNM* are a registered copyright and trademark. This provides FHWA with the exclusive right to use these names. The copyright and trademark encompass the user's guide, technical manual, software source, and executable codes.

The following sections provide a brief overview of TNM. For detailed information, the technical manual and user's guide should be consulted. Refer to the following FHWA website for current information and guidance on TNM:

http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_v25

Additional detailed technical guidance from FHWA is available at the following website:

http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/

4.5.1.1 TNM Reference Energy Mean Emission Levels

TNM computes highway traffic noise at nearby receivers and aids in the design of noise barriers. The noise sources include an entirely new database of 1994–1995 REMELs that is detailed in *Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM), Version 1.0* (Fleming et al. 1995). The database includes speed-dependent emission levels for constant speeds on level roadways from idle to 80 mph, for the following vehicle types.

- **Automobiles:** all vehicles having two axels and four tires—designated primarily for transportation of nine or fewer passengers, i.e., automobiles, or for transportation of cargo, i.e., light trucks. Generally with gross vehicle weight less than 9,900 pounds.
- **Medium Trucks:** all cargo vehicles with two axles and six tires—generally gross vehicle weight is greater than 9,900 pounds but less than 26,400 pounds.
- **Heavy Trucks:** all cargo vehicles with three or more axles—generally with gross vehicle weight greater than 26,400 pounds.

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- **Buses:** all vehicles having two or three axles and designed for transportation of nine or more passengers.
- **Motorcycles:** all vehicles with two or three tires with an open-air driver/passenger compartment.

TNM contains the following pavement types.

- DGAC.
- PCC.
- OGAC.
- Average: a combination of both DGAC and PCC pavements which is comprised of, on average, approximately 75% DGAC pavement and 25% PCC pavement.

TNM defaults to *average* for pavement type. The use of any other pavement type must be substantiated and approved by FHWA. Therefore, unless definite knowledge is available on the pavement type and condition and its noise-generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels.

In addition, the database includes data for the following.

- Vehicles on grades.
- Three different pavements (DGAC, OGAC, and PCC).
- Accelerating vehicles.
- Acoustic energy apportioned to two subsource heights above the pavement (0 feet and 5 feet for all vehicles, except for heavy trucks, where the subsource heights are 0 feet and 12 feet).
- Data stored in one-third-octave bands.

The TNM Baseline REMEL curves shown in Figure 4-1 were plotted from the following TNM Baseline equations:

$$\text{Speed} = 0 \text{ (idle)}: L(s_i) = 10\log_{10}(10^{C/10}) \quad \textbf{(4-3)}$$

$$L(s_i) = C \quad \textbf{(4-4)}$$

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$$\text{Speed} > 0: L(s_i) = 10\log_{10}[(0.6214s_i)^{A/10} + 10^{B/10} + 10^{C/10}] \quad \textbf{(4-5)}$$

Where:

$L(s_i)$ = REMEL for vehicle type *i* at speed *s* in kilometers per hour

s_i = speed of vehicle type *i* in kilometers per hour

A, B, C are constants for each vehicle type, shown below (Table 4-2)

Note: For speeds in miles per hour omit 0.6214 in Equation 4-5.

Table 4-2. TNM Constants for Vehicle Types

	Constants		
Vehicle Type	A	B	C
Autos	41.740807	1.148546	50.128316
Medium trucks (two axles, dual wheels)	33.918713	20.591046	68.002978
Heavy trucks (three axles)	35.879850	21.019665	74.298135

Note: Baseline REMELs = REMELs for the following conditions.

- Average pavement (average for all pavements in the study, including PCC, DGAC, and OGAC).
- Level roadways (grades of 1.5% or less).
- Constant-flow traffic.
- A-weighted, total noise level at 50 feet.

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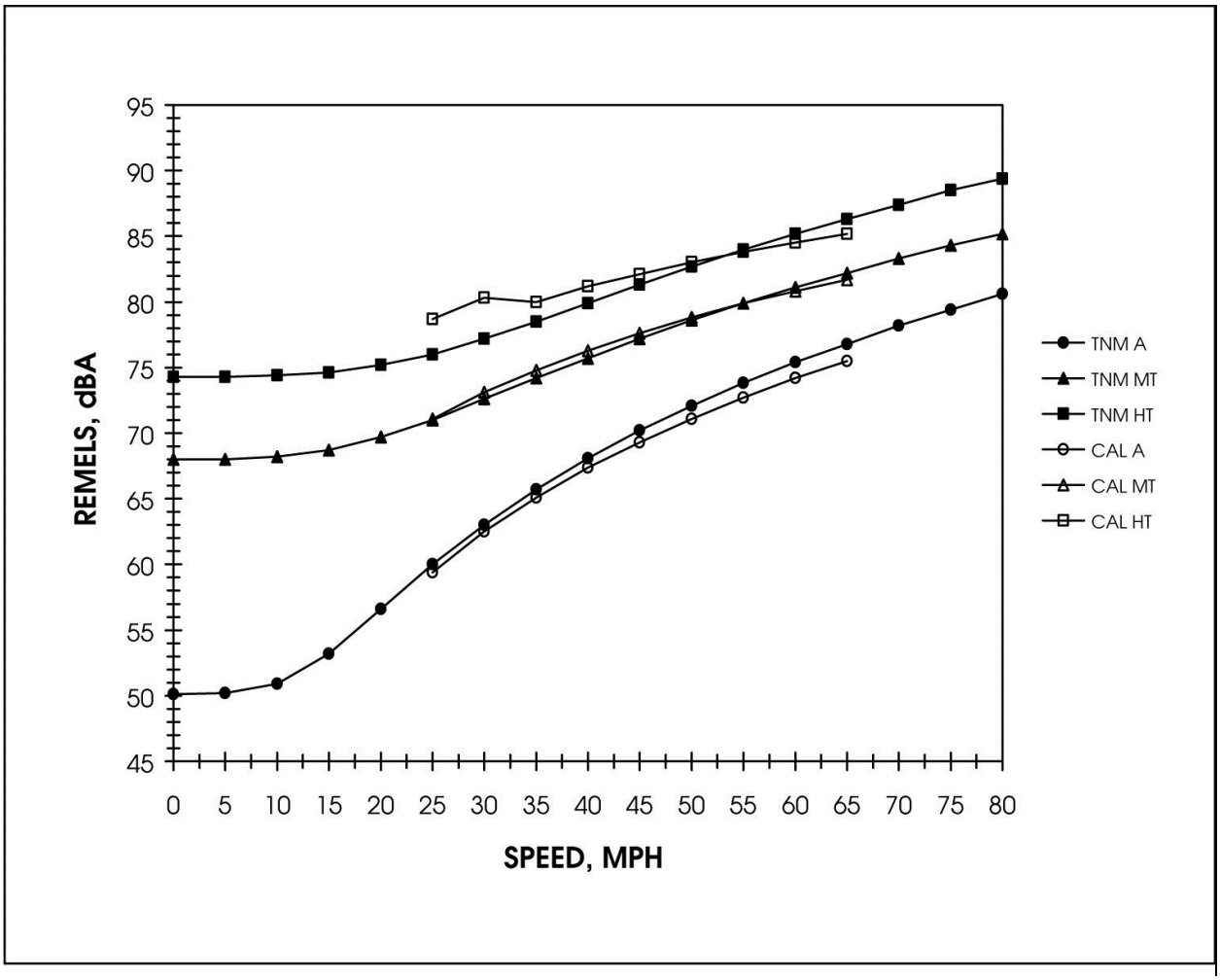

Figure 4-1. A-Weighted Baseline FHWA TNM REMEL Curves

4.5.1.2 Noise Level Computations

TNM calculations of noise levels include the following components.

- Three noise descriptors (L_{eq}[h], L_{dn}, and CNEL—see Section 2.2.2.2).
- Capability of inserting traffic control devices, including traffic signals, stop signs, tollbooths, and on-ramp start points (the TNM calculates vehicle speeds and emission levels, and noise levels accordingly).
- Computations performed in one-third-octave bands for greater accuracy (not visible to users).
- Noise contours if specified.

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Roadways and roadway segments define noise source locations (x-y-z coordinates). Hourly traffic volumes determine the noise characteristics of the source.

4.5.1.3 Propagation, Shielding, and Ground Effects

The TNM incorporates sound propagation and shielding (e.g., noise barriers) algorithms, which are based on research of sound propagation over different ground types, atmospheric absorption, and shielding effects of noise barriers (including earth berms), ground, buildings, and trees. However, the TNM does not include the effects of atmospheric refraction, such as varying wind speed and direction or temperature gradients. TNM propagation algorithms assume neutral atmospheric conditions (zero wind speed, isothermal atmosphere). The propagation algorithms can use the following user input information.

- Terrain lines (x-y-z coordinates) define ground location. Source and receiver heights above the ground are important in noise propagation.
- Ground zones (x-y-z coordinates) define perimeters of selected ground types. Ground type may be selected from: a ground-type menu (e.g., lawn, field grass, pavement), specified default, or user input flow resistivity (if known).
- Berms may be defined with user-selectable heights, top widths, and side slopes. They are computed as if they are terrain lines.
- Rows of buildings (x-y-z coordinates) with percentage of area shielded relative to the roadways may be input to calculate additional attenuation.
- Tree zones (x-y-z coordinates) may be included for additional attenuation calculations if appropriate.

The propagation algorithms also include double diffraction. The net diffraction effect is computed from the most effective pair of barriers, berms, or ground points that intercept the source-to-receiver line of sight.

4.5.1.4 Parallel Barrier Analysis

TNM calculates the noise reduction provided by a barrier placed between a roadway and a receiver. If another barrier is placed on the opposite side of the roadway there is potential for multiple reflections between the two barriers to degrade the noise reduction provided by the original barrier at the receiver. (See Section 5.1.7.4 for a detailed discussion of this issue.)

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TNM cannot directly calculate the degradation in barrier performance caused by parallel barriers. There is however a separate two-dimensional module in the program that can calculate the degradation caused by multiple reflections at a single receiver for a given parallel barrier configuration. This degradation, expressed in dB, is then applied to the TNM model results for that receiver.

4.6 Comparing Results with Appropriate Criteria

After the predicted noise levels (including model calibration, if appropriate) have been determined, they should be compared with the appropriate impact criteria in the Protocol. Examination of traffic noise impacts includes comparing the following for each project alternative when appropriate.

- Predicted noise levels with existing noise levels (for "substantial increase" impacts).
- Predicted noise levels with the appropriate NAC (for "approach or exceed" impacts).
- Predicted noise level of classroom interior with 52 dBA-L_{eq}(h) (as required by California Street and Highways code).

4.7 Evaluating Noise Abatement Options

If traffic noise impacts have been identified, noise abatement must be considered. Noise abatement measures may include those listed in the Protocol. These potential measures are based on avoiding impacts, interrupting noise paths, or protecting selected receptors. If the project alternative locations are flexible, alignments and profiles can be selected to avoid sensitive receptors or reduce the noise impacts. Most often, highway alignments and profiles are selected based on other overriding factors. The construction of noise barriers is usually the most common noise abatement option available. The consideration of noise abatement described in the Protocol requires at a minimum a preliminary design of the abatement. Section 5 provides guidance on the design considerations of noise barriers.

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Section 5

Noise Barrier Design Considerations

The primary function of highway noise barriers is to shield receivers from excessive noise generated by highway traffic. Although there are other strategies for attenuating transportation-related noise, noise barriers are the most common noise attenuation option used by Caltrans.

Many factors need to be considered in the proper design of noise barriers. First, barriers must be acoustically adequate. They must reduce the noise as described by policies or standards. Acoustical design considerations include barrier material, locations, dimensions, shapes, and background noise levels. Acoustical considerations, however, are not the only factors leading to proper design of noise barriers.

A second set of design considerations, collectively labeled non-acoustical design considerations, is equally important. Noise barriers can have secondary effects related to security in surrounding areas, aesthetics, community continuity, and other non-acoustical factors. With appropriate planning and design these potential effects from noise barriers can be reduced or avoided.

The current edition of the *Highway Design Manual* Chapter 1100 should be consulted for specific noise barrier design criteria. Because these may change in the future, the discussion in this section will focus on general applications and consequences of the design criteria, not on the criteria themselves. The Caltrans Headquarters Division of Environmental Analysis should be consulted for the latest status.

The acoustical and non-acoustical design considerations in this section conform to the *FHWA Highway Noise Barrier Design Handbook* (Fleming et al. 2011).

5.1 Acoustical Design Considerations

The FHWA TNM described in Section 4 is used for determining proper heights and lengths of noise barriers. The models assume that the noise

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barriers do not transmit any sound through the barrier. Only the noise diffracted by the barrier and any unshielded segments are considered. Therefore, the material of the barrier must be sufficiently dense or thick to ensure that the sound transmission through the barrier will not contribute to the total noise level calculated by the model at the receiver.

The material, location, dimensions, and shape of a noise barrier all affect its acoustical performance. The various effects associated with these factors are discussed in Sections 2 and 4.5.

Figure 5-1 is a simplified sketch showing what happens to vehicle noise when a noise barrier is placed between the source and receiver. The original straight path from the source to receiver is now interrupted by the barrier. Depending on the barrier material and surface treatment, a portion of the original noise energy is reflected or scattered back toward the source. Another portion is absorbed by the material of the barrier, and another is transmitted through the barrier. The reflected (scattered) and absorbed noise paths never reach the receiver.

The transmitted noise continues on to the receiver with a loss of acoustical energy (redirected and some converted into heat). The common logarithm of energy ratios of the noise in front of the barrier and behind the barrier, expressed in decibels, is the TL. The TL of a barrier depends on the barrier material, primarily its weight, and the frequency spectrum of the noise source.

The transmitted noise is not the only noise from the source reaching the receiver. The straight line noise path from the source to the top of the barrier, originally destined in the direction of “A” without the barrier, now is diffracted downward toward the receiver (Figure 5-2). This process also results in a loss of acoustical energy.

Therefore, the receiver is exposed to both the transmitted and diffracted noise. Whereas the transmitted noise only depends on barrier material properties, the diffracted noise depends on the location, shape, and dimensions of the barrier. These factors will be discussed in the following sections.

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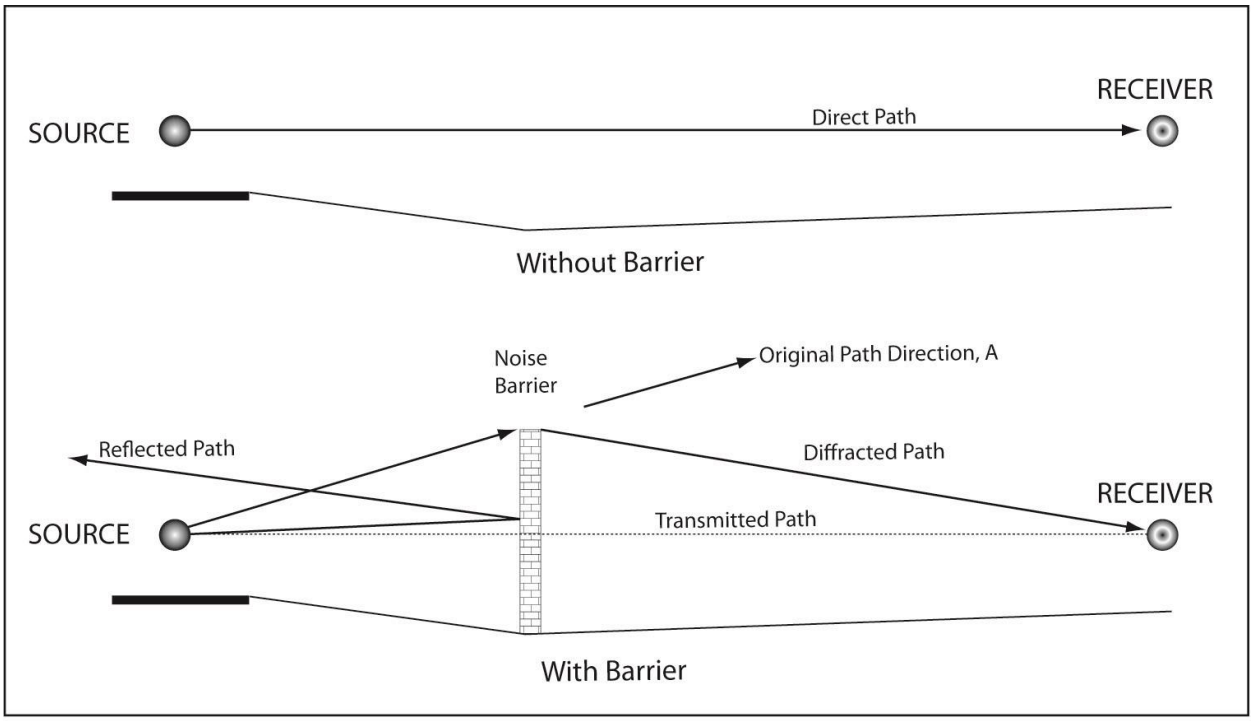

Figure 5-1. Alteration of Noise Paths by a Noise Barrier

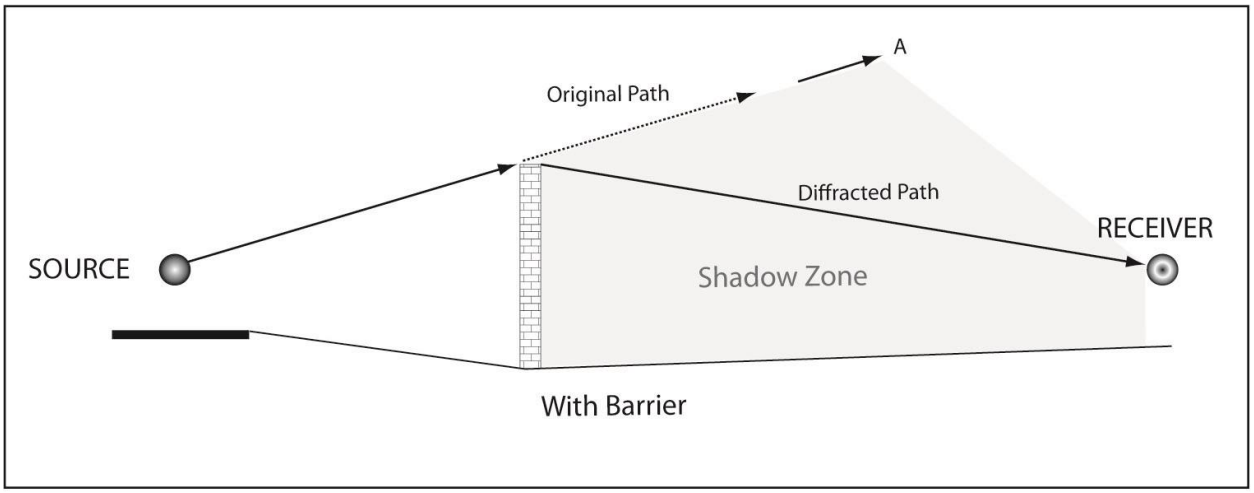

Figure 5-2. Barrier Diffraction

5.1.1 Barrier Material and Transmission Loss

For acoustical purposes, any material may be used for a barrier between a noise source and a noise receiver as long as it has a TL of at least 10 dBA more than the desired noise reduction. This ensures that the only noise path to be considered in the acoustical design of a noise barrier is the

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diffracted noise path. For example, if a noise barrier is designed to reduce the noise level at a receiver by 8 dBA, the TL of the barrier must be at least 18 dBA. The transmitted noise may then be ignored because the diffracted noise is at least 10 dBA more.

As a general rule, any material weighing 4 pounds per square foot or more has a transmission loss of at least 20 dBA. Such material would be adequate for a noise reduction of at least 10 dBA due to diffraction. Please note that this weight can be attained by a variety of material types. The denser a material is, the thinner it may be. TL also depends on the stiffness of the barrier material and frequency of the source.

In general the maximum noise reduction that can be achieved from a barrier is about 20 dBA for thin screens (walls) and 23 dBA for berms. Therefore, a material that has a TL of 33 dBA (23 + 10) or more would be adequate for a noise barrier in most situations.

Table 5-1 gives approximate TL values for some common materials, tested for typical A-weighted traffic frequency spectra. They may be used as a rough guide in acoustical design of noise barriers. For accurate values, material test reports by accredited laboratories should be consulted. These product specifications can usually be provided by the manufacturer.

Table 5-1. Approximate Transmission Loss Values for Common Materials

Material	Thickness (Inches)	Weight (Pounds per Square Foot)	Transmission Loss (dBA)
Concrete block, 8 by 8 by 16 inches, light weight	8	31	34
Dense concrete	4	50	40
Light concrete	6	50	39
Light concrete	4	33	36
Steel, 18 gage	0.050	2.00	25
Steel, 20 gage	0.0375	1.50	22
Steel, 22 gage	0.0312	1.25	20
Steel, 24 gage	0.025	1.00	18
Aluminum, sheet	0.0625	0.9	23
Aluminum, sheet	0.125	1.8	25
Aluminum, sheet	0.25	3.5	27
Wood, fir	0.5	1.7	18
Wood, fir	1	3.3	21
Wood, fir	2	6.7	24

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Material	Thickness (Inches)	Weight (Pounds per Square Foot)	Transmission Loss (dBA)
Plywood	0.5	1.7	20
Plywood	1	3.3	23
Glass, safety	0.125	1.6	22
Plexiglas	0.25	1.5	22

Table 5-1 assumes no openings or gaps in the barrier material. However, some materials such as wood are prone to develop openings or gaps because of shrinkage, warping, splitting, or weathering. These openings decrease the TL values. The TL of a barrier material with openings can be calculated if the ratio of area of openings to total barrier area and TL of the material are known. The following formula can be used to calculate the transmission loss with the openings (TL_o):

$$TL_o = TL - 10\log_{10}(A_o * 10^{TL/10} + A_c) \quad \textbf{(5-1)}$$

Where:

TL_o = transmission loss of material with openings

TL = transmission loss of material without openings

A_o = area of openings as a fraction of the total area of the barrier

A_c = area of closed portion as a fraction of the total area of the barrier = $1 - A_o$

This method of calculation assumes that the openings or gaps are distributed uniformly over the surface of a barrier. For example, a barrier made of 2-inch-thick fir planks has openings that make up about 5% of the total area and are about equally distributed. The transmission loss of the material with these gaps can then be determined. From Table 5-1, the TL for 2-inch fir is 24 dBA. A_o is 5%, or 0.05; A_c is 1 – 0.05 = 0.95. Therefore:

$$TL_o = 24 - 10\log_{10}(0.05 * 10^{2.4} + 0.95) = \textbf{12.7, or about 13 dBA}$$

The reduced TL could affect the barrier's performance. For example, it is assumed that before the barrier the noise level was 75 dBA and the intention was to reduce noise levels by 10 dBA (i.e., the diffracted noise was to be 65 dBA, and the transmitted noise was to be 75 – 24 = 51 dBA). The total noise level would have been 65 + 51 = 65 dBA. With the gaps, however, the transmitted noise is now 75 – 13 = 62 dBA, and the total noise level is 65 + 62 = 66.8 dBA. The effectiveness of the barrier is reduced by almost 2 dBA. Instead of a designed noise reduction of 10 dBA, an actual noise reduction of only 8 dBA will be realized in this case.

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Properly treated materials will reduce or eliminate noise leakage. For example, lumber should be treated with preservatives that provide proper penetration and do not interfere with any protective coatings (e.g., paint) to be applied later. The wood also should have a low moisture content, requiring kiln drying after waterborne preservatives have been used. Wood planks should have tongue-and-groove deep enough to allow for shrinkage without gaps to maintain a high TL. Such tongue-and-groove is usually non-standard.

Several other ratings are used to express the ability of materials in specific construction configurations to resist sound transmission. Two of these are the Sound Transmission Class (STC) and Exterior Wall Noise Rating (EWNR). Both are most often used in conjunction with indoor acoustics.

STC is universally accepted by architects and engineers. The rating uses a standard contour against which the TL values in one-third-octave bands are compared in the frequency range between 125 and 4,000 Hz. The standard contour is moved up or down relative to the test curve until the sum of the differences between them is 32 dB or less, and the maximum difference at each one-third-octave center frequency is no more than 8 dB. The STC is the TL value of the standard contour at the 500-Hz center frequency.

The disadvantage of this rating scheme is that it is designed to rate noise reductions in frequencies of normal office and speech noises, not for the lower frequencies of highway traffic noise. The STC can still be used as a rough guide, but it should be pointed out that for frequencies of average traffic conditions, the STC is 5 to 10 dBA more than the TL. For example, material with an STC rating of 35 has a TL of about 25 to 30 dBA for traffic noise.

The EWNR rating scheme is different from the STC in that it uses a standard contour developed from typical highway noise frequencies. Therefore, it agrees closely with the A-weighted TL for traffic noise. The FHWA *Highway Traffic Noise: Analysis and Abatement Guidance* (Federal Highway Administration 2011) provides further useful information for calculating outdoor to indoor traffic noise reductions.

5.1.2 Barrier Location

The previous section indicated that by selecting materials with sufficient TL, noise transmitted through a barrier may be ignored because its contribution to the total noise level is negligible. The only remaining noise of concern is diffracted noise. Sections 2 and 4 discuss the basics of diffraction and barrier attenuation. The principal factor determining barrier

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attenuation is the Fresnel number, which is related to the path length difference (PLD) between the original straight line path between the source and receiver (source–receiver) and the diffracted path, described by the source, to top of the barrier, to the receiver (source–top of barrier–receiver). The greater this difference, the greater the barrier attenuation, to a limit of 20 dB for walls and 23 dB for berms. Figure 5-3 shows the PLD concept.

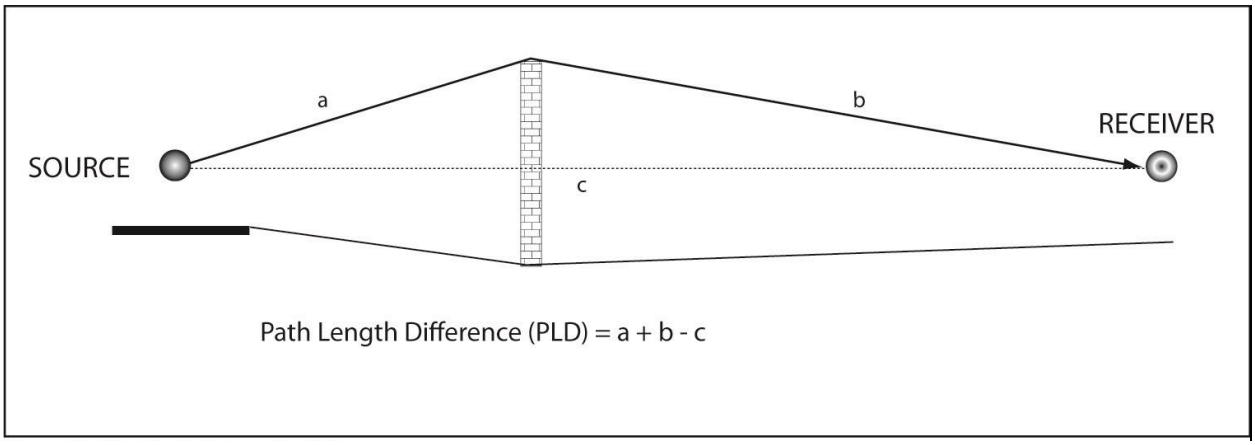

Figure 5-3. Path Length Difference

In level, at-grade roadway-receiver cross sections, a noise barrier of a given height provides greater barrier attenuation when it is placed either close to the source or close to the receiver. The least effective location would be about halfway between the source and receiver. Figure 5-4 shows these situations for two source heights (autos and heavy trucks). Location *b* gives the lowest barrier attenuations for a given barrier height.

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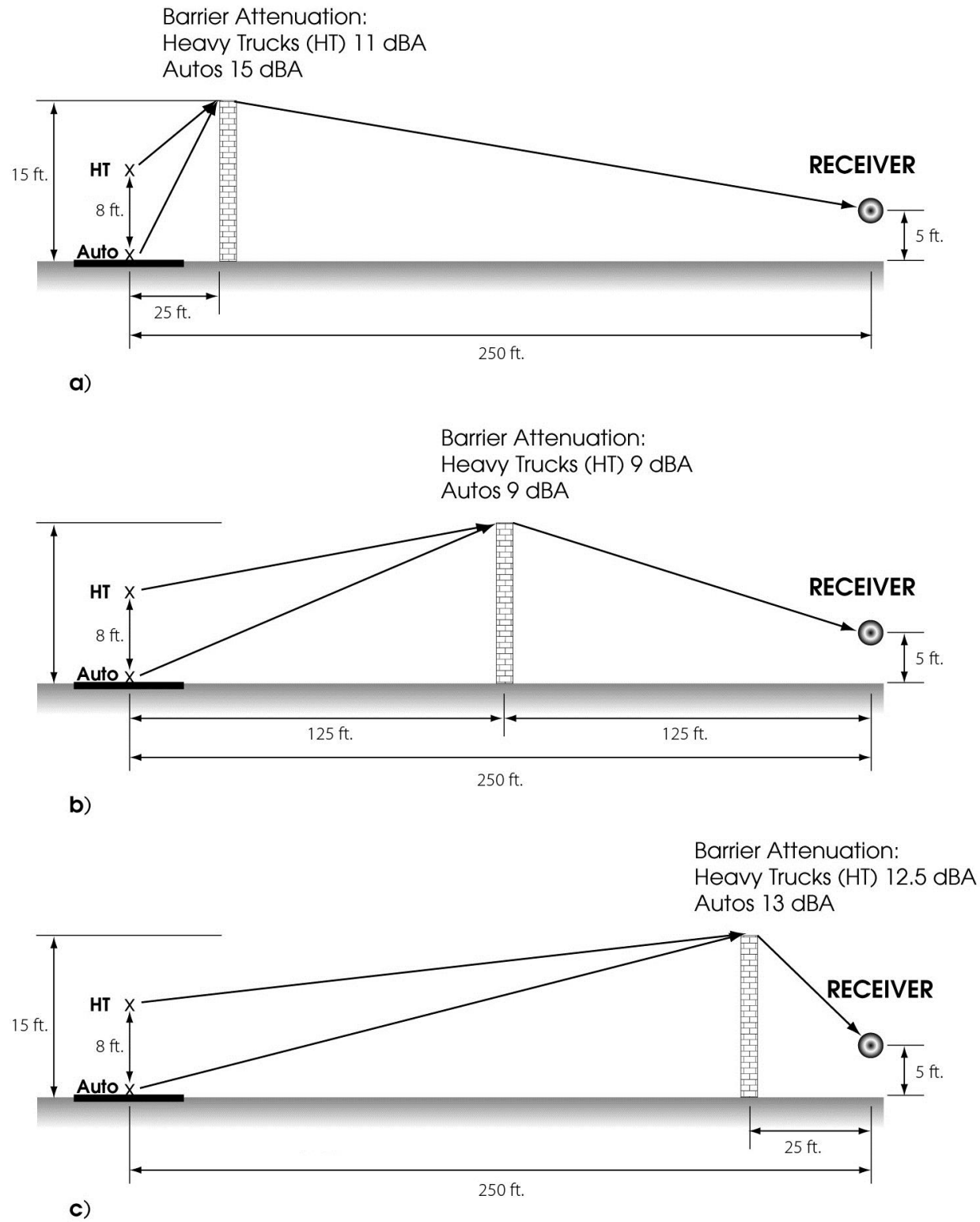

Figure 5-4. Barrier Attenuation as a Function of Location (At-Grade Highway)—Barrier Attenuation is Least When Barrier is Located Halfway between the Source and Receiver *b*; the Best Locations are Near the Source *a* or Receiver *c*

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In depressed highway sections, the barrier is most effective near the receiver on top of the cut (Figure 5-5). Please note that the without-barrier path is generally not a straight path between the source and receiver. The top of cut is already a fairly effective noise barrier. The PLD in this case is the difference between the paths described by source–top of barrier–receiver line, and source–top of cut–receiver line. The barrier attenuation is then calculated from the difference in barrier attenuation provided by the top of cut and top of the noise barrier.

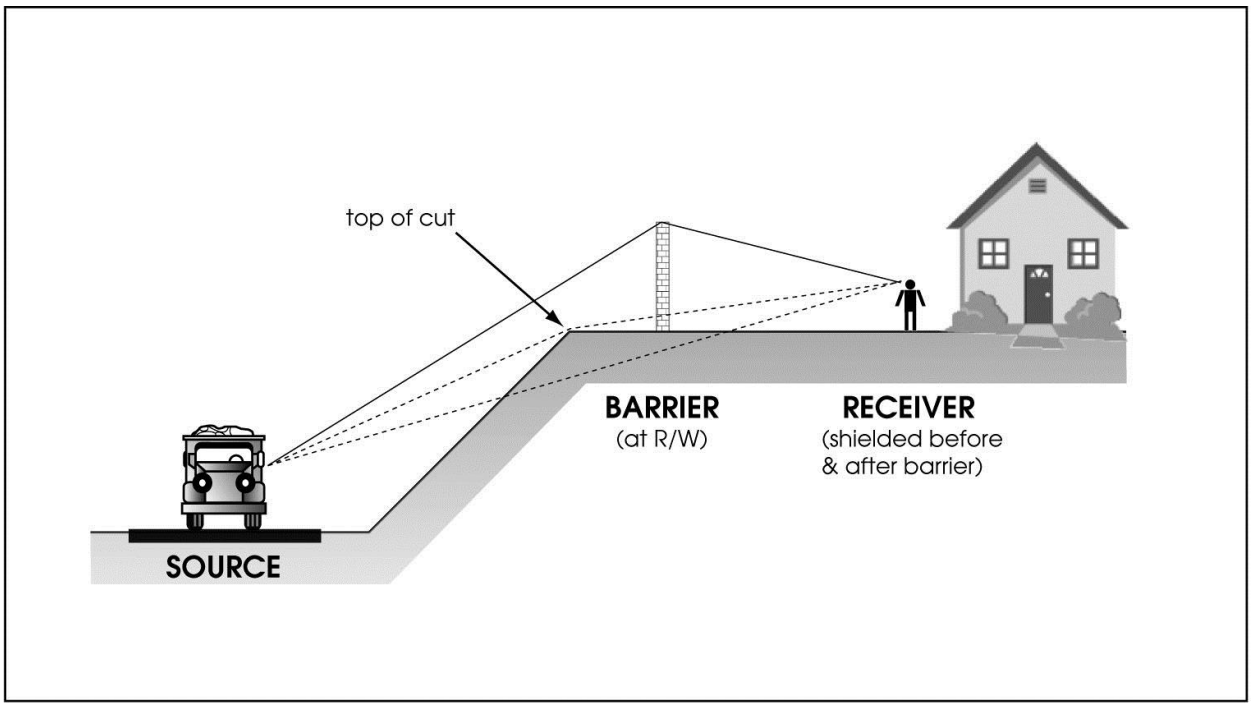

Figure 5-5. Typical Barrier Location for Depressed Highways

Because the attenuation per incremental increase in barrier height diminishes with the effective height of a barrier (see Section 5.1.3), this difference may be small. Noise barriers at the top of depressed highway sections are generally not very effective in reducing noise because the top-of-cut of the cut section by itself may already be providing substantial noise reduction.

The most effective location of noise barriers along highways on fills is on top of the embankment (Figure 5-6). Any attempt to place the barrier closer to the receivers will result in a higher barrier for the same or less attenuation. The same is true for elevated highways on structures. The most effective barrier location from an acoustical standpoint is on top of the structure.

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The preceding discussions point out that the most acoustically effective location for a noise barrier depends on the source-to-receiver geometry. In most cases, the choices are fairly obvious. To recap the simplest situations:

- **Highway at Grade:** barrier location near the edge of shoulder or at the right-of-way (barrier is close to the noise source).
- **Highway in Depressed Section:** barrier at the right-of-way (barrier is close to the receiver).
- **Elevated Highway on Embankment or Structure:** barrier near edge of shoulder (barrier is close to the noise source).

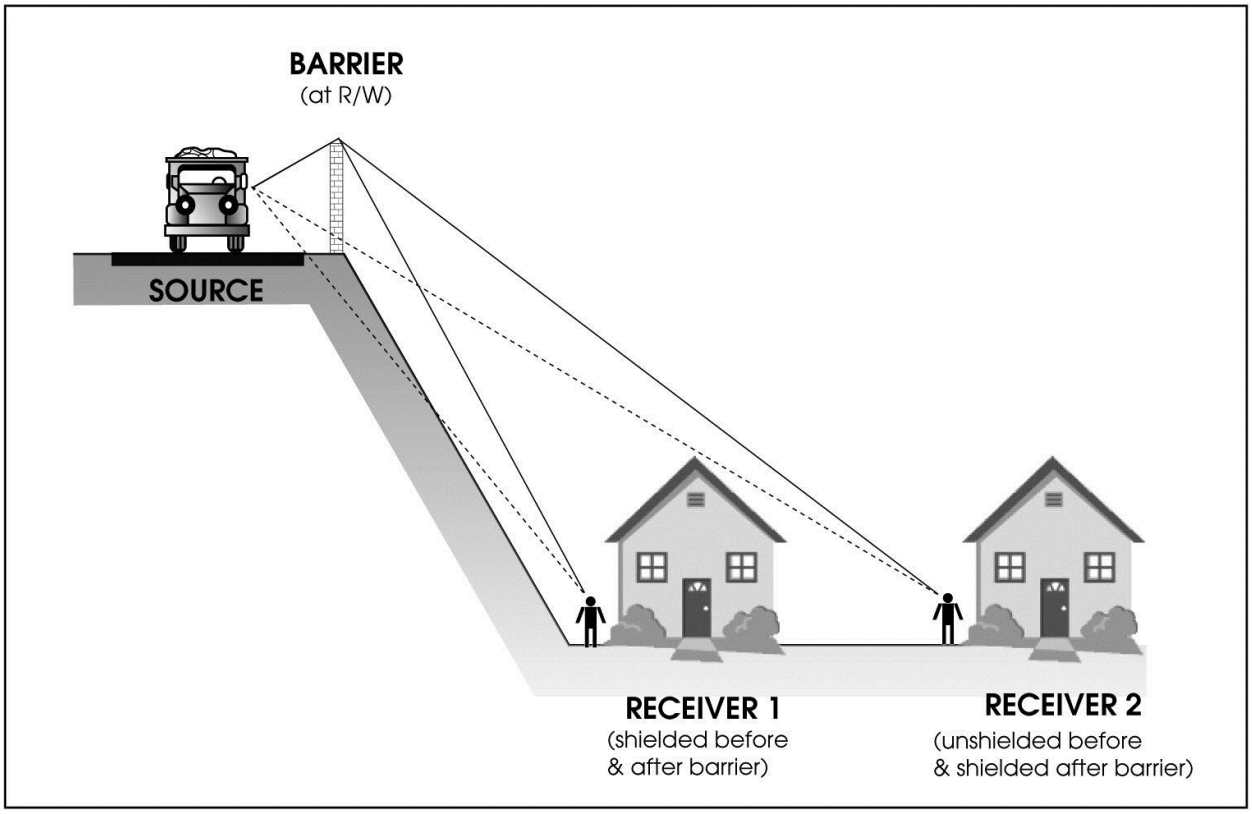

Figure 5-6. Typical Barrier Location for Elevated Highways

In some cases, however, the choices are not as simple. In more complex highway/receiver geometries, the best locations from an acoustical standpoint may need to be determined by using TNM for several barrier location alternatives.

Transitions between cuts and fills, ramps, and interchanges are some examples of cases that need careful consideration. Figures 5-7 to 5-9 show typical noise barrier locations in some of these transitional areas. Barrier overlaps are often necessary in these cases (Figures 5-7 and 5-8).

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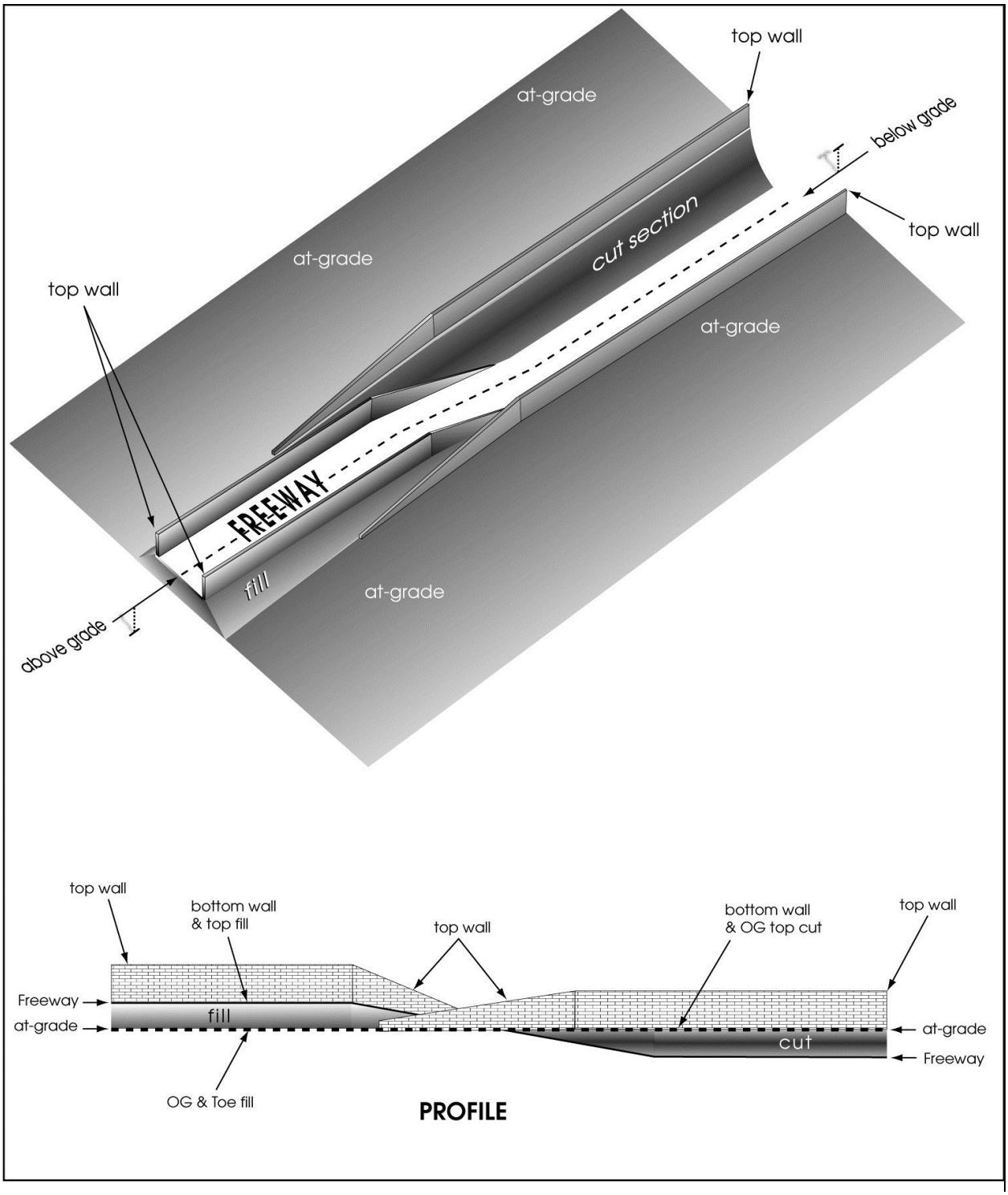

Figure 5-7. Barriers for Cut and Fill Transitions

One of the more common reasons for barrier overlaps is to provide maintenance access to the areas within the right-of-way that are on the

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receiver side of noise barriers (Figure 5-7). This will be discussed in more detail in the maintenance consideration portion of this section.

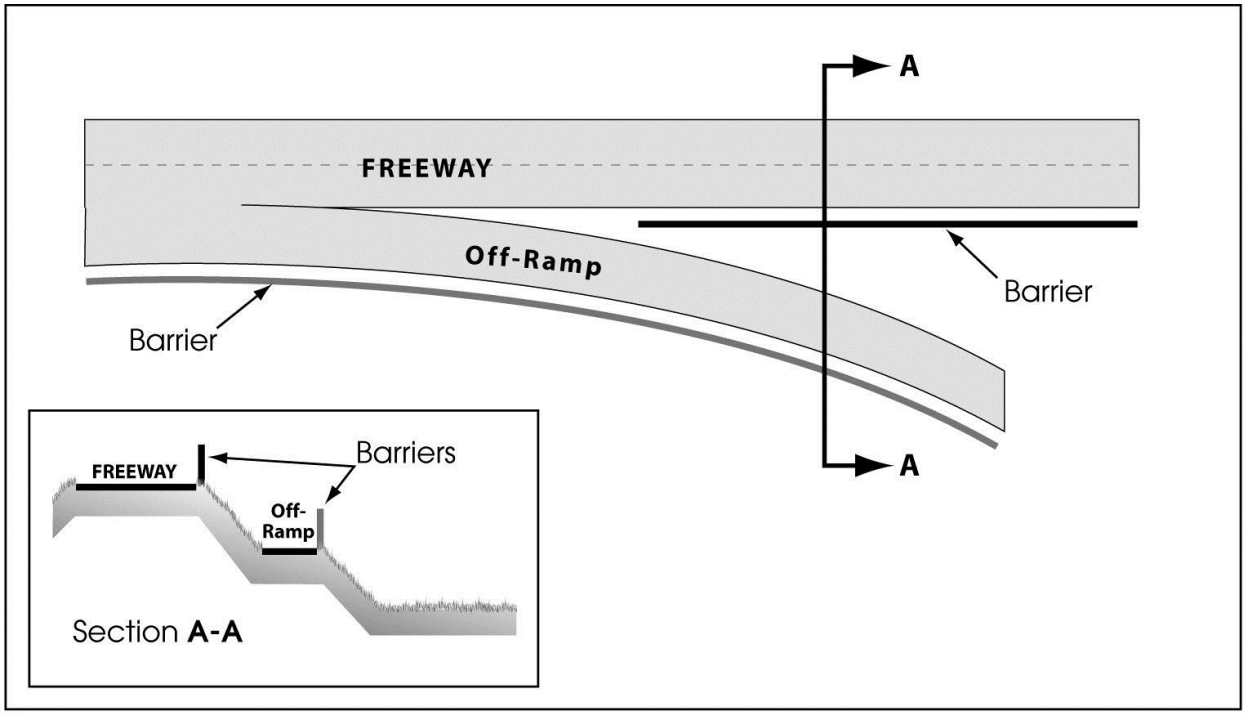

Figure 5-8. Barriers for Highway on Fill with Off-Ramp

Restrictions on lateral clearances, sight distances, and other safety considerations may also dictate final noise barrier locations. The current version of the Caltrans *Highway Design Manual* should always be consulted before finalizing alternate noise barrier alignments.

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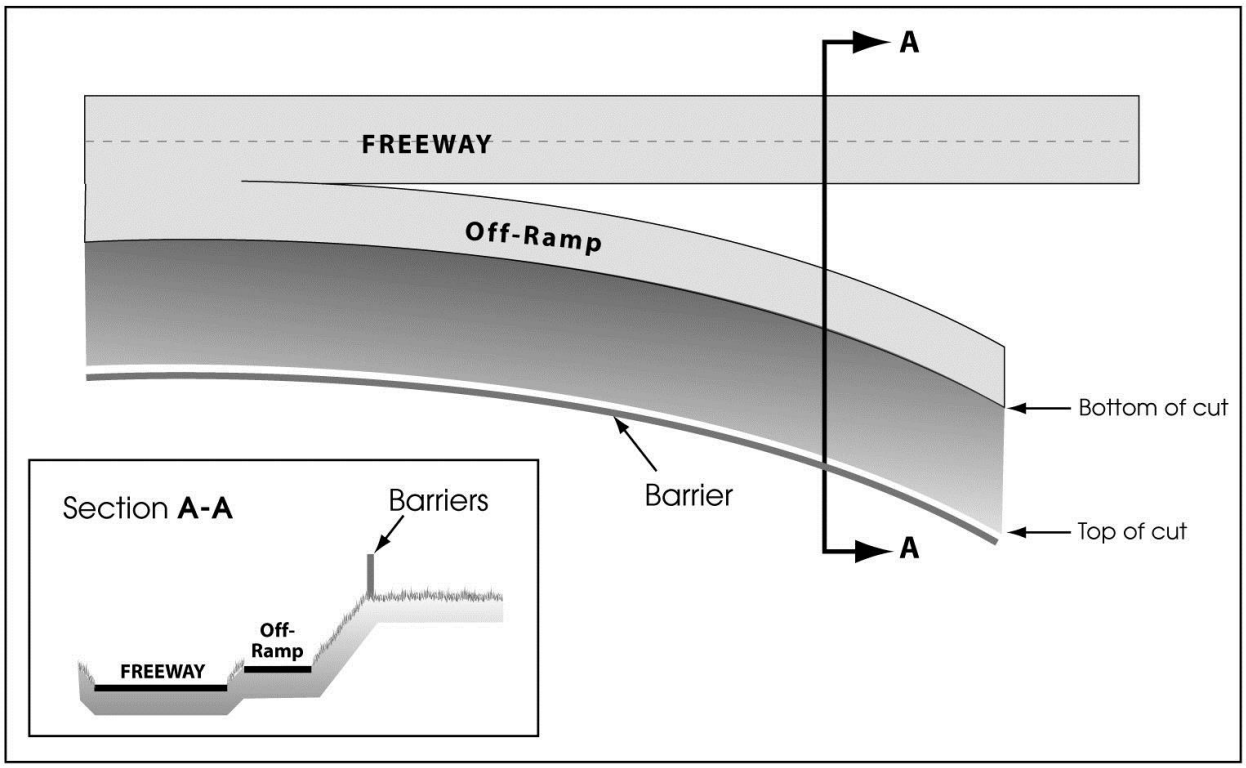

Figure 5-9. Barriers for Highway in Cut with Off-Ramp

5.1.3 Barrier Dimensions

Noise barrier dimensions depend largely on the freeway geometry, topography of the surrounding terrain, location of the noise barrier, and size of the area to be shielded by the barrier. Barrier attenuation depends on the path length difference between the direct (before-barrier) and diffracted (after-barrier) noise paths. Figure 5-3 reviews the concept. Because the location of the bottom of the barrier is not part of the triangle, the highway geometry and terrain topography determine how high the barrier should be for a given barrier attenuation. Figure 5-10 illustrates this concept.

Similarly, the length of the barrier is governed by the extent of the area to be shielded and the site geometry and topography (Figure 5-11).

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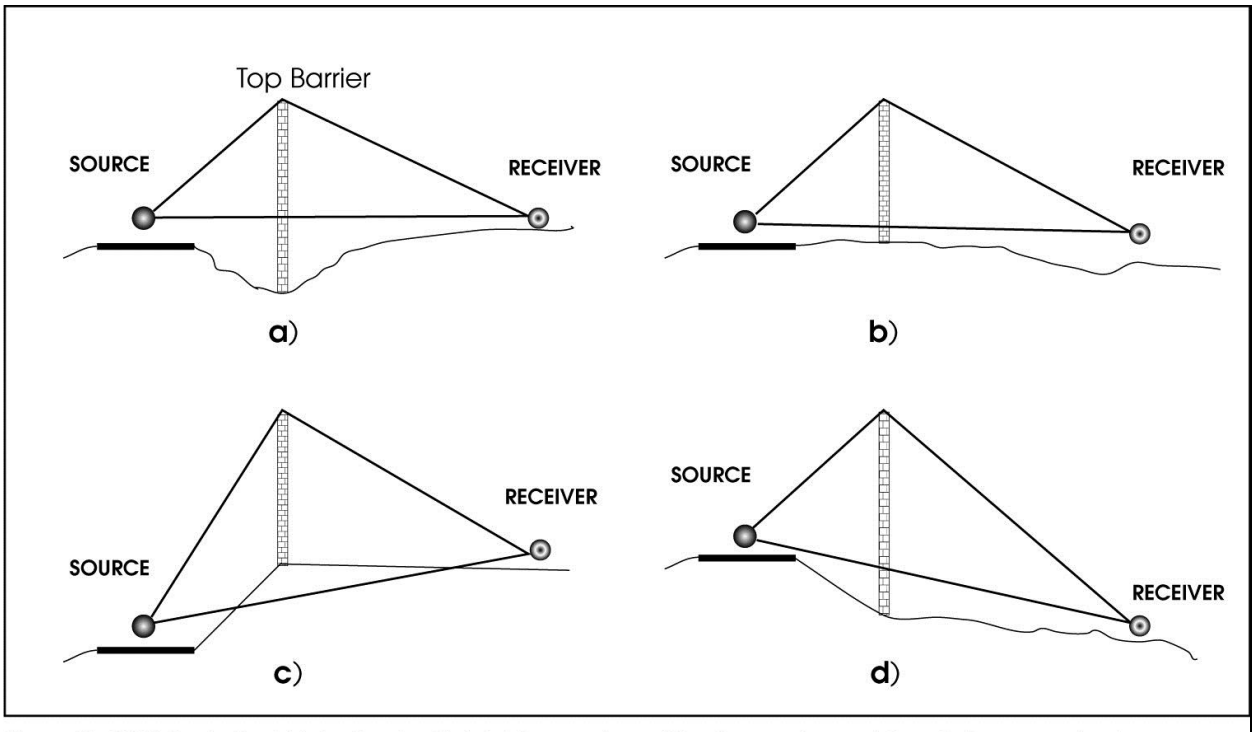

Figure 5-10. Actual Noise Barrier Height Depends on Site Geometry and Terrain Topography (Same Barrier Attenuation for *a*, *b*, *c*, and *d*)

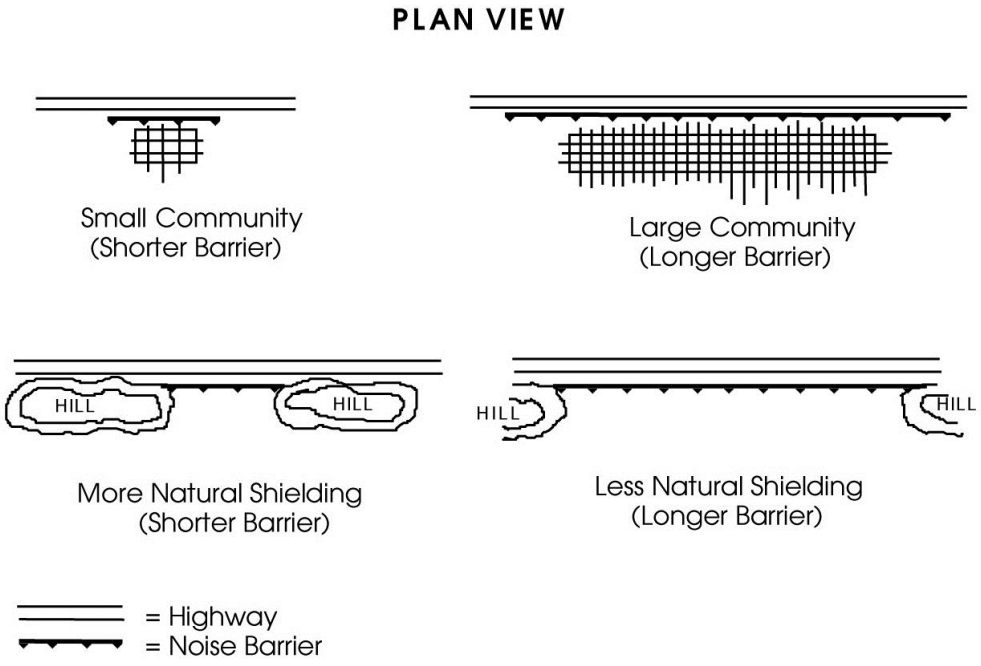

Figure 5-11. Noise Barrier Length Depends on Size of the Area to be Shielded and Site Geometry and Topography

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5.1.3.1 Height

Barrier height generally has the most direct influence on the effectiveness of a noise barrier. Figure 5-3 reviews the PLD concept. An increase in height of a noise barrier will result in a greater PLD and therefore greater noise attenuation. This increase in noise attenuation is not linear with the increase in height.

Figure 5-12 shows the barrier attenuation as a function of wall height at a 5-foot-high receiver, 50 feet behind a soundwall located along the right-of-way of a typical urban at-grade eight-lane freeway. The traffic consists of 10% heavy trucks, 5% medium trucks, and 85% autos. Attenuations are plotted for wall heights from 6 to 16 feet, representing minimum and maximum heights identified in the Caltrans *Highway Design Manual* Chapter 1100. Also shown is the height at which the line of sight between an 11.5-foot truck stack and a 5-foot-high receiver is intercepted by the wall. For this particular highway/barrier/receiver geometry, the intercept height is 9 feet and the associated attenuation is 7.5 dB.

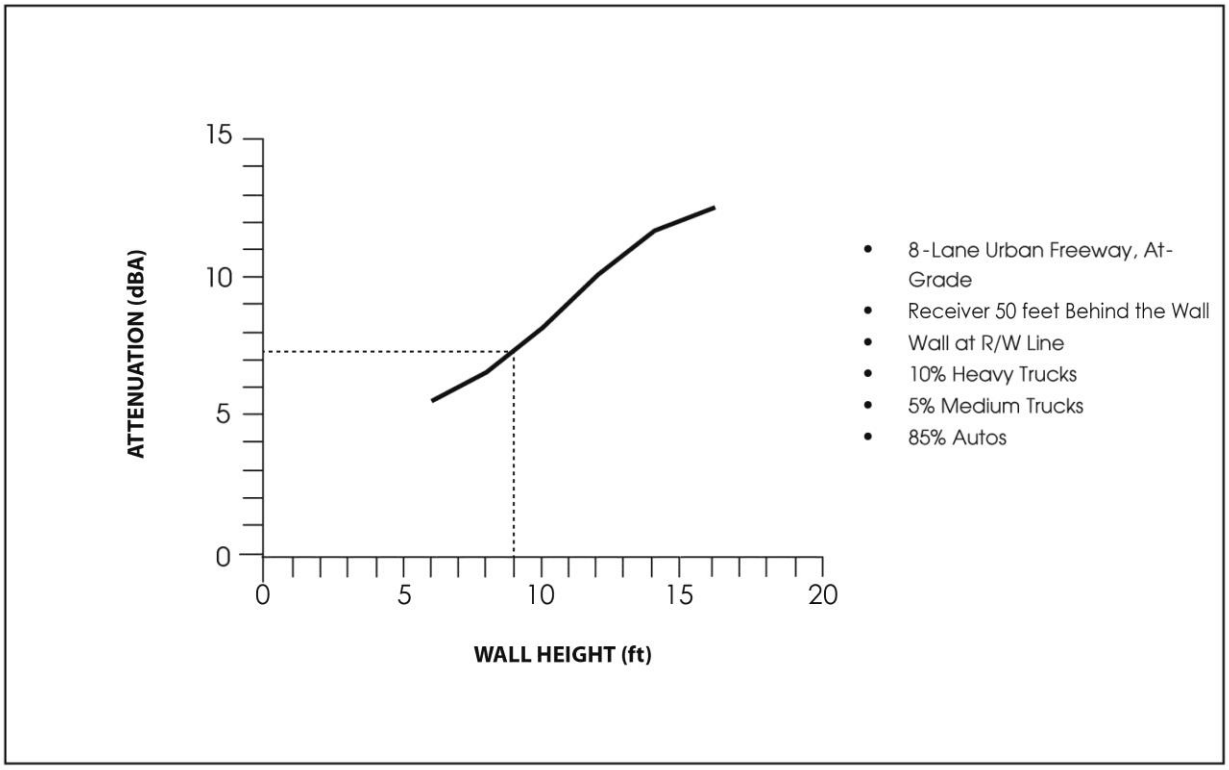

Figure 5-12. Soundwall Attenuation vs. Height for At-Grade Freeway

Please note that in this case the change in attenuation per incremental change in wall height is highest between wall heights of 9 and 11 feet, at 0.9 dBA per 1 foot. Above and below this range, the values are lower.

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Once the optimum height has been reached, any further increases in noise barrier height results in diminishing returns in effectiveness. Higher barriers are often necessary to meet design goals.

Noise barriers along depressed freeways are less effective than those along at-grade freeways. In deep cuts, the receiver often is already effectively shielded by the tops of cuts. In some cases, this top-of-cut shielding may not reduce noise levels enough to satisfy barrier design criteria, and an additional barrier behind the top of cut may be necessary to achieve further noise reductions.

When designing such a barrier, the designer should recognize that the without-barrier or before-barrier condition includes the shielding of the existing top of cut. Because of the diminishing-returns effect, a barrier of a given height along a depressed freeway will generally be less effective than a barrier of the same height in an at-grade situation. The diminishing-returns effect, however, is not the only factor to consider.

In general a berm is more effective in reducing noise than a wall of the same height because of additional diffraction, ground absorption, and path length effects. The top of cut associated with a depressed freeway essentially acts like a berm in terms of noise attenuation. Figure 5-13 shows the barrier attenuation vs. height plots for a receiver 50 feet behind a barrier located on the right-of-way of a typical urban eight-lane freeway in a 25-foot-deep depressed section. The traffic mix is the same as that for Figure 5-12, described above. Two attenuation curves are shown.

The upper curve represents attenuation differences between a wall (after-construction condition) and the top of cut (before-construction condition) in which the latter is treated as an existing wall. Such a condition would exist if a soundwall were built on top of an existing retaining wall (i.e., the top of cut would be the top of retaining wall).

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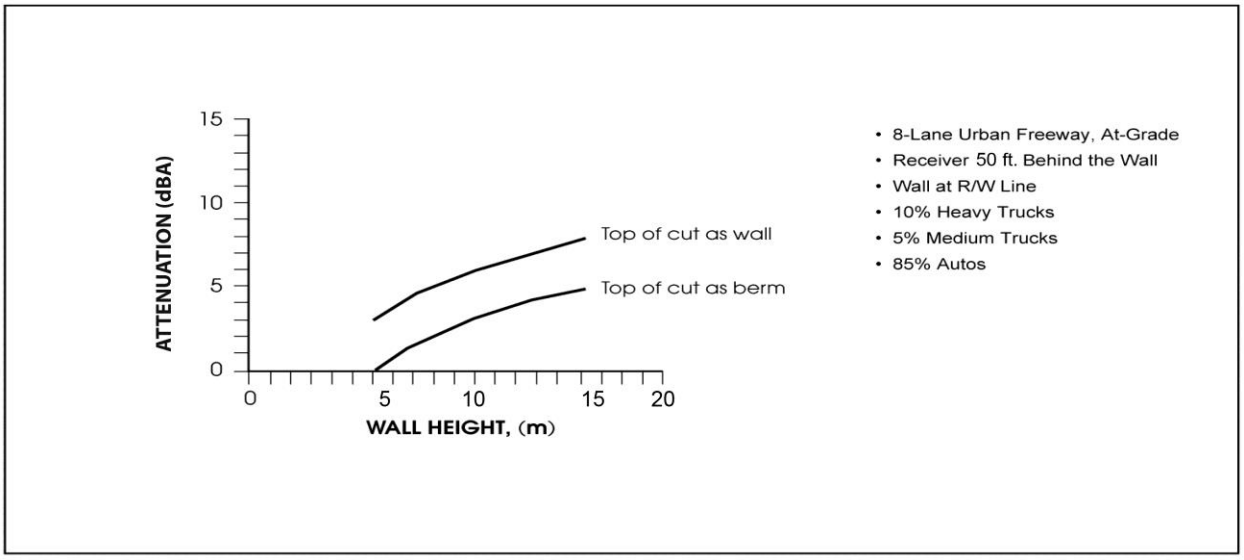

Figure 5-13. Soundwall Attenuation vs. Height for 25-Foot Depressed Freeway

Both the before and after conditions would then involve a wall. Likewise, if the before-and-after-conditions consist of berms (built at or near the top of cut), the upper curve also would be a correct representation. The lower curve consists of attenuation differences between a soundwall and the existing top of cut, with the latter treated as a berm. The additional 3-dBA attenuation provided by the before condition is eliminated by the wall, making it less effective.

A similar phenomenon may also be encountered when freeways are built on embankments. Receivers located near the top of fill may be fully or partially shielded from traffic by the top of fill or hinge point. For these receivers, a wall built on top of the embankment may be less effective than for receivers located farther from the freeway.

The above discussions illustrate the importance of noise source, barrier, and receiver relationships in designing effective noise barriers. These geometries not only affect the barrier attenuation, but also noise propagation in many cases. Section 2.1.4 discusses hard- and soft-site characteristics. The excess noise attenuation provided by a soft site is caused by the noise path's proximity to a noise-absorbing ground surface. If a noise barrier is constructed between a source and receiver, the diffracted noise path is lifted higher off the ground, causing less noise absorption by the ground and a lower rate of noise attenuation with distance. Figure 5-14 illustrates this concept.

In "a," the before-barrier situation shows a noise attenuation rate of 4.5 dBA per doubling of distance. In "b," the after-barrier attenuation is 3

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dBA per doubling of distance. The lower attenuation rate reduces the barrier's effectiveness.

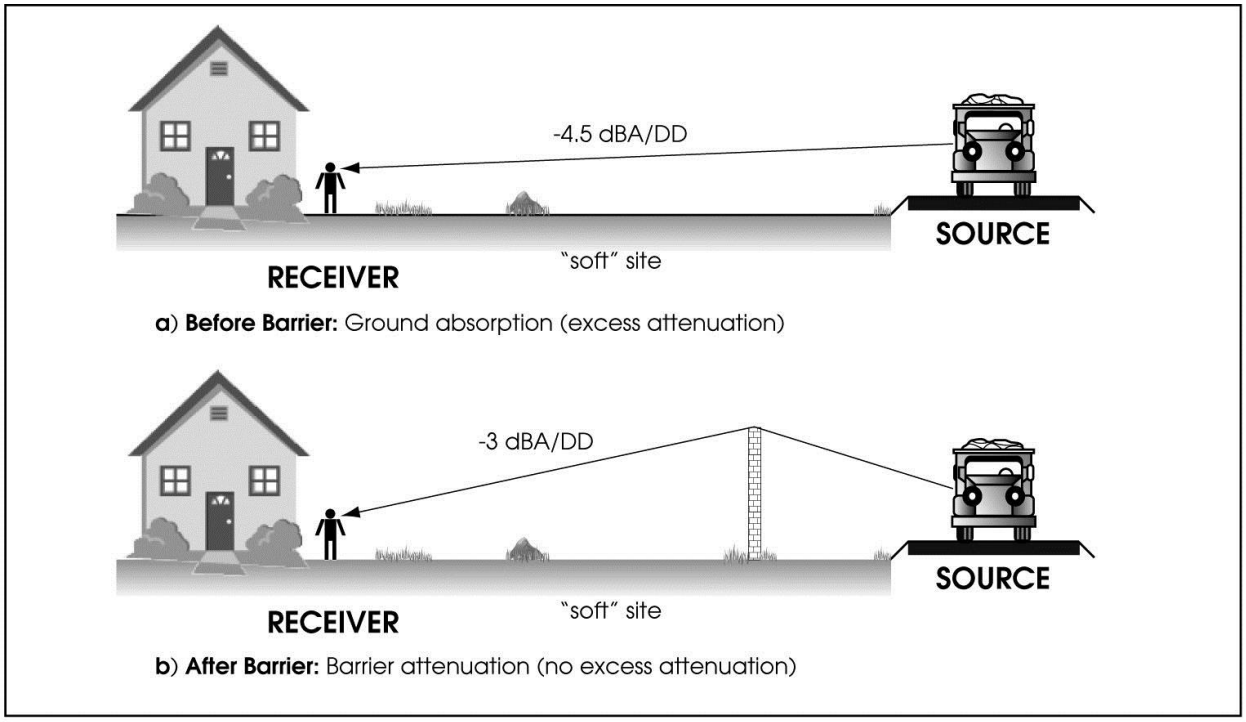

Figure 5-14. Loss of Soft-Site Characteristics from Constructing a Noise Barrier

The potential of a barrier to be less effective than indicated by barrier attenuation alone gave rise to the term insertion loss. Section 5.1.5 discusses the difference between barrier attenuation and insertion loss in detail. The insertion loss of a barrier is the net noise reduction provided by a barrier at a receiver. It includes barrier attenuation and before- and after-barrier differences in noise propagation characteristics (i.e., it is the actual noise reduction caused by inserting a noise barrier between source and receiver). A measured insertion loss is usually referred to as field insertion loss.

Finally, another height consideration in the acoustical design of noise barriers is Caltrans guidance to break the line of sight between an 11.5-foot-high truck exhaust stack and 5-foot-high receiver in the first row of houses. This guideline, detailed in *Highway Design Manual* Chapter 1100, is intended to reduce the visual and noise intrusiveness of truck exhaust stacks at the first-line receivers.

Barrier heights determined by TNM often satisfy the acoustical requirements without shielding high truck exhaust stacks. Although such barriers may reduce noise levels sufficiently to meet feasibility and design goal requirement, they have generated complaints from the public in the

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past when truck stacks were visible. The line of sight break criterion occasionally governs the height of a noise barrier.

The 11.5-foot height used for truck stacks was determined to be the average (50th-percentile) height of truck stacks in a 1979 District 7 study, including 1,000 heavy trucks measured at a truck inspection station along I-5. This means that the line-of-sight break will shield first-line receivers from the exhaust stacks of about half of the trucks on the highways.

The 11.5-foot dimension is not related to the noise source heights used for heavy trucks in TNM and therefore should not be used for noise predictions. Determining the line-of-sight break is a separate process from predicting noise and is completed with the line-of-sight module in TNM. Generally, it is desirable to calculate and plot the break profile along the barrier alignment before the acoustical design of the noise barrier. . If more than one barrier alignment is under consideration, the line-of-sight break must be calculated for each alignment alternative.

The line-of-sight break height depends on the three-dimensional locations of the 11.5-foot truck stack, receiver, and bottom of the barrier (interface between barrier and ground). To calculate the height for a certain source, barrier, and receiver combination, the designer needs to determine the critical truck stack lane, which is the lane in which the 11.5-foot truck stack creates the highest line-of-sight break. Figure 5-15 shows a quick method of determining which lane is critical. If the receiver is located above a baseline drawn through far- and near-lane truck stacks, the far lane is critical. If the receiver is located below this line, the near lane is critical. When the receiver is on the line, either lane is critical. Please note that the line does not need to be horizontal or level.

Highway Design Manual Chapter 1100 does not give guidance on whether the entire barrier or only a portion of the barrier should break the line of sight for a certain receiver. On one extreme, a series of line-of-sight intercepts can be calculated from one receiver, covering the entire barrier. On the other extreme, only one intercept can be calculated using a perpendicular line from the receiver to the barrier or highway. In the absence of an official policy, it is recommended that a distance of 2D left and right along the centerline of the critical lane, measured from a perpendicular line from the receiver to the lane, be used (where D = the distance from receiver to the lane). Also, it is recommended that the portion of the barrier evaluated be further constrained by a maximum distance from receiver to truck stack (D_t) of 500 feet. Figure 5-16 shows the recommended constraints.

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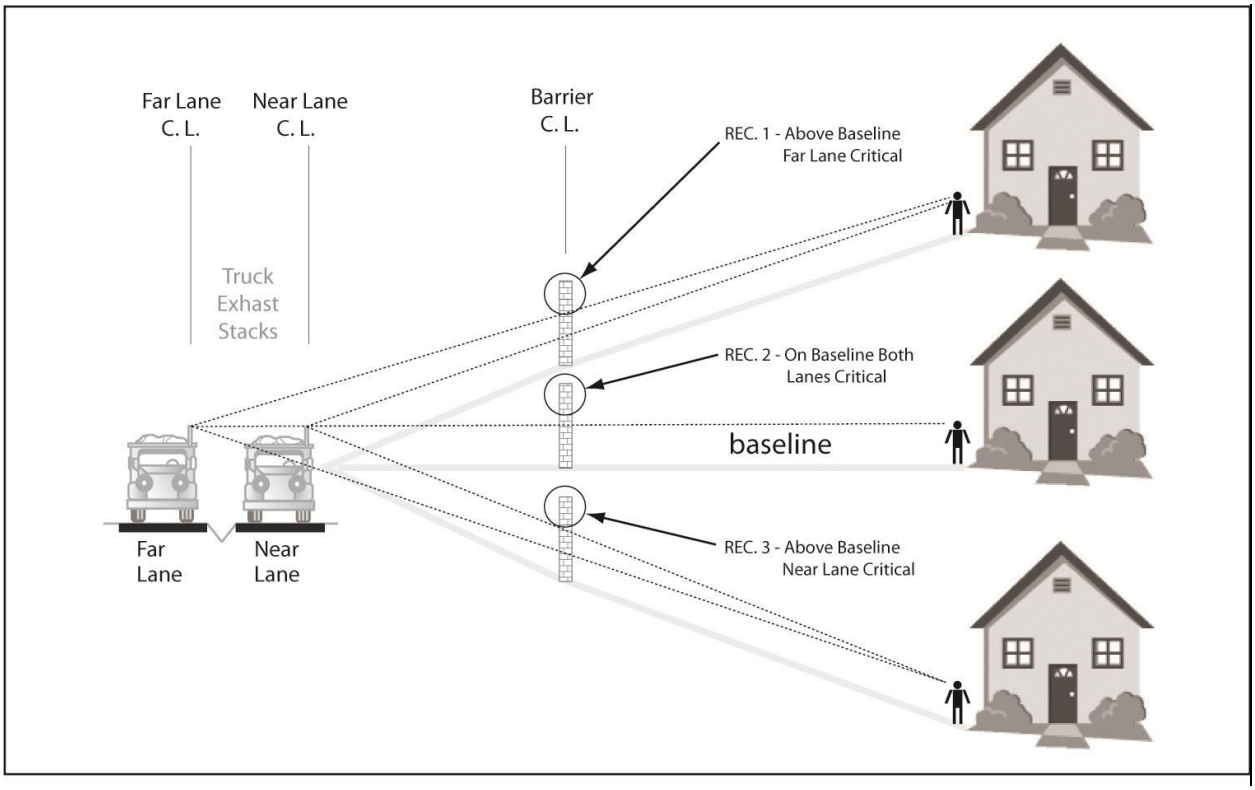

Figure 5-15. Determination of Critical Lane for Line-of-Sight Height

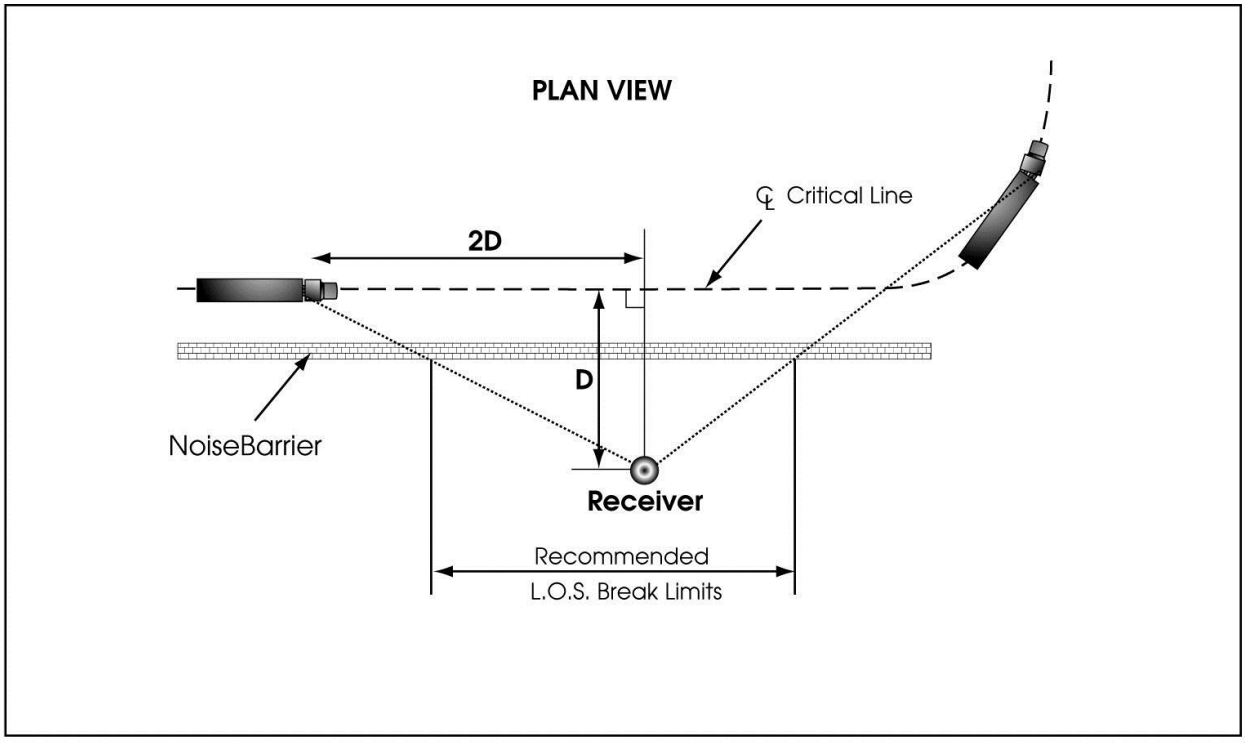

Figure 5-16. Recommended Line-of-Sight Break Limits

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5.1.3.2 Length

A noise barrier should be sufficiently long to protect the end receivers (see Figure 5-17). If the barrier is not long enough, the exposed roadway segment will contribute a significant portion of noise energy received and sharply reduce the effectiveness of the barrier. For example, if a barrier ends at the receiver, half of the roadway is exposed, and the noise reduction by the barrier is 3 dBA or less.

As a general rule, a noise barrier should extend at least 4D beyond the last receiver (where D = the perpendicular distance from barrier to receiver) (see Figure 5-18). The "4D rule," however, should be considered a starting point, and the FHWA TNM should be used to precisely locate the end of the barrier. Often, the critical end receivers are not in the first row of homes, but several rows farther from the highway (see Figure 5-17). As the barrier-to-receiver distance increases, highway noise becomes lower, but the barrier segment angle is also reduced, making a potential noise barrier less effective. The FHWA TNM is needed to resolve these opposing factors.

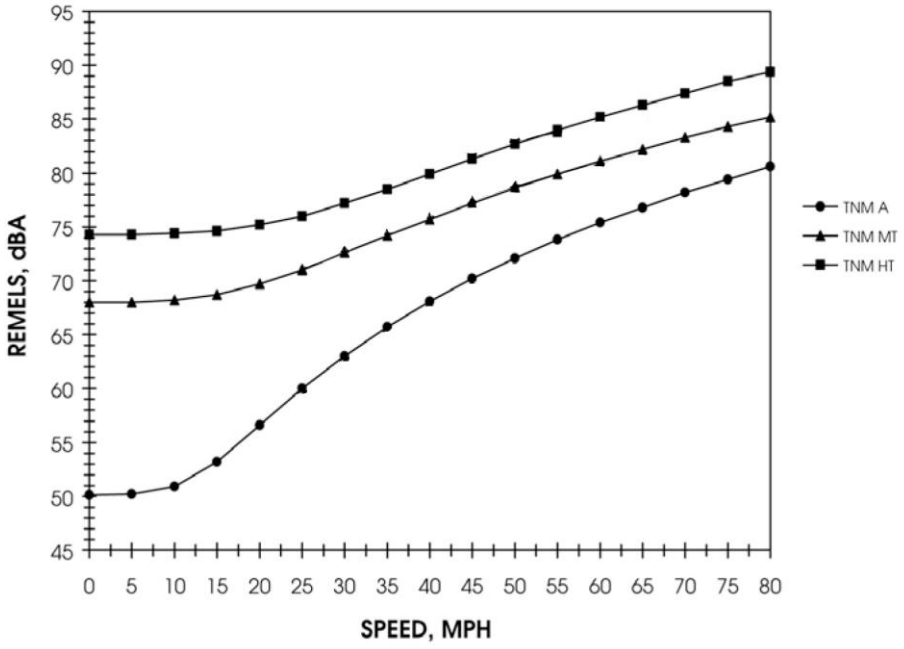

Figure 5-17. Barrier Extended Far Enough to Protect End Receivers

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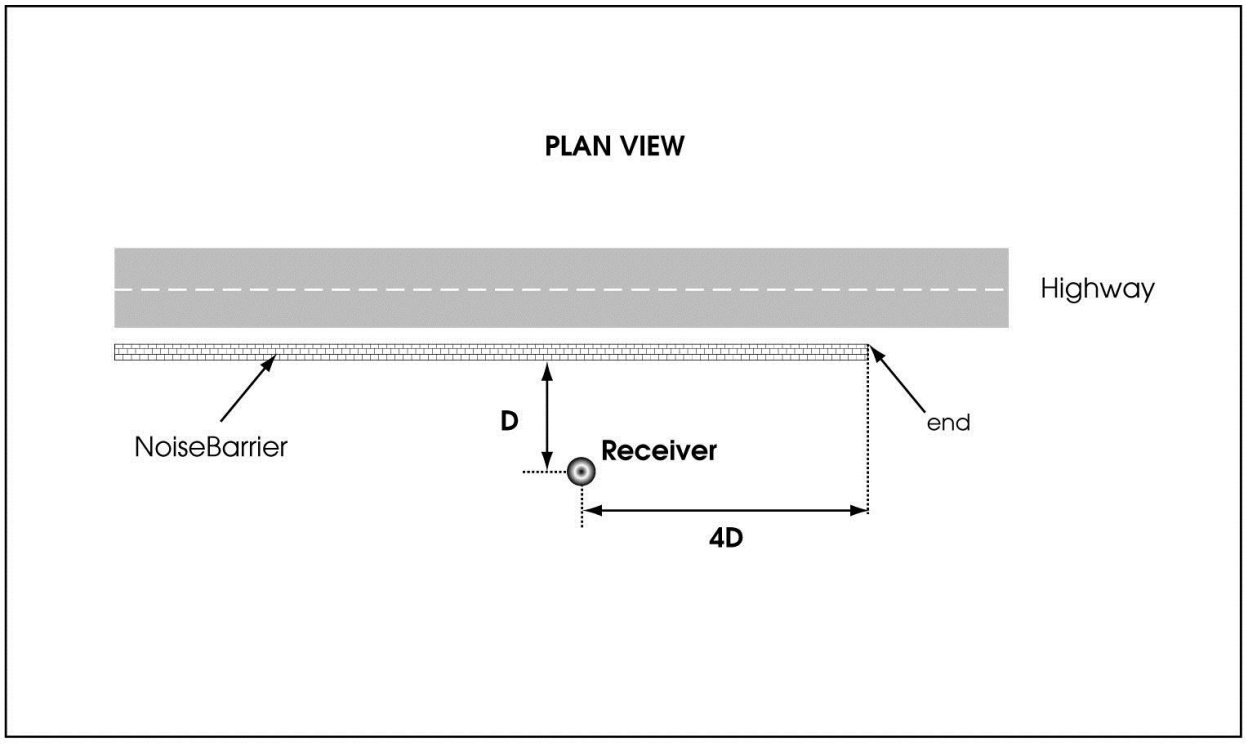

Figure 5-18. 4D Rule

Another way of addressing end receivers is shown in Figure 5-19. The barrier is "hooked" around the critical receivers. The obvious advantage of this design is the shorter barrier length compared to the normal barrier extension. The disadvantage is the need for legal agreements between Caltrans and the private property owners concerning construction easements, barrier maintenance, and responsibilities.

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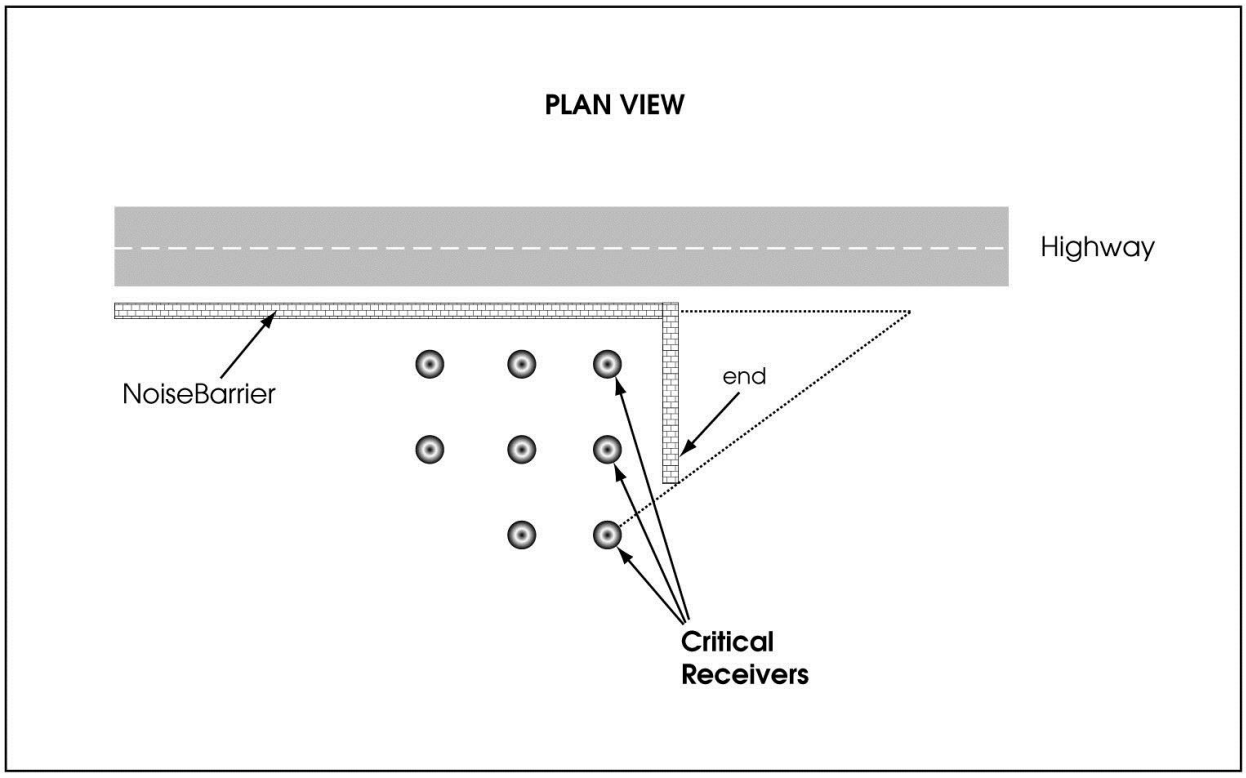

Figure 5-19. Barrier Wrapped around End Receivers, an Effective Alternative

5.1.4 Barrier Shape

Section 4.5.1 indicates that the FHWA TNM distinguishes between two noise barrier shapes: thin screen (wedge) and earth berm. Figure 5-20 shows representations of the two barrier shapes.

Given the same site cross section, distance between source and receiver, and barrier height, a berm allows greater barrier attenuation than the thin screen (wedge), such as a soundwall. In general the actual extra attenuation associated with a berm is somewhere between 1 and 3 dBA.

There are several probable causes for the extra 3-dBA attenuation for a berm. The flat top of the berm allows a double diffraction, resulting in a longer path-length difference. Also, the noise path is closer to the ground (berm surface) than for a thin screen, allowing more ground absorption.

Other barrier shapes have been researched, including “T-tops,” “Y-tops,” pear-shaped tops, and curved walls. Given the same total wall height, these do little to improve barrier attenuation, usually only about 1 or 2 dBA at most. Figure 5-21 shows some different shapes. The added cost of constructing and complexity of these shapes usually does not justify the small acoustical benefit.

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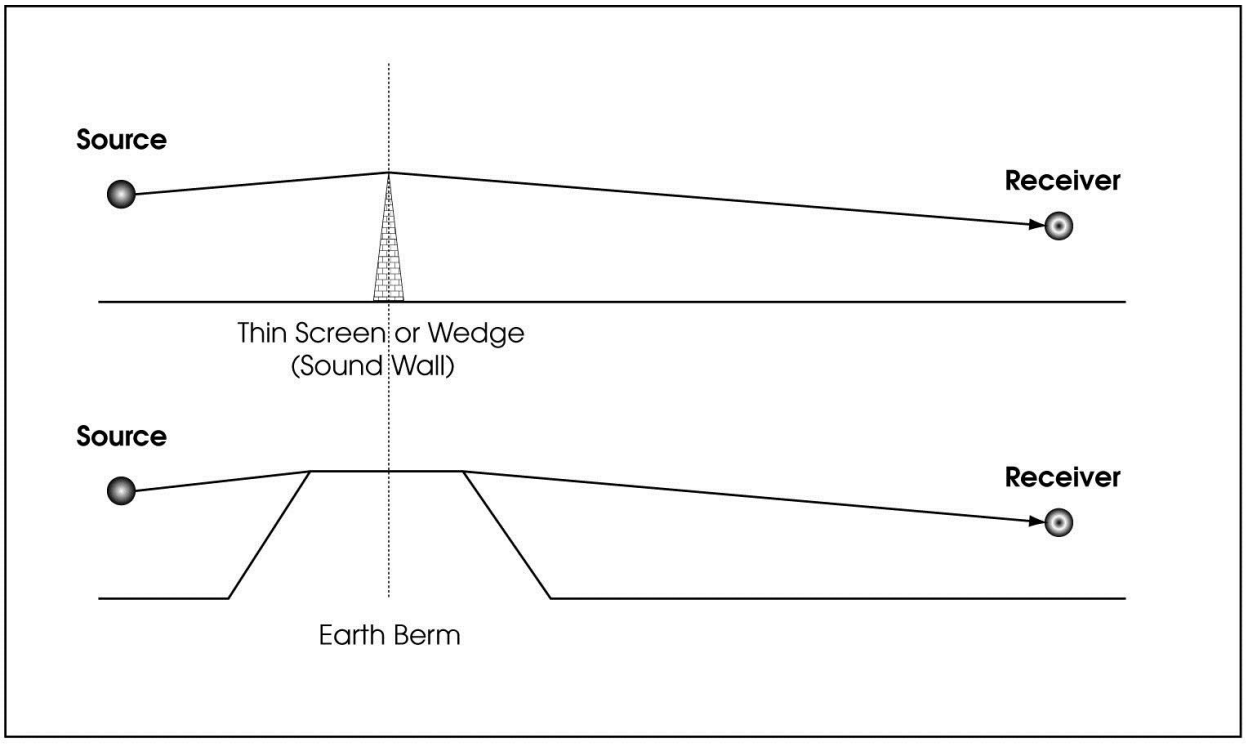

Figure 5-20. Thin Screen vs. Berm (Berm Gives More Barrier Attenuation)

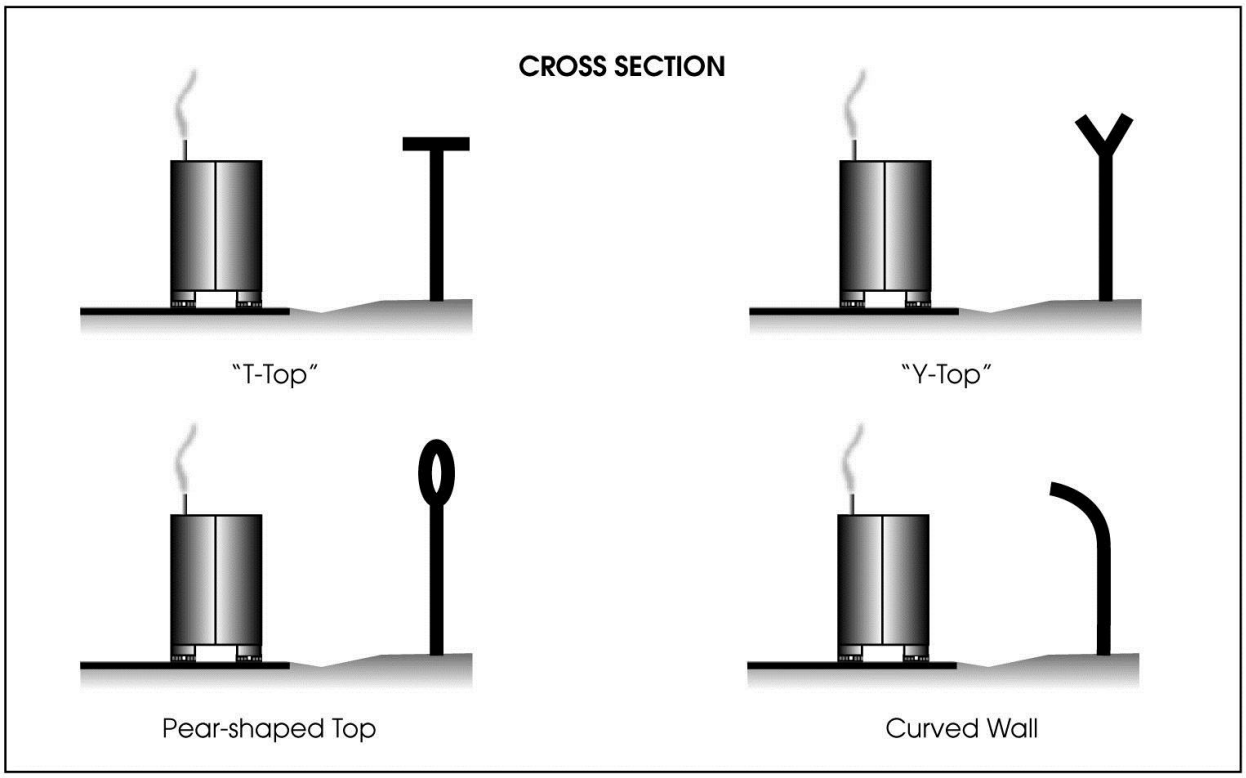

Figure 5-21. Various Wall Shapes (Minimal Benefit for Extra Cost)

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There is also a question of jeopardizing safety with any overhang, especially when the barrier is constructed near the edge of the shoulder.

5.1.5 Barrier Insertion Loss vs. Attenuation

In simple terms, barrier insertion loss is the difference in noise levels before and after a barrier is constructed. It accounts for barrier attenuation, contributions from unshielded roadway segments, changes in dropoff rates, and interaction with existing barriers (e.g., reflections or additional shielding).

Figure 5-22 illustrates the difference between barrier insertion loss and attenuation. Barrier attenuation only accounts for noise attenuated from noise barrier diffraction, integrated over the length of the noise barrier. Barrier insertion loss is the net noise reduction and includes barrier attenuation, changes in noise path heights and associated changes in ground effects, flanking noise, and other noise sources. When designing noise barriers, barrier insertion loss is the primary factor of interest.

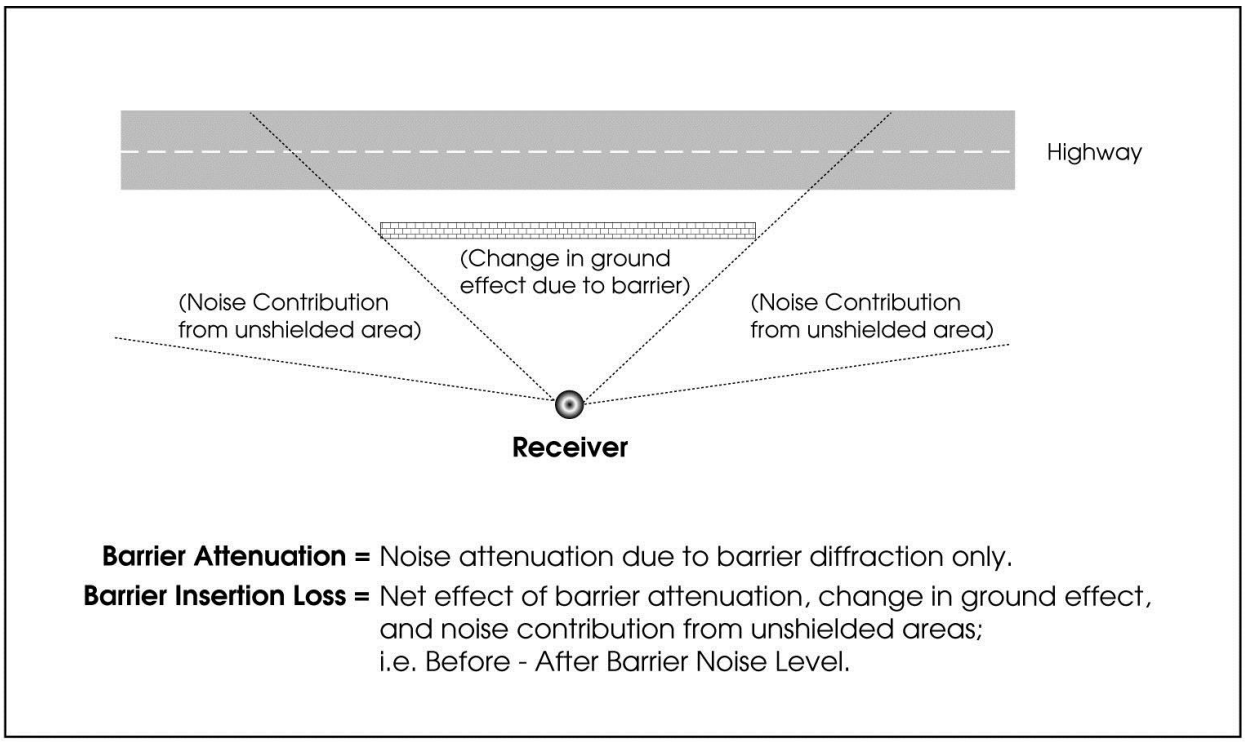

Figure 5-22. Barrier Insertion Loss vs. Attenuation

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5.1.6 Background Noise Levels

One important factor to be considered but often overlooked in noise barrier design is the background noise level within a community. A noise barrier cannot reduce noise levels below the noise level generated by local traffic on surface streets. For instance, if the background level (without the highway) is 65 dBA at the target receivers, and a proposed project will raise this level to 68 dBA, a noise barrier will not be able to reduce the noise level to less than 65 dBA. Therefore, the community background noise level always should be added into the predicted noise levels and considered in the noise abatement design process. Only if it is obvious that the background noise from local sources will not influence the noise barrier's insertion loss (i.e., is at least 10 dBA less than the predicted noise level with the noise barrier) can the background noise be ignored.

The following is an example of how background noise levels can influence noise barrier calculations.

Given

Background noise level: 60 dBA at receivers

New facility (without background): 68 dBA at receivers

Total predicted: 69 dBA at receivers

The goal of this exercise is to design a noise barrier that will reduce the total noise level at the receiver by at least 5 dBA. The model predicts traffic noise levels without the background noise level. However, the background noise level should be accounted for in the total noise attenuation. Therefore, the predicted noise level needed to reduce the total predicted noise level at the receiver to 64 dBA must be calculated.

Calculation

If the barrier reduces the noise from the new facility by 5 dB the facility noise level would be 64 dBA. When the background noise is considered the resulting sound level would be 65 dBA (60 dBA + 64 dBA). This is only a 4 dB reduction from the total predicted noise level of 69 dBA. Additional attenuation is needed to provide at least 5 dB of noise reduction relative to the total predicted noise level.

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The goal is for the background sound level plus the new facility noise level behind the barrier to be 64 dBA (5 dBA below the total predicted noise level of 69).

background (B) + new facility noise level behind barrier (N) = 64 dBA

$$B + N = 64 \text{ dBA}$$

$$60 + N = 64 \text{ dBA}$$

$$N = 64 - 60$$

$$N = 10\log(10^{(64/10)} - 10^{(60/10)}$$

$$N = 61.8 \approx 62 \text{ dBA}.$$

Therefore the barrier must provide a total noise reduction of 7 dB and result in a noise level of 62 dBA behind the barrier for the net noise reduction to be at least 5 dBA.

5.1.7 Reflected Noise and Noise Barriers

5.1.7.1 Noise Reflection

The reflection of noise from barriers can be a source of concern for residences in the vicinity of a barrier. A barrier that reduces noise at receivers on one side of the highway could potentially alter the noise at receivers on the other side. The complex nature of noise barrier reflections, difficulties in measuring them, and controversy surrounding the significance of their impacts deserve detailed discussion.

More noise barriers have been constructed in California than in any other state, in many different configurations of alignment, profile, and height. These barriers are located along one or both sides of highways of different widths; along ramps, connectors, and interchanges; and in urban, suburban, and, rural regions under varying traffic conditions. The receivers for which they were designed are located in many different types of terrain, topography, and climate. The combinations and permutations associated with the vast variety of conditions inevitably increase the possibility of creating controversies over the extent of noise reflections by barriers. Therefore, it is only natural that noise reflection issues are on the

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rise in California, especially because almost all noise barriers here are made of noise-reflective material with hard, smooth surfaces, such as masonry and concrete. In most cases, the noise increases from reflections are so small that most people do not notice them. The people who do perceive increases in noise are usually suddenly made aware of freeway noise by an event that triggers that awareness (e.g., construction of the noise barrier). Measured increases from noise reflections of more than 2 dBA have never been measured by Caltrans, but claims of 10 and even 20 dBA increases have been made occasionally.

Many complaints of large increases in noise came from residents living far from the highway and were actually from changes in meteorology. Atmospheric refraction from wind shear and temperature gradients can account for 10- to 15-dBA variations when the same sources are measured from distances of approximately 1 to 2 miles. To measure the effects of noise reflections, before- and after-barrier noise measurements need to be carefully matched by wind speed, wind direction, temperature gradients, air temperature, humidity, and sky cover. Likewise, if a person perceives a noticeable increase in noise levels from a reflective noise barrier, he or she must be able to compare it mentally with a before-barrier condition that included the same meteorology. Of course, this process is very unreliable. The effects of noise barriers on distant receivers are discussed in Section 7.

This section addresses various aspects of noise reflection concerns in detail. The following classifications of reflective noise with respect to noise barriers and other structures will be discussed.

- Single barriers (on one side of the highway).
- Parallel barriers (on both sides of the highway).
- Structures and canyon effects.

Compared with reflections measured under similar conditions, results of theoretically modeled noise reflections normally show higher values. This overprediction of reflection models has been attributed to the inability of models to accurately account for all the variables, such as interactions with atmospheric effects and the unknown degree to which traffic streams interfere with reflections.

Reflective noise is not peculiar to noise barriers. Retaining walls and other structures reflect noise in the same manner as noise barriers. The principles discussed in this section can be applied to reflective barriers, reflective retaining walls, or any other smooth, continuous, hard surfaces.

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5.1.7.2 Single Barriers

Simple Terrain

Figure 5-23 is the simplest two-dimensional representation of single-barrier reflections. The presence of a reflective barrier on the opposite side of an at-grade highway essentially doubles the acoustic energy at the receiver. In addition to the direct noise ray "d," the barrier reflects a noise ray "r" of roughly the same acoustic energy (actually, "r" is longer than "d" and will result in slightly less acoustical energy). Theoretically, only one reflective ray reaches the receiver because the angle of incidence equals the angle of reflection (both depicted as θ in Figure 5-23). Therefore, even if they are equal, "r" and "d" cause a doubling of energy that increases the noise level by 3 dB at the receiver.

Figure 5-24 shows that for an infinite line source and noise barrier the reflections are also an infinite line source. At each point along the highway, there is only one reflection ray that reaches the receiver and for which the angle of incidence equals the angle of reflection.

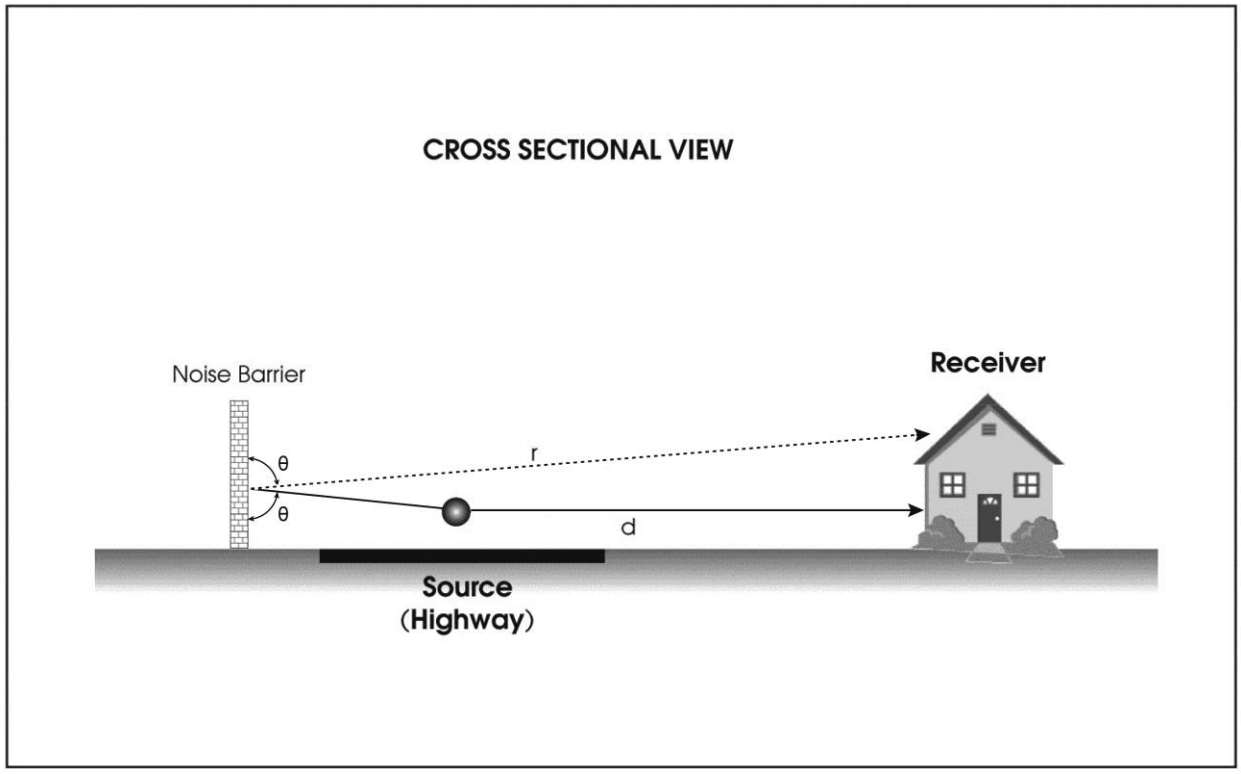

Figure 5-23. Single-Barrier Reflection (Simplest Representation)

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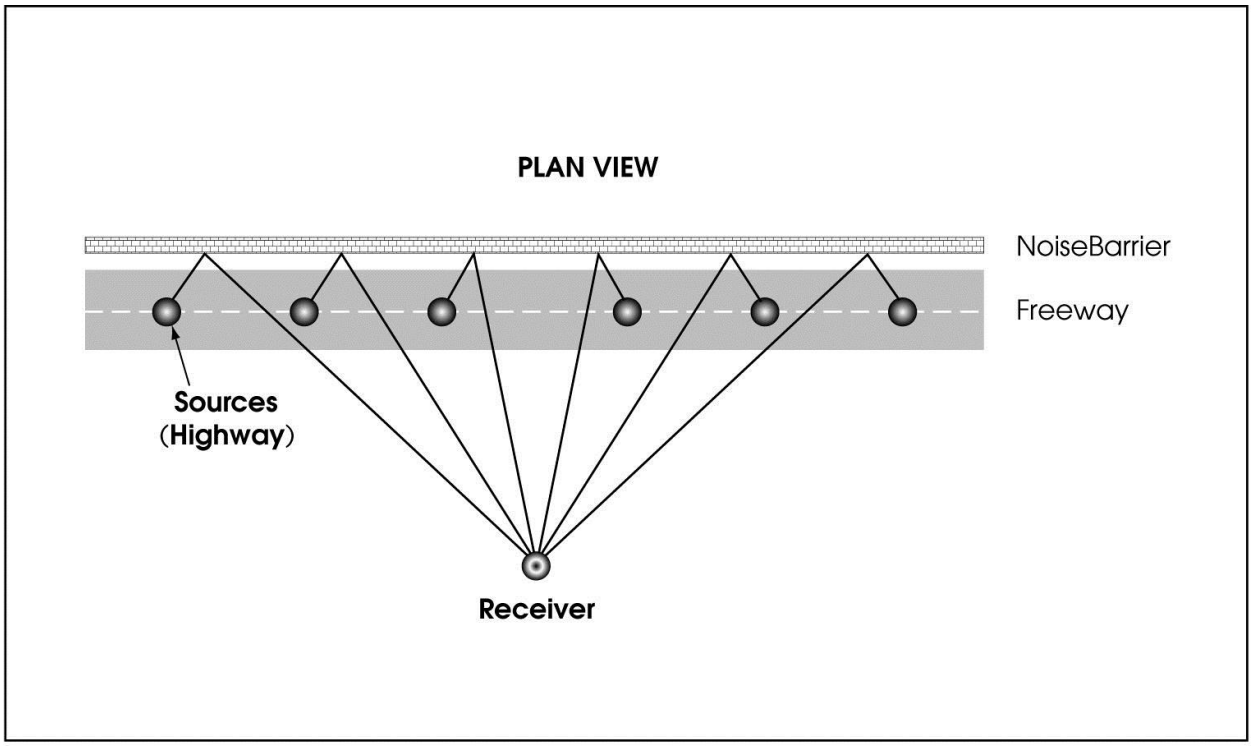

Figure 5-24. Single-Barrier Reflections (Infinite Line Source and Noise Barrier)

Figure 5-25 is a more realistic depiction, which includes pavement reflections. Please note, however, that a noise barrier on the opposite side still increases the noise level by 3 dB, although the before and after noise levels are 3 dB higher (because of pavement reflections) than in Figures 5-23 and 5-24. In plan view, the pavement reflections would also be shown to be a line source. The reflection point R_1 (Figure 5-25) may fall off the pavement on absorptive ground, reducing the before-barrier noise levels at the receiver. The pavement reflection point R_2, however, which is significant only after building the barrier, usually will be on the pavement. Therefore, the difference between before- and after-barrier noise levels could in theory slightly exceed 3 dBA.

The effects of single-barrier reflections are distance-dependent. At distant receivers, the ratios of direct/reflected noise path lengths and those for near- and far-lane distances approach 1. When this is the case, contributions of direct and reflected noise from each lane contribute roughly the same energy (there will always remain a slight loss of acoustical energy because of imperfect reflections). The result would be an increase that approaches 3 dBA for distant receivers. For receivers close to the highway, however, the distance ratios become less than 1, and the noise at the receiver is dominated by direct noise from the near lanes. The result is less contribution from reflected noise.

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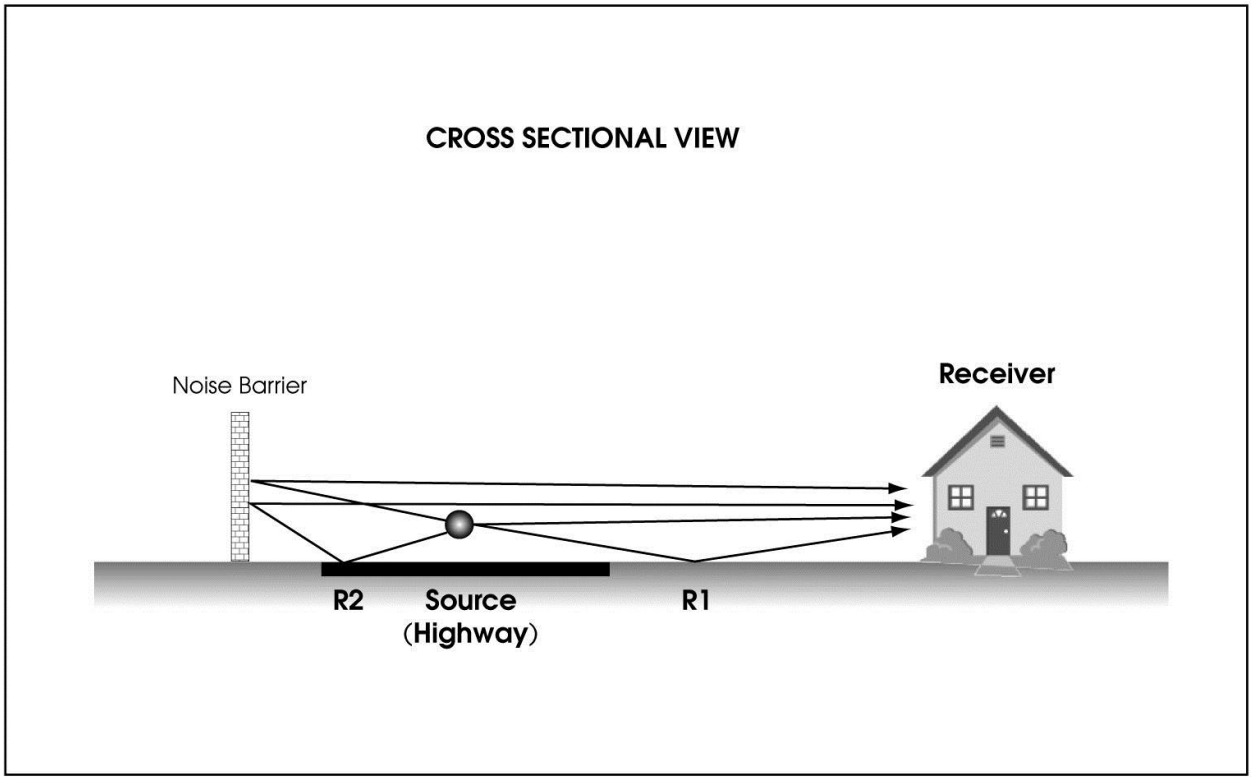

Figure 5-25. Single-Barrier Reflection (More Accurate Representation)

Figure 5-26 shows the distance dependency of the noise increases from barrier reflections for a typical eight-lane at-grade freeway. At 50 feet from the edge of the traveled way, the increase is only 1.3 dBA, at 200 feet it is 2.0 dBA, and at 400 feet it is 2.4 dBA. The increases were calculated assuming equal noise source distributions in the near and far (eastbound and westbound) lanes and hard-site propagation.

Real-world situations are far more complicated than shown in Figures 5-23 to 5-26. The noise sources are distributed over the width of the highway, the paths of the barrier noise reflections are always longer than the direct noise paths, reflective barriers are not perfect reflectors, and the traffic stream likely interferes with the reflections. Because of these factors, reflected noise contributions are less than those of direct noise and seldom increase noise levels by more than 1 or 2 dB.

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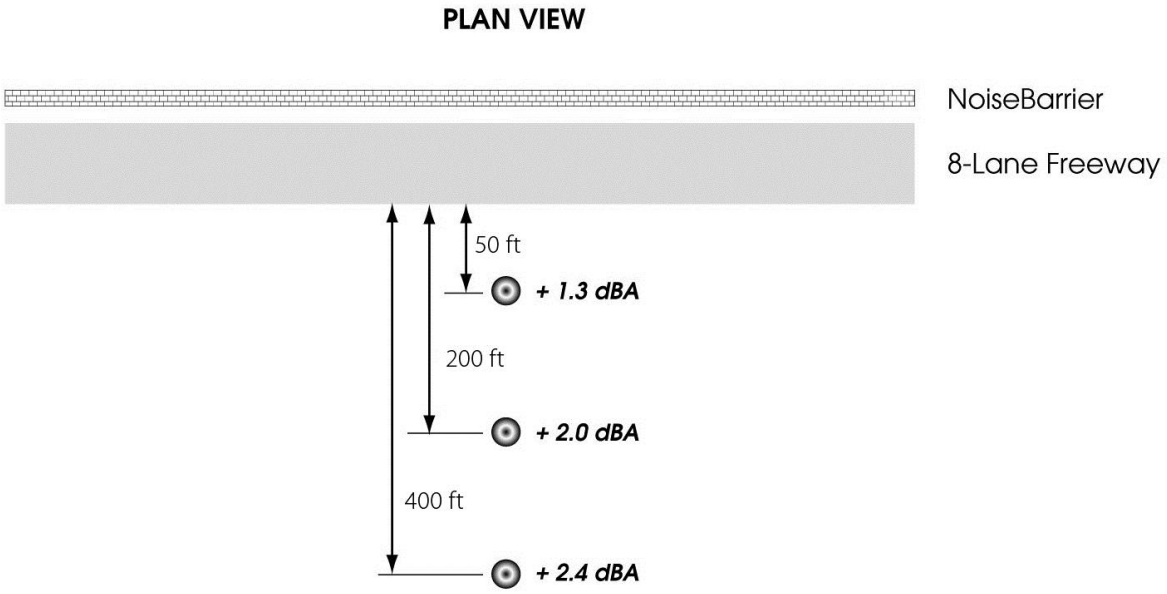

Figure 5-26. Noise Increases from Single-Barrier Reflections

Complex Terrain

In more complex terrain there are instances when single-barrier reflected noise could increase noise levels perceptibly at a receiver. One such case is shown in Figure 5-27, which depicts a receiver that is effectively shielded by terrain or the top of a depressed highway cut. If a noise barrier or retaining wall were constructed on the opposite side of the highway, unshielded reflected noise ray "r" could contain significantly more acoustical energy than the shielded direct ray "d," causing a noticeable increase in noise at the receiver. However, real-world situations are far more complex than illustrated. Some of the noise sources or noise paths may be shielded, while others may not. In general, if most of the traffic cannot be seen from the receiver while most of the noise barrier is visible, it is possible that the barrier noticeably increased noise levels at the receiver.

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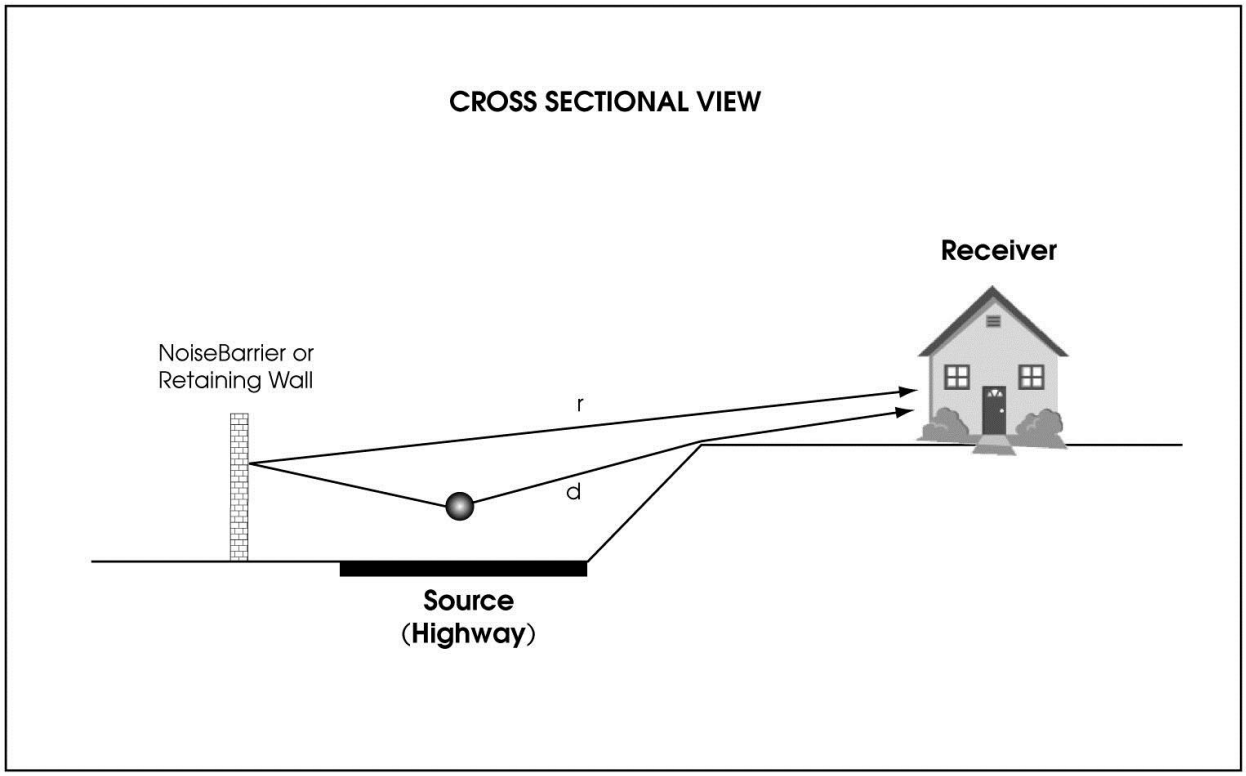

Figure 5-27. Single-Barrier Reflection (Direct Noise Shielded, Reflected Noise Not Shielded)

Reflections off single barriers located at the top of cut (Figure 5-28) generally are directed over a 5-foot-high receiver on the opposite side and therefore are usually not a concern for low receivers. However, higher receivers— the second floor of a residence or receivers located on a higher hill behind the front receivers—still may be affected by the reflections if the direct noise is shielded.

Situations depicted in Figures 5-27 and 5-28 (high receivers only) may increase noise levels by 3 to 5 dBA, depending on the angle of reflections and the height and length of the reflective barrier.

Single barriers on the top of fills (Figure 5-29) generally do not present any reflection issues. The reflected noise ray is usually well above the receiver.

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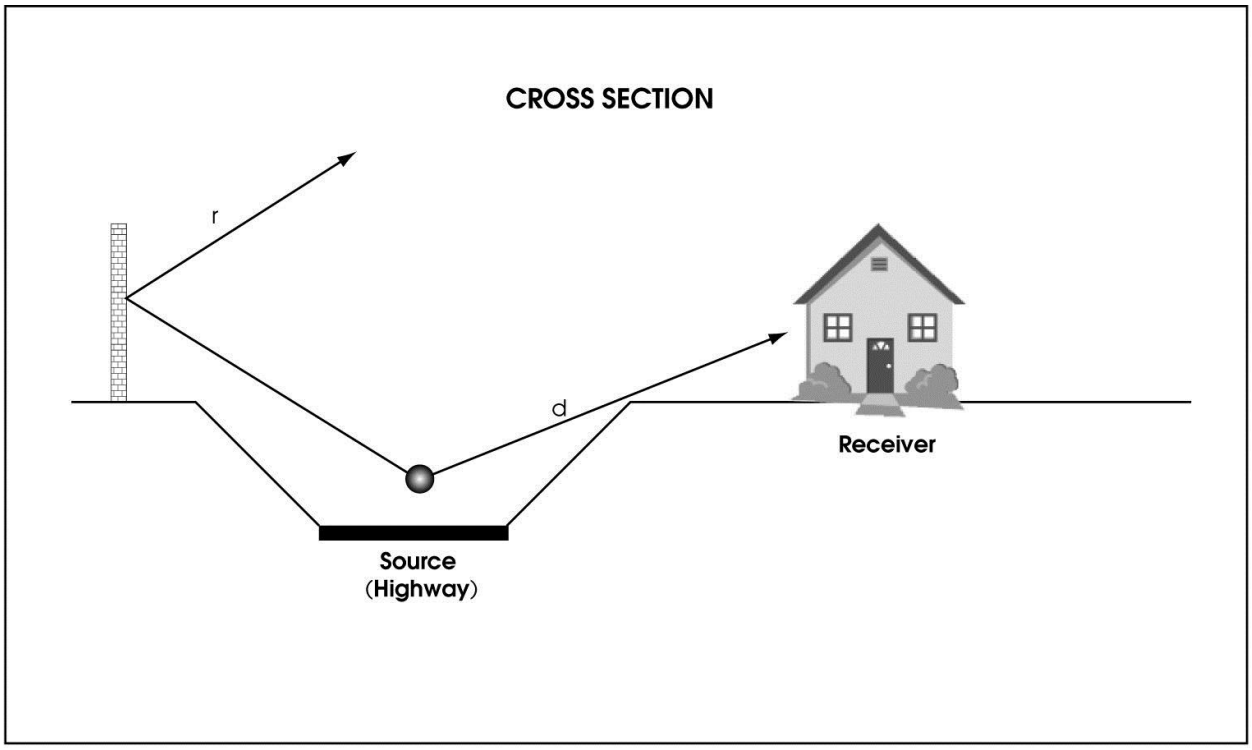

Figure 5-28. Single-Barrier Reflection (Noise Barrier on Top of Opposite Cut)

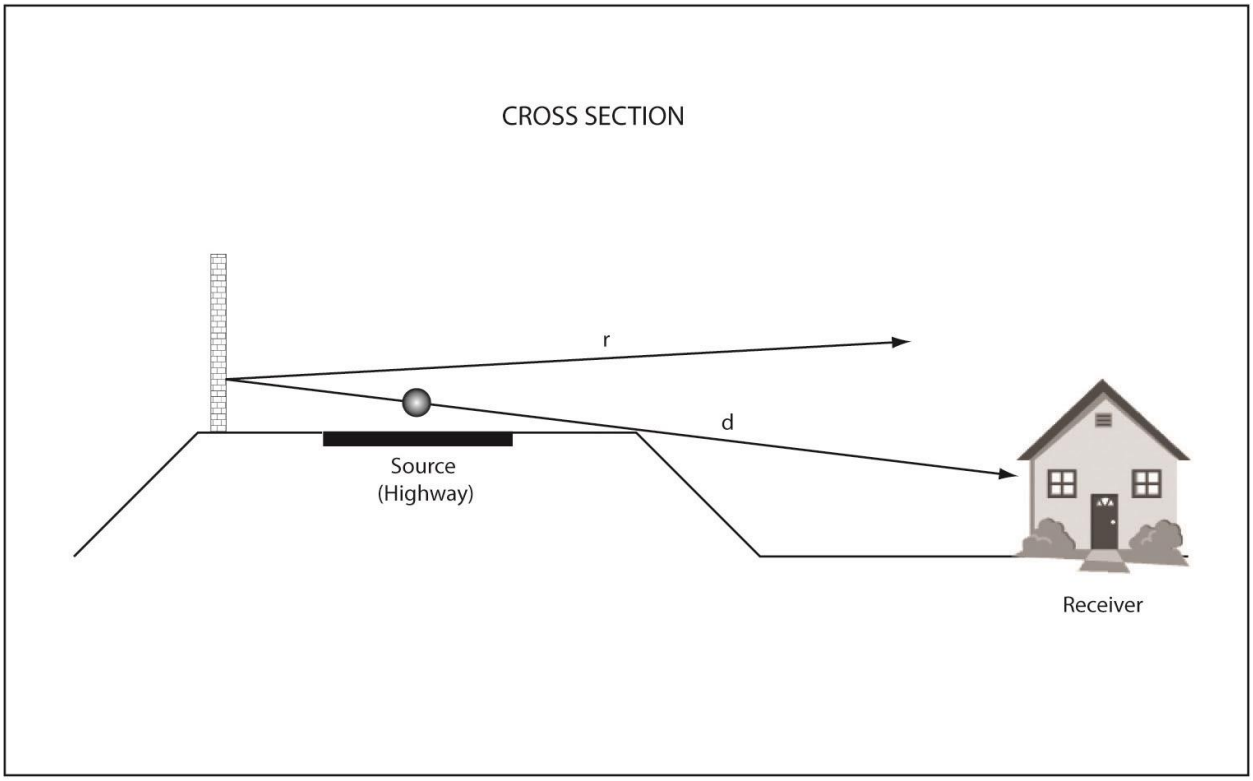

Figure 5-29. Highway and Noise Barrier on Fill

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5.1.7.3 Modeling Single Barrier Reflections

TNM currently has no provisions for calculating single barrier reflections. In the future, however, it is planned to have that capability.

For simple situations, the effects of reflections can be evaluated in TNM using image sources. Figures 5-30 and 5-31 illustrate these concepts in cross section and plan views.

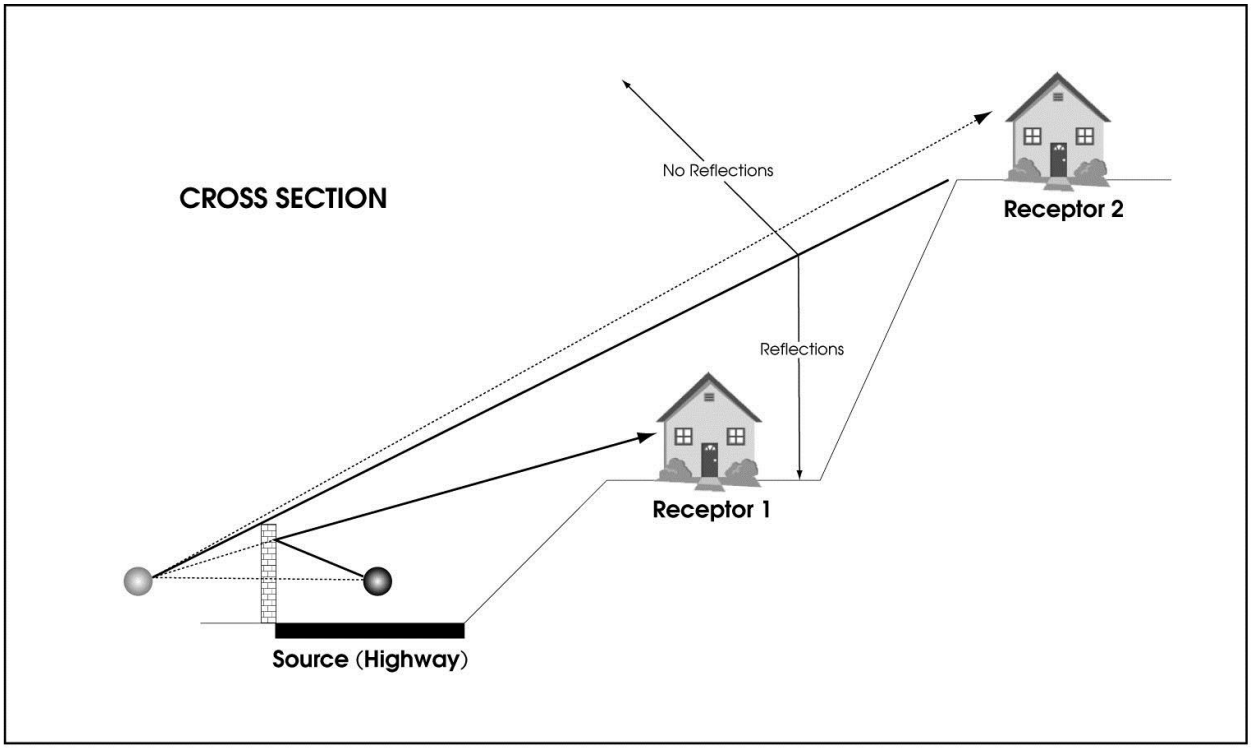

Figure 5-30. Placement of Image Sources (Cross Sectional View)

Figure 5-30 illustrates the placement of an image source in cross section by drawing a line perpendicular to the reflective wall (or its vertical extension) that passes through the real source. The image source is positioned on that line at the same distance from the wall as the real source but on the opposite side. The image source is analogous to a mirror image of the real source, with the wall acting as the mirror.

It is important to point out that just as mirror images cannot be seen from all angles, not all image sources necessarily contribute to reflections. A straight line drawn from the image source to the receiver must pass through the wall before the image source can contribute to the noise at the receiver. Please note that Receptor 1 lies in the "zone of reflections," while Receptor 2 does not experience reflective noise. In some cases, there

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are reflections from cars but not heavy trucks, or vice versa, depending on the site geometry. In other cases, only traffic noise from certain lanes will be reflected, while noise from others will not. Accurate site cross sections will reveal which image sources are relevant.

Figure 5-31 illustrates how an image source can be created in a plan view. A general case is shown with a finite wall that is not parallel to the roadway. Examination of Figure 5-31 reveals that for the purposes of creating an image source a finite wall creates a unique finite image line source for a particular receiver on the opposite side of a highway.

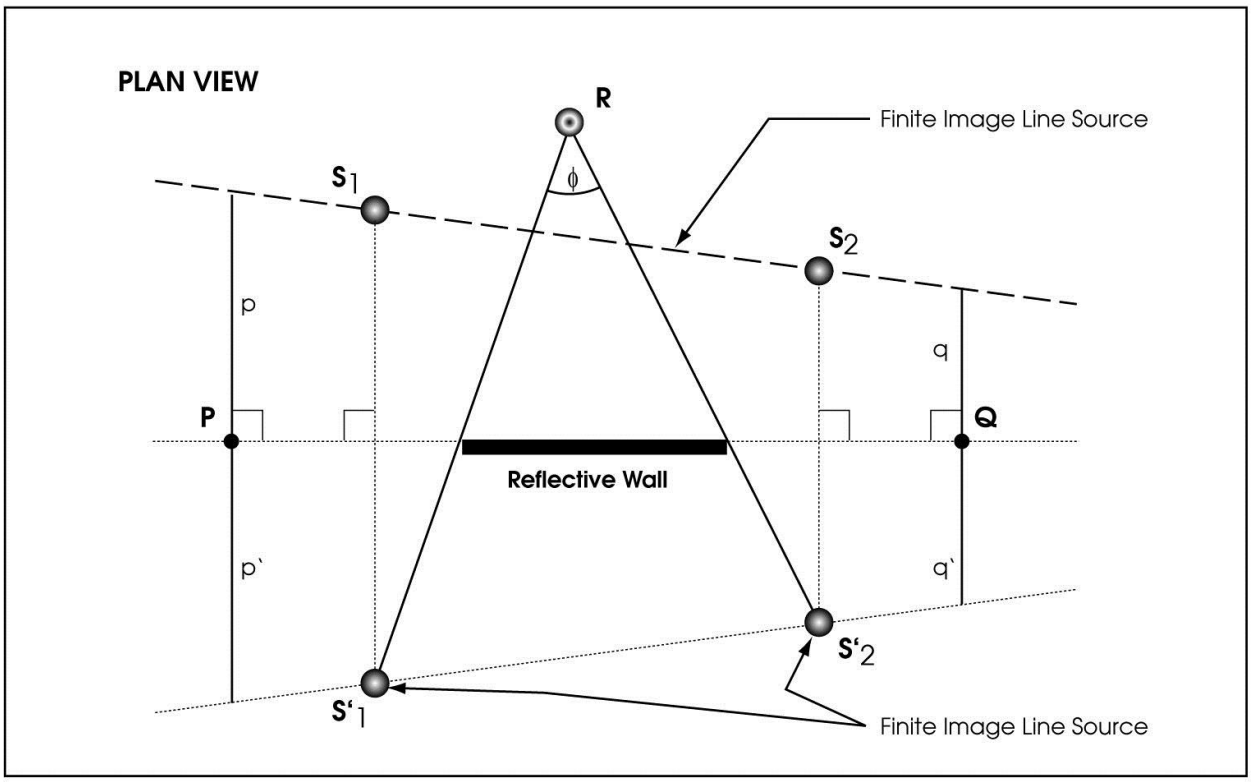

Figure 5-31. Placement of Image Sources (Plan View)

To construct the finite image line source, lines perpendicular to the wall or its extensions at two random locations (e.g., *P* and *Q*) can be drawn. Along these lines, distances *p* and *q* from the wall to the roadway line L, at *P* and *Q*, respectively, can be measured and reconstructed on the image side of the wall ($p = p'$, $q = q'$). A line L' connecting the two points defined by distances *p'* and *q'* establishes the direction of the image line source. Next, the termini of the infinite image line source can be determined by the intersections of line L' with two lines from the receiver *R* through both end points of the wall. S'_1 and S'_2 are now the end points of the finite image line source and represent image sources of real sources S_1 and S_2. To correctly account for the reflections at *R*, the finite image source S'_1 –

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S'_2 must be input along with the infinite real line source L. Because the reflective wall does not shield *R*, it must not be included in the analysis.

Please note that for a given source and noise barrier length, the locations S'_1 and S'_2 will be receiver-dependent. For each receiver location, the finite image source $S'_1 - S'_2$ will have a different length unless both the real line source and reflective wall are deemed infinite. When analyzing the effects of the reflections from the wall, each receiver must be analyzed and modeled separately unless both the line source and reflective wall are infinitely long. However, where receiver locations do not change the length of $S'_1 - S'_2$ significantly, the length may be averaged and applied to these receivers.

Only primary reflections should be considered when employing the above methods. Further, because each receiver is affected by a different set of reflections, the number of receivers modeled should be minimized. Even in that case, however, modeling of reflective noise can be very cumbersome. TNM does not currently have provisions for reflection calculations except for the parallel barrier analysis module discussed in the next section.

5.1.7.4 Parallel Barriers

Multiple reflections between reflective parallel noise barriers can potentially reduce the acoustical performance of each individual barrier. Figure 5-32 shows a simple illustration of only five of the many possible reflective paths in addition to the direct path to the top of the barrier. Theoretically, there are an infinite number of possible reflective noise paths. Each reflection essentially becomes a new source, which may add to the noise diffracted by the barrier nearest to the receiver. This in turn may reduce the barrier's effectiveness.

However, Figure 5-32 clearly shows that as the number of reflections for each possible path increases, the path length becomes significantly longer. However, in all instances the barrier-to-receiver distance is the same. Only the path lengths from source to receiver that are located between the barriers change. For the direct path, this distance is defined as $W - S$, where W is the separation distance between the two barriers and S is the distance from the far barrier to the source.

For the first reflective path, the distance is approximately $W + S$. For the second reflective path, it is approximately $3W - S$. Further examination of Figure 5-32 shows that the path length difference between the first reflective path and the direct path is $2S$. The difference between the second and first reflective paths is $2(W - \mathrm{S})$. The pattern repeats itself for

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subsequent reflections. These increases in path length distances for each subsequent reflection soon make their contribution to the total diffracted noise insignificant (only the first few reflections are important).

For example, for the special case where $W = 2S$ (source halfway between the barriers), each subsequent reflective path increases by W. Assuming that the distance between the source and receiver $D = W$ (a fairly typical situation) and the Noise Reduction Coefficient (NRC) is 0.05 (95% of energy reflected at each reflection point), the contribution of each subsequent reflection decreases rapidly because of increasing path length, as shown in Table 5-2. The table assumes only the effects of increasing distances and a slight absorption by the walls (5% at each reflection point), and does not include the effects of the location of the final point of reflection with respect to the source location. This affects the amount of diffraction by the wall on the receiver side, which will be different for each reflective path. Pavement reflections, constructive and destructive interference of sound waves, frequency shifts, effects of the traffic mix, traffic stream, and lane distribution are ignored also.

Noise contributions from parallel barrier reflections obviously depend on the source-to-receiver distance. For a fixed W, the relative distance attenuation for each reflective path decreases as D increases. The contribution of each reflection also increases as W decreases in relation to D (Figure 5-32).

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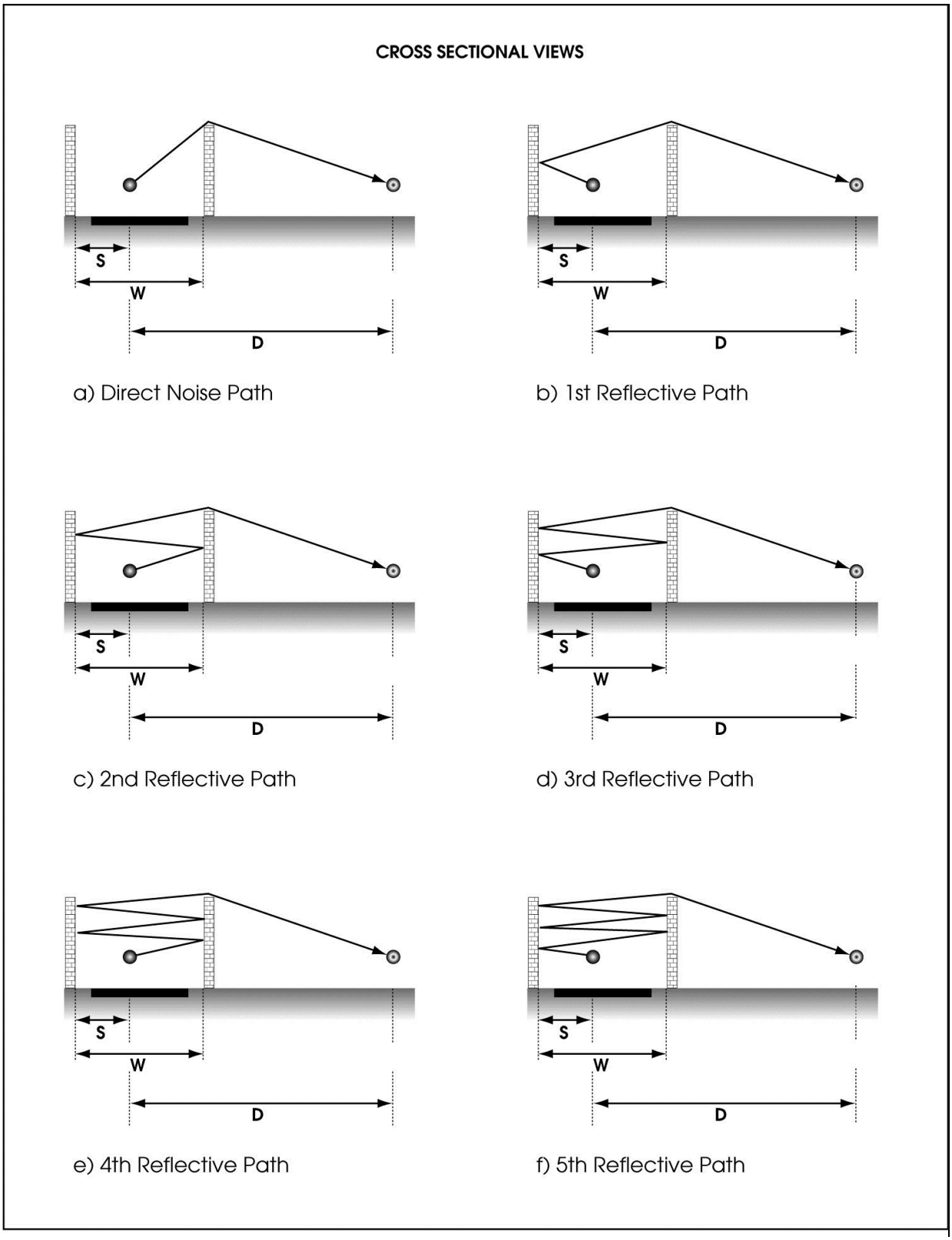

Figure 5-32. Various Reflective Noise Paths for Parallel Noise Barriers

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Table 5-2. Contribution of Reflections for Special Case Where W = 2S, D = W, and NRC = 0.05

Noise Path	Distance, (Source to Receiver of Reflected Paths)	(1) Distance Adjustment (Direct to Reflective Path) 10log(W / NW) (where N = 2 through 11) (dBA)	(2) Absorbed (NRC = 0.05) (dBA)	(1 + 2) Contribution (RE: Direct) (dBA)	Cumulative Total Noise Level (RE: Direct) (dBA) (Direct + 1st Reflective + 2nd Reflective, etc.)
Direct	W	0 (Ref.)	0	0 (Ref.)	0 (Ref.)
1st reflective	2W	-3.0	-0.2	-3.2	+1.7
2nd reflective	3W	-4.8	-0.45	-5.25	+2.5
3rd reflective	4W	-6.0	-0.7	-6.7	+3.0
4th reflective	5W	-7.0	-0.9	-7.9	+3.3
5th reflective	6W	-7.8	-1.1	-8.9	+3.6
6th reflective	7W	-8.5	-1.3	-9.8	+3.8
7th reflective	8W	-9.0	-1.6	-10.6	+3.9
8th reflective	9W	-9.5	-1.8	-11.3	+4.1
9th reflective	10W	-10.0	-2.0	-12.0	+4.2
10th reflective	11W	-10.4	-2.2	-12.6	+4.3

Noise contributions of reflections between parallel barriers degrade the performance (insertion loss) of each noise barrier. The amount of degradation that takes place depends on the site geometry and barrier configurations. In addition to the factors shown in Figure 5-32 and Table 5-2, there is another important relationship between the ratio of the separation between two parallel barriers (W) and their average height (H_{AVG}), and the amount of insertion loss degradation. As a rule, if the W / H_{AVG} ratio is 10:1 or more, the insertion loss degradation is less than 3 dBA. This has been supported by research done by Caltrans and others (California Department of Transportation 1991 and Federal Highway Administration 1990). Because of suggested noise barrier height limits in the *Highway Design Manual*, parallel noise barriers in California typically have a W / H_{AVG} ratio of 10:1 or more. Although there have been claims to this effect, there are no known instances in which reflective parallel noise barriers in any configuration have ever measurably increased noise levels over those without noise barriers. The W / H_{AVG} guideline applies not only to noise barriers, but also to retaining walls or combinations of both. Figure 5-33 illustrates these concepts.

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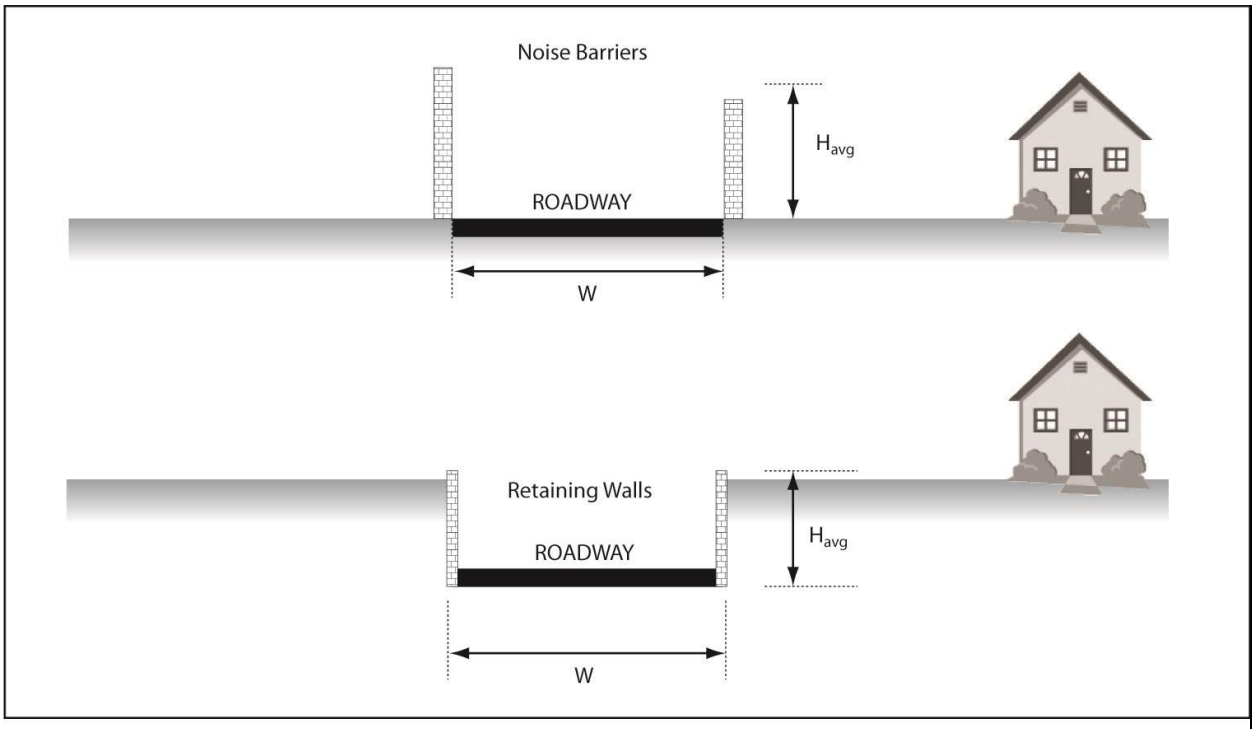

Figure 5-33. W / H_{AVG} Ratio Should be 10:1 or Greater

5.1.7.5 Reflections off Structures and Canyon Effects

Generally, the same rules that apply to reflections off noise barriers also apply to those off retaining walls. Because the height limitations to noise barriers do not pertain to retaining walls, there is more potential for noise reflections, especially when the retaining walls are along stretches of depressed freeways. However, no noise barriers in this configuration have ever been shown objectively and conclusively to result in higher noise levels than those of a similar at-grade freeway because of reflective noise.

Complex multi-level highway interchanges can present some challenges in noise abatement design. The widespread spatial distributions of traffic noise sources and receivers make it difficult to design noise barriers that interrupt all direct noise paths between the many source-to-receiver combinations. Additionally, reflective surfaces of concrete structural components create many opportunities for noise reflections to circumvent noise barriers. Figure 5-34 shows one example of a potential complication created by the interaction of structures and noise barriers.

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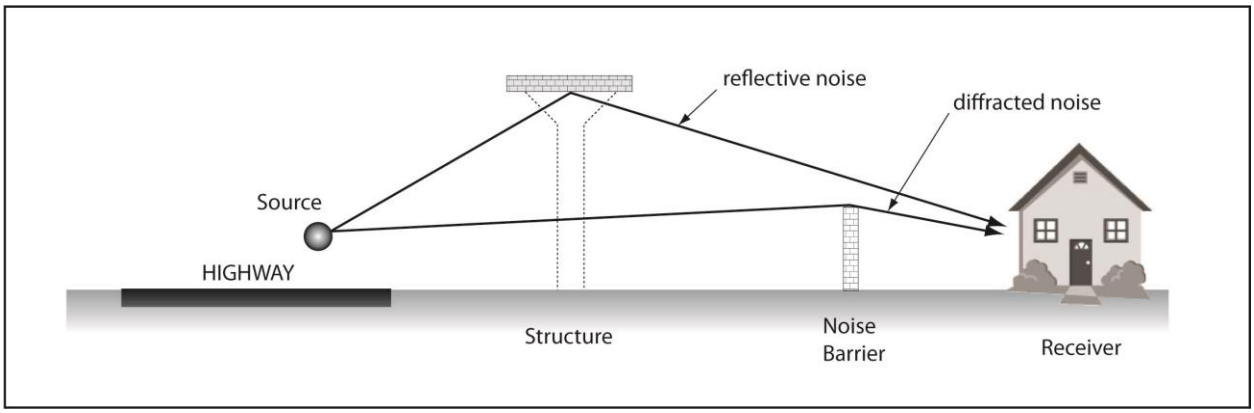

Figure 5-34. Noise Reflection off Structure

The structure in the illustration provides a point (or line) of reflection off the structure's soffit. This essentially creates a new line source with respect to the receiver shown. Unlike the highway noise sources that are shielded from the receiver by the noise barrier, the reflected noise (new source) is not shielded.

High median barriers (e.g., 5-foot-high concrete glare screens) are typically not considered an issue. Because of the barriers' limited height, reflections most likely are scattered and interrupted by the traffic stream.

The effects of reflections near tunnel portals can substantially increase noise at receptors near the portal. A study conducted in Germany (Woehner 1992) provides guidance on how to reduce noise at tunnel portals by applying acoustical absorption to the tunnel walls near the opening. The report indicates that the depth of treatment into the tunnel should be 2 to 3 times the diameter of the tunnel opening.

To date, Caltrans measurements have yet to conclusively reveal issues associated with the interaction between structures and noise barriers. The effects of reflections off structures would be limited because of the small reflecting surface and therefore affect only a relatively small group of receivers because of the small reflecting surface.

Studies of highways through canyons typically have shown noise increases of less than 3 dBA from canyon effects. Noise increases generated from highways in narrow canyons with steep side slopes theoretically could be more than 3 dBA, depending on groundcover and the steepness and smoothness of side slopes. The canyon walls, to some extent, act as parallel soundwalls with respect to multiple reflections. However, unless the slopes are perfectly vertical, buildup of reflections will be more limited because of the slope angles.

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Highways on hillsides with nearly vertical rock cuts are somewhat similar to the single barrier situation discussed previously. No perceptible noise increases are expected. Because of the angle of the cut slope, reflections are directed skyward, while receivers would likely be below the highway.

5.1.7.6 Double-Deck Bridge Reflections

A special case of multiple noise reflections is a double-deck bridge. Frequently, noise measurements taken at receivers near such a structure differ substantially from those modeled for the same conditions because of the model's inability to account for the noise contributions generated by lower-deck traffic, and reflecting between the lower road deck and the bottom (soffit) of the upper deck. An example of how to calculate the contributions of these reflections manually will be shown in this section.

In Figure 5-35, the noise levels at the receiver are determined by the direct diffracted path from the lower deck traffic (sources S_1 and S_2), traffic from the upper deck, and contributions from reflections between the lower deck and the soffit of the upper deck. The direct noise levels from the lower and upper decks can be modeled in the TNM. The contributions of the multiple reflections between the decks, however, cannot be modeled in TNM and require manual calculations that can be added to the results of TNM. To accomplish this, ignore the contributions of the upper-deck traffic and begin by modeling the geometry of the lower deck, the receiver, and the associated traffic at S_1 and S_2. In Figure 5-35, the direct paths from S_1 and S_2 are diffracted by the barrier at the edge of the lower deck.

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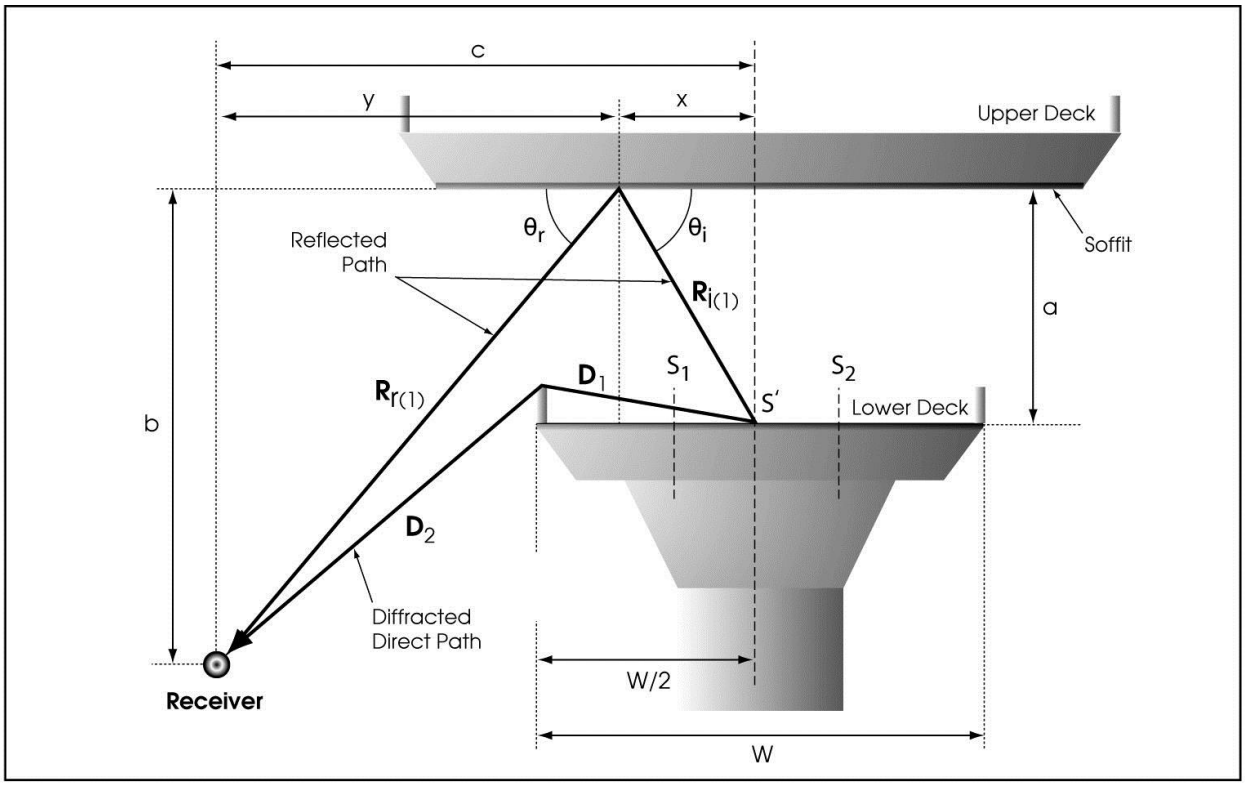

Figure 5-35. Double-Deck Structure Reflections, First Reflective Path

Contribution of Primary Reflection

Begin by analyzing only the primary (first) reflective path, $R_{(1)}$, as shown in Figure 5-35. Subsequent reflections will be analyzed similarly and will be discussed later in this section. $R_{(1)}$, consisting of the incident path $R_{i(1)}$ and path after first reflection $R_{r(1)}$, is not diffracted by the edge of the bridge. For simplicity, one path originating from S' is shown to represent an average of the primary reflective paths from both S_1 and S_2. The direct diffracted paths from S_1 and S_2 are similarly shown as one average path originating at S'. This approximation will yield results that are sufficiently accurate. Please note that all the sources depicted in Figure 5-35 are actually lines shown on end (disappearing into the paper). Therefore, all the direct and reflected paths are actually planes and propagate as line sources.

If the path lengths of both the direct diffracted and reflected paths are known, the line-source noise contribution of the reflective path relative to the direct path can be calculated as follows:

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$$10\log(D/R_{(1)}) \quad \textbf{(5-2)}$$

Where:

D = direct path length ($D_1 + D_2$)

$R_{(1)}$ = primary reflected path length ($R_{i(1)} + R_{r(1)}$)

However, this would be true only if D would be undiffracted. Any calculated reflected noise contributions would be relative to the undiffracted noise level originating from S_1 and S_2. These contributions could then be added to the diffracted noise level at the receiver. The difference between the undiffracted and diffracted noise levels can be calculated from modeled results.

The diffracted noise level at the receiver can be modeled with the geometry shown in Figure 5-35, eliminating the upper deck. The required dimensions are all given: the line source locations S_1 and S_2; the location of the edge of the bridge deck, including a jersey or other barrier; and the dimensions a to c.

The undiffracted noise level requires relocation of the receiver while keeping the distance of the diffracted path length, and raising the receiver high enough to not be influenced by the barrier at the edge of the bridge deck. This requires the straight-line path of the receiver to be at least 5 feet higher than the top of the (jersey) barrier. The difference between the diffracted and undiffracted noise level at the receiver can now be expressed relative to the undiffracted noise level. For instance, if the diffracted noise level is 60 dBA and the undiffracted noise level is 70 dBA, the latter is the reference, and the former becomes -10 dBA.

The contribution of the primary reflections (simplified by a single path representing both paths from S_1 and S_2) can now be calculated using Equation 5-2. Using Figure 5-35, calculate the lengths of D and $R_{(1)}$. D can be calculated as described below:

$$D = D_1 + D_2 \quad \textbf{(5-3)}$$

Where:

$D_1 \approx W/2$

$D_2 = \sqrt{[(b-a)^2 + (c - W/2)^2]}$

The calculation of $R_{(1)}$ requires additional manipulation. First, it is known the primary reflective path consists of $R_{i(1)}$ and $R_{r(1)}$, and the angle of incidence (θ_i) equals the angle of reflection (θ_r). It is also known that the primary reflective path must originate at S' and end at the receiver. Within these constraints, the location of the point of reflection, which lies on the soffit of the upper deck, a distance *x* from S' and a horizontal distance *y*

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from the receiver, which in turn lies a horizontal distance of *c* from S', can be calculated as described below. (It should be emphasized that the point of reflection and the source at S' are actually lines.)

Because $\theta_i = \theta_r$, x/y = a/b (sides of proportional triangles)
Therefore, x = y(a/b) and y = x(b/a)
In c = x + y (given), substitute y(a/b) for x
Therefore, c = y(a/b) + y = y[(a/b) + 1] and y = [c/(a/b) + 1] = bc/(a + b)
Similarly, x(b/a) can be substituted for y
By the above process, x = ac/(a + b)

Because a, b, and c are given, x and y can be readily calculated.

$R_{i(1)} = \sqrt{(x^2 + a^2)}$ and $R_{r(1)} = \sqrt{(y^2 + b^2)}$.
$R_{(1)} = R_{i(1)} + R_{r(1)}$

The noise contribution of R_1 relative to the undiffracted noise level at the receiver now can be calculated.

Example 1
Given
a = 30 feet
b = 50 feet
c = 60 feet = x + y
W = 66 feet
Undiffracted noise level from lower deck at image receiver = 70 dBA, $L_{eq}(h)$
Diffracted noise from lower deck is 60 dBA, $L_{eq}(h)$

Calculate
1. Contribution of primary reflection
2. Total noise level from lower deck at receiver (including primary reflection)

Step 1: Compute D
$D = D_1 + D_2$
$D_1 = W / 2 = 66 / 2 = 33$ feet
$D_2 = \sqrt{[(b - a)^2 + (c - W / 2)^2]} = \sqrt{[(50 - 30)^2 + (60 - 33)^2]} = 33.6$ feet
D = 33 + 33.6 = **66.6 feet**

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Step 2: Compute $R_{(1)}$

$R_{(1)} = R_{i(1)} + R_{r(1)}$

$R_{i(1)} = \sqrt{[x^2 + a^2)}$

$R_{r(1)} = \sqrt{[y^2 + b^2)}$

a and b are given

$x = ac / (a + b)$

$y = bc / (a + b)$

$x = (30 * 60) / (30 + 50) = 22.5$ feet

$y = (50 * 60) / (30 + 50) = 37.5$ feet

$R_{i(1)} = \sqrt{[22.5^2 + 30^2)} = 37.5$ feet

$R_{r(1)} = \sqrt{[y^2 + b^2)} = \sqrt{[37.5^2 + 50^2)} = 62.5$ feet

$R_{(1)} = 37.5$ feet + 62.5 feet = 100 feet

From Equation 5-2, the contribution of the primary reflective path is $10\log(D / R_{(1)})$, or $10\log(66.6 / 100) = -1.8$ dBA (RE: undiffracted noise level). The total noise level (RE: undiffracted noise level) is -10 dBA (diffracted noise level from lower deck) plus -1.8 dBA (from primary reflection), or $10\log(10^{-10/10} + 10^{-1.8/10}) = -1.2$ dBA. This means that because of the undiffracted primary reflection, the noise level from the lower deck at the receiver rose from (70 – 10) = 60 dBA to (70 – 1.2) = 68.8 dBA.

At this point, a discussion of the geometry and characteristics of the upper deck soffit surface is appropriate. In Figure 5-35, the point of reflection of the primary reflective path falls on the soffit. This may not always be the case, however, depending on the width of the upper deck and locations of the traffic sources and receivers. Each reflection must begin at the source and end at the receiver and the angles of incidence and reflection must be equal. If any of the constraints are not met, the reflection will not contribute. To determine whether the reflection contributes, *x* must be calculated first. The upper bridge deck must be sufficiently wide for the point of reflection to fall on the soffit surface, as determined by the distance *x* in Figure 5-35. If it does not, the reflection will not be a noise contributor. Similarly, the orientation of the upper deck relative to the lower deck must be accurately known. In Figure 5-35, the two decks are assumed to be parallel. If they are not, additional angle complications will be encountered in determining the reflective paths.

Other factors have been ignored so far. The soffit surface seldom is a perfect reflector (i.e., less than 100% of the incident sound energy is reflected back) at each point of reflection. If the sound absorptive characteristics of the soffit are known, Equation 5-2 can be expanded to include the fraction of incident noise energy that is reflected at each reflection point.

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The equation can then be written as follows:

$$10\log[(D / R_{(1)})(1 - \alpha), \text{ or } (1 - NRC)] \quad \textbf{(5-4)}$$

Where:

α or NRC = fraction of noise energy absorbed by soffit material

(1 – α) or (1 – NRC) = fraction being reflected

If α or NRC = 1, all noise energy is absorbed; none is reflected.

If α or NRC = 0, no noise energy is absorbed; all is reflected

Difference between α and NRC is discussed in Section 5.1.7.7 below.

For example, the NRC for a concrete surface is frequently given as 0.05. In Example 1, the contribution of the primary reflective noise path would be 10log[(66.6 / 100)(1 – 0.05)] = -2.0 dBA, instead of -1.8 dBA for a 100% reflection of noise energy. The difference between perfect reflection (NRC = 0) and NRC = 0.05 is 0.2 dBA. This difference is independent of distance and cumulative for each reflection point.

Contributions of Subsequent Reflective Paths

Figure 5-36 shows additional reflective noise paths from S' to the receiver. The second reflective path is almost identical to the primary noise path and consists of two reflection points, the first at S' on the pavement and the second almost coinciding with the primary reflection point.

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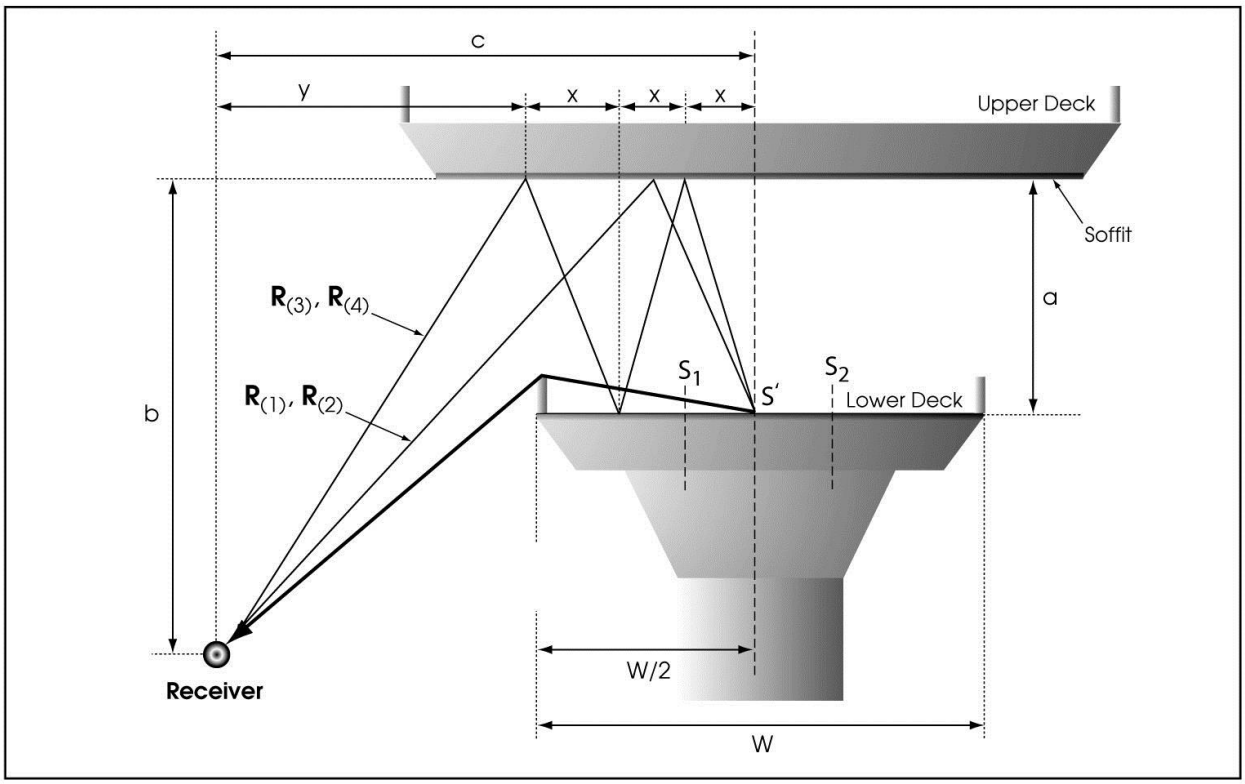

Figure 5-36. Multiple Reflective Paths

The difference between the primary and secondary noise paths is very small; therefore, they can be assumed to be the same. However, its contribution must be accounted for separately. The same is true for any even-numbered reflective path (e.g., the fourth reflective path almost coincides with the third reflective path). As discussed before, the number of possible reflective paths is limited to the following restrictions.

- Each reflective path must start at S' and end at the receiver.
- For each reflective path, the angles of incidence and reflection must be equal.
- For the *n*th reflective path, the last upper reflection point at distance $(n)x$ must fall on the soffit surface.
- The last lower reflection point at distance $(n - 1)x$ must fall on the lower deck surface.

For each reflective path, the distance x can be calculated as shown for the primary path. For the *n*th reflective path, $c = y + (n)x$. Therefore, $x = ac / [(n)a + b)$ and $y = bc / [(n)a + b)$. Also, $y = c - nx$. Actually, n refers to the odd-numbered reflective paths only. Each even-numbered reflective path is approximately equal to the previous odd-numbered one. Therefore, the noise contributions for the even-numbered reflective paths

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are also approximately the same as the previous odd-numbered reflective path (i.e., the noise contribution of $R_{(2)}$ equals $R_{(1)}$, and the contribution of $R_{(4)}$ equals $R_{(3)}$). The reflective path lengths can be calculated as shown in Example 1.

Using the same data as Example 1, the contributions of the remainder reflections can be determined. As stated, $R_{(2)} \approx R_{(1)}$, and the contributions are equal. $R_{(3)}$, which consists of three short incident/reflection paths (Figure 5-36) and a final long reflective path to the receiver, and its contribution can be calculated as follows.

Example 2

$x = ac / (3a + b) = (30)(60)/(90 + 50) = 12.9$ feet

$y = c – 3x = 60 – 3(12.9) = 21.3$ feet

Also, $y = bc / (3a + b)$, which can serve as a check:

$y = (50)(60) / (90 + 50) = 21.4$ feet

(Slight difference in results of y is because of rounding.)

Three short paths (all equal) $= \sqrt{(x^2 + a^2)} = \sqrt{(12.9^2 + 30^2)} = 32.7$ feet

Final reflective path $= \sqrt{(y^2 + b^2)} = \sqrt{(21.3^2 + 50^2)} = 54.3$ feet

$R_{(3)} = 3(32.7) + 54.3 = 152.4$ feet

$R_{(3)}$ contribution $= 10\log(D / R_{(3)}) = 10\log(66.6 / 152.4) = -3.6$ dBA

$R_{(4)}$ contribution = $R_{(3)}$ contribution = -3.6 dBA

Close examination of Figure 5-36 indicates that the number of possible reflective paths is limited by *x* and the smaller of the half-widths of the soffit or lower deck. By comparing the half-widths of both the soffit and lower deck with calculated $n(x)$, where *n* is each whole interval of *x*, the number of reflection points will become apparent. However, it should be noted that the final reflective path is the *n*th + 1 reflective path (in this case, $n + 1 = 4$).

Finally, the results from Examples 1 and 2 can be tabulated in summary form. An example of this format is shown in Table 5-3. All the reflective noise contributions shown are referenced to the undiffracted noise level at the receiver, but at the distance of the diffracted path. Because the reflective contributions are all without diffractions but the noise at the receiver (without reflections) is diffracted, all contributions to the undiffracted noise at the receiver must be normalized. As indicated in the discussion of primary reflection, undiffracted noise can be modeled by placing the receiver in such a position that no diffraction takes place. The previous discussion used undiffracted noise of 70 dBA and diffracted noise (without including reflections) of 60 dBA. The results table reuses these values. In that case, the reference is 70 dBA and all other values are relative to this reference. Also included is the correction for non-perfect

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reflections (assumed NRC = 0.05 [Equation 5-4] at each reflection point). Please note that reflective paths 2 and 4 actually have two and four reflection points very close to the source and therefore will be corrected for NRC 0.05.

Table 5-3. Summary of Reflective Noise Contributions and Cumulative Noise Levels

(1) Reflective Path Number $R_{(n)}$	(2) Contribution Relative to Ref.[a] [10log(D / $R_{(n)}$)]	(3) Correction for NRC = 0.05(n) 10log(1 – 0.05)	(4) [(2) + (3)] Adjusted Contribution (AC_n) Re: Ref.[a]	(5) Cumulative Noise Level (L_n)[b] Re: Ref.[a]	(6) [(5) + Ref.[a]] Absolute Noise Level
None	-10 dBA	None	0	L= -10 dBA (Given)	60 dBA (Given)
1	-1.8 dBA	-0.2 dBA	AC_1 = -2.0 dBA	L_1 = -1.4 dBA	68.6 dBA
2	-1.8 dBA	-0.4 dBA	AC_2 = -2.2 dBA	L_2 =+1.2 dBA	71.2 dBA
3	-3.6 dBA	-0.7 dBA	AC_3 = -4.3 dBA	L_3 = +2.3 dBA	72.3 dBA
4	-3.6 dBA	-0.9 dBA	AC_4= -4.5 dBA	L_4 = +3.2 dBA	73.2 dBA

[a] Ref. = reference of 70 dBA.

[b] Cumulative noise levels in column 5 are calculated as follows:
$L_1 = 10\log(10^{L/10} + 10^{AC1/10})$ $L_2 = 10\log(10^{L1/10} + 10^{AC2/10})$
$L_3 = 10\log(10^{L2/10} + 10^{AC3/10})$ $L_4 = 10\log(10^{L3/10} + 10^{AC4/10})$

5.1.7.7 Minimizing Reflections

When designing reflective parallel noise barriers, it is recommended that a minimum 10:1 W / H_{AVG} ratio is maintained between the two barriers to avoid perceivable barrier performance degradations. Earth berm noise barriers are not reflective and therefore not affected by W/H_{AVG} ratios of less than 10:1.

Sound absorption has been promoted as a solution for noise reflection issues. As part of an ongoing program, Caltrans considers a variety of proprietary noise barrier products and systems, some of which have sound-absorptive characteristics. . For more information on barrier materials and new products, the designer should check with the Caltrans Headquarters Office of Design and Local Programs for availability of approved materials, and the Division of Structures Design to determine which materials have been approved for use on noise barriers. Sound-absorptive materials can be an inherent property of the barrier or added on to an existing barrier (retrofit). The Caltrans new products webpage lists approved noise barrier products. These barrier products include reflective, absorptive, transparent, and bridge-rail-mounted options. The new products webpage is available here:

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http://www.dot.ca.gov/hq/esc/approved_products_list/

The amount of noise absorption of the materials is rated by a noise absorption coefficient α. The coefficient is defined as the ratio of the acoustical energy absorbed by the material to the total energy incident on that material. For any particular material, α is frequency-dependent, and its value for each specific frequency ranges from 0 (perfect reflector) to 1 (perfect absorber). To rate the overall absorptive characteristics of the material, a measure of the average α over the frequency range of interest is useful. For traffic noise frequencies, an appropriate measure is the NRC, which is the arithmetic average of α in four octave bands with center frequencies of 250, 500, 1,000, and 2,000 Hz, calculated as follows:

$$NRC = (\alpha_{250} + \alpha_{500} + \alpha_{1,000} + \alpha_{2,000})/4 \quad \textbf{(5-5)}$$

If approved absorptive materials are considered, a minimum NRC of 0.85 should be used as a criterion. This value means that 85% of the incident noise energy is absorbed and 15% reflected. For a single reflection, this can only add a maximum of 0.6 dBA to the direct noise level, instead of the theoretical 3 dBA for a perfect reflector (NRC = 0).

5.1.8 Miscellaneous Acoustical Design Considerations

There are various other factors that can affect the acoustical performance of noise barriers. Some (maintenance access, emergency access, and drainage openings) are discussed in *Highway Design Manual* Chapter 1100. The criteria in Chapter 1100 are based on actual noise measurements performed by the TransLab in the 1980s. Although the information is mostly useful to the designer of the noise barrier, it is repeated here for the noise analysts because they often need to field questions about the acoustical integrity of the noise barrier's design features. Refer to the Caltrans website for the latest version of the *Highway Design Manual*.

5.1.8.1 Maintenance Access behind Noise Barriers

Noise barriers placed within the area between the shoulder and right-of-way line complicate the ongoing maintenance operations behind the noise barrier. From a maintenance perspective, it would be best to place the noise barrier on the right-of-way line, which would avoid access issues and the need of a chain link fence. However, this location may not be

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preferable for acoustical reasons, as discussed in Section 5.1.2. If the right-of-way line borders a frontage road or other public easement, access to the strip of land between the barrier and the right-of-way can be provided through gates in the chain link right-of-way fence. If not, access may be provided by offsets in the barrier (Figure 5-37). The acoustical integrity of the noise barrier can be maintained by either providing a solid gate of appropriate material and transmission loss (see Section 5.1.1) to close the opening between the two barriers, or by providing a barrier overlap of two-and-a-half to three times the offset distance without closing the opening (Figure 5-38).

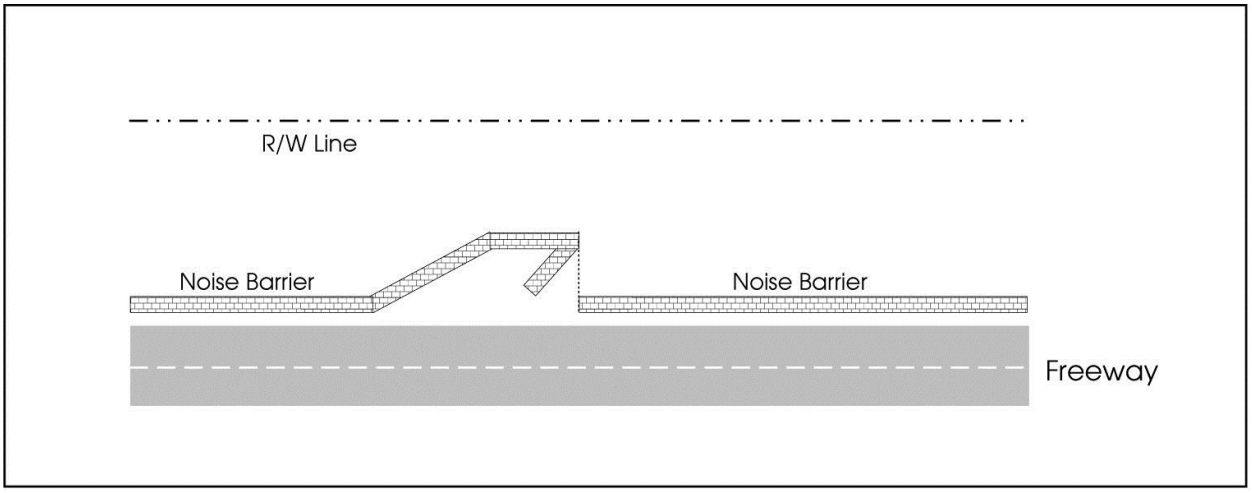

Figure 5-37. Barrier Offset with Solid Gate

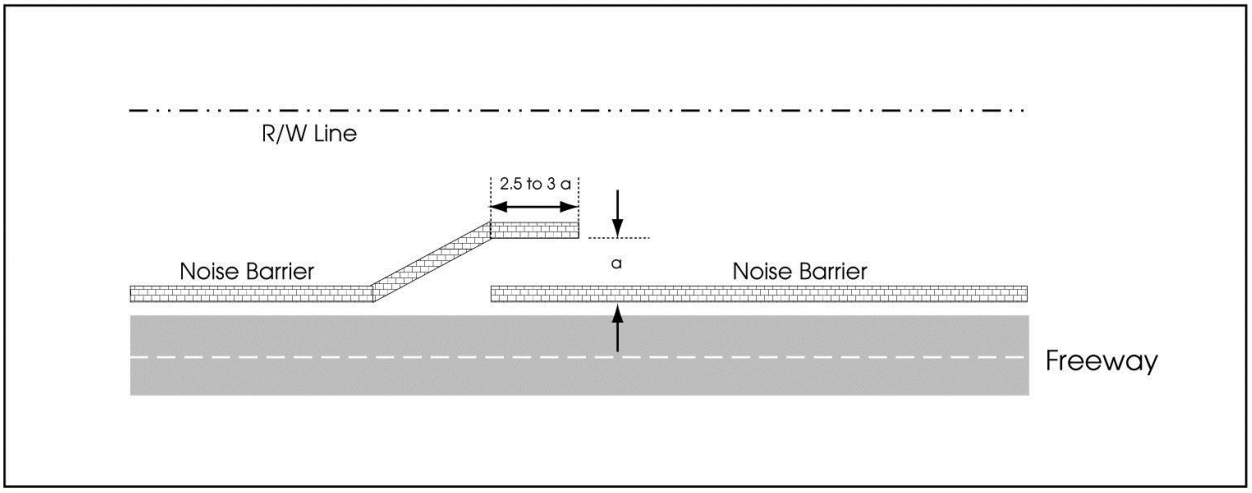

Figure 5-38. Barrier Overlap Offset 2.5 to 3 Times the Width of the Access Opening

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5.1.8.2 Emergency Access Gates in Noise Barriers

In addition to access gates and openings in noise barriers for routine maintenance, emergency access gates may be constructed to provide access to a freeway when emergency vehicles cannot reach the scene of an accident. The gates are not intended to provide alternate emergency access to adjacent neighborhoods. Small openings in the noise barrier may also be provided to allow fire hoses to be passed through. The number of gates should be minimized, and the gates should be at least 1,000 feet apart. Where possible, the maintenance openings and emergency access gates should be combined in one location. The Division of Structures Design has incorporated the design of the gates in the soundwall details. The fire hose openings should be located as close as possible to the fire hydrants on the local streets. The size and spacing of the openings normally do not compromise the acoustical performance of a noise barrier. Design details of these openings are available from the Division of Structures Design.

5.1.8.3 Drainage Openings in Noise Barriers

Drainage through noise barriers is sometimes required for various site conditions. Depending on size and spacing, small unshielded openings at ground level can be provided in the barriers to allow drainage without compromising the acoustical performance of the barrier. This can be accomplished if the following size and spacing criteria are observed.

- Openings of 8 by 8 inches or smaller if the openings are spaced at least 10 feet on center.
- Openings of 8 by 16 inches or smaller if the openings are spaced at least 20 feet on center and the noise receiver is at least 10 feet from the nearest opening.

The location and size of drainage openings need to be designed based on the hydraulics of the area. The designer should also consider possible erosion that may occur at the drainage openings.

Where drainage requirements dictate openings that do not conform to these criteria, shielding of the opening may be necessary to uphold the acoustical performance of the noise barrier in the vicinity of a receiver. Shield design should be done with consultation of the district hydraulics unit and noise analyst.

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5.1.8.4 Vegetation as Noise Barriers

In spite of a general perception of its effectiveness in lowering noise levels, shielding by shrubbery and trees typically used in landscaping along highways provides an imperceptible amount of noise reduction (less than 1 dB) (California Department of Transportation 1995). Such plantings are not effective for reducing highway noise. A possible explanation for the contradiction of objectively measured noise with general perception is that shrubs shielding traffic from the receiver reduce the visual awareness of the traffic. In such cases, the reduction in visual awareness of the traffic is commonly accompanied by a reduction in auditory awareness of the traffic. The role of landscaping and planting in enhancing the aesthetics of a noise barrier and combating graffiti are addressed in the next section.

5.2 Non-Acoustical Considerations

Final selections of materials, locations, heights, lengths, and shapes of noise barriers include non-acoustical considerations such as safety and aesthetics. Although the noise analyst is normally not involved with these decisions, the analyst should be aware that recommended acoustical designs of noise barriers are sometimes altered because of non-acoustical considerations.

5.2.1 Safety

Safety considerations include lateral clearances, sight distance requirements, and guardrail or safety-shaped barrier requirements. These safety considerations are addressed in *Highway Design Manual* Chapter 1100.

The Division of Structure Design has developed standard plans for noise barriers (soundwalls). Standard plans for soundwalls can be downloaded from the Caltrans website:

http://www.dot.ca.gov/hq/esc/oe/construction_standards.html

Other designs, retrofit treatments, and alterations to noise barriers should be approved by the Office of Structure Design. Approved commercial noise barrier products including absorptive barriers are listed on the Caltrans website:

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http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/noise_barrier_systems.pdf

The standard plans also include designs for gates that provide emergency access to community fire hydrants, emergency access for stranded motorists, and rapid access to accidents, as discussed in Section 5.1.8.

A minimum height criterion of 6 feet for soundwalls in *Highway Design Manual* Chapter 1100 was partially designed to control pedestrian access to the freeway. The online version of the *Highway Design Manual* at the Caltrans website should be checked for the latest changes and referrals.

5.2.2 Aesthetics

The visual impact of noise barriers on adjoining communities and motorists is a major consideration in the design of noise barriers. A high noise barrier placed close to single-story residences could result in a visual effect. A high barrier also can create shadows, impede natural airflows, or block panoramic views. *Highway Design Manual* Chapter 1100 outlines maximum recommended heights for noise barriers located at distances of 15 feet or less and more than 15 feet from the traveled way.

In general, visual dominance of high walls near residences is reduced when the soundwall is located at least two to four times its height from the nearest receiver. The visual impact is further softened with berms and landscaping (Figure 5-39). Landscaped earth berms are aesthetically superior to soundwalls and acoustically perform equally or slightly better. However, in many locations, they are not suitable because of space limitations.

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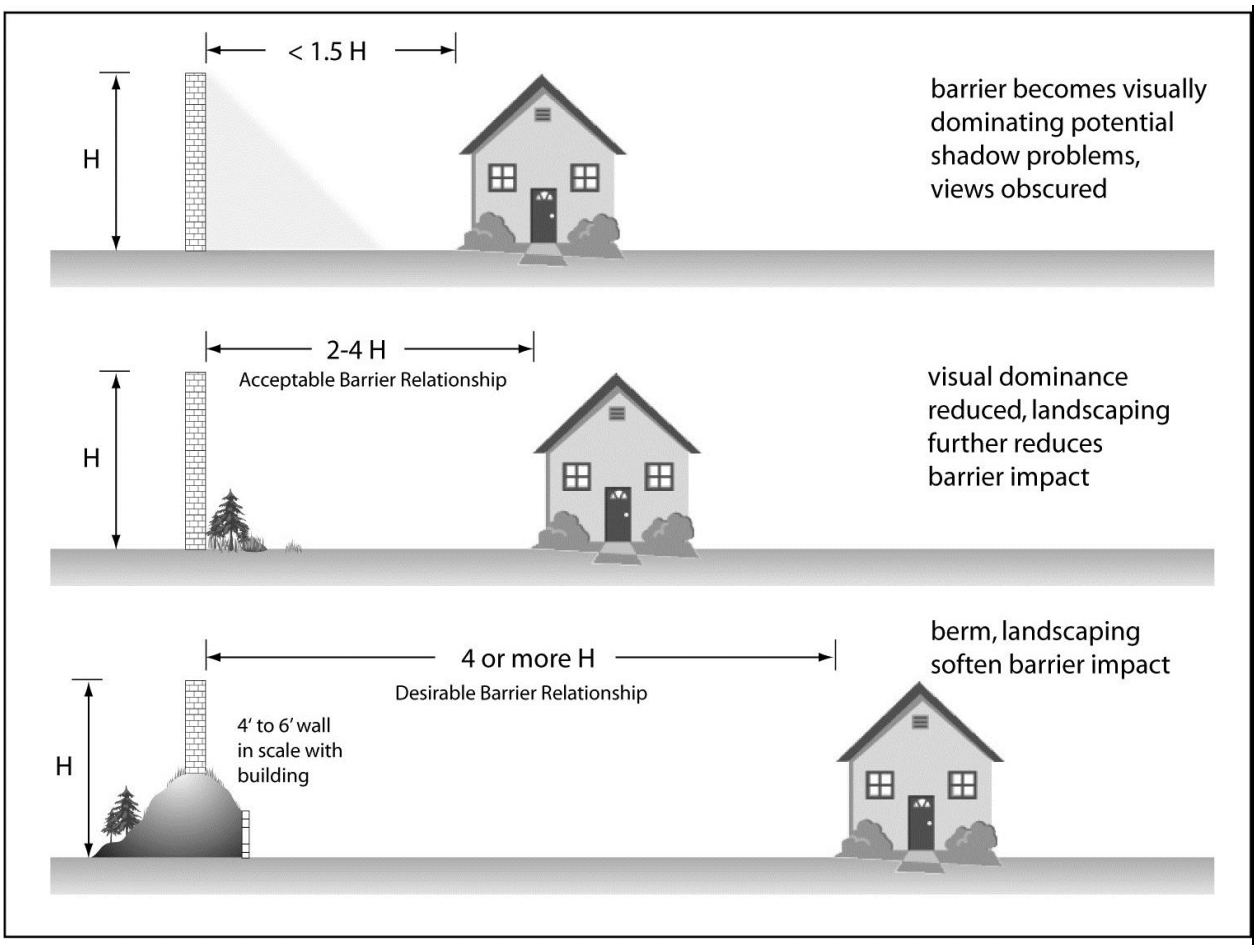

Figure 5-39. Spatial Relationship of Barrier to Adjoining Land Use

Soundwalls should not have abrupt beginnings or endings; they should be tapered or stepped. Aesthetic treatments are normally developed by the Division of Landscaping. If landscaping is to be placed adjacent to the soundwall where it eventually will screen a substantial portion of the wall, only minimal aesthetic treatment is justified.

Walls should reflect the character of the surroundings as much as possible. In cases where the general architecture of a community has a certain character, soundwall material, texture, and color should fit this character at the community side of the wall. Ideally, the community should have some input in the aesthetic design of noise barriers.

On the motorist side of the wall, the emphasis should be on the overall form, color, and texture of the wall. Visual effects on the driver from brick patterns and other forms and shapes should be considered when designing soundwalls. Small details will not be noticed at normal highway speeds. Instead, the emphasis should be on avoiding a tunnel effect through

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various forms, and visual treatments. Landscaping can be used effectively to accomplish this goal. As discussed, shrubs and trees used for landscaping along a highway do not provide effective shielding by themselves, but they can enhance the aesthetics of a noise barrier and combat graffiti by denying access to a large smooth surface and reducing its visibility from the highway or community side.

Further guidance on aesthetics can be found in *Highway Design Manual* Chapter 1100. Another useful reference on all aspects of noise barrier design and extensive coverage of aesthetics is the *FHWA Noise Barrier Design Handbook* (Fleming et al. 2011).

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Section 6

Noise Study Reports

The primary function of a noise study report is to present the methods and results of a traffic noise analysis, as well as the data supporting the conclusions, to a target audience that includes both laypersons and technical noise analysts. To satisfy both audiences, the author can provide a summary for laypersons and decision-makers, and a technical report for experienced readers who desire more detail than what is provided in the summary.

The summary should briefly describe the existing land use and noise environment, project alternatives, future noise environment, traffic noise impacts, and noise abatement and mitigation considered. The technical report needs to fully support the conclusions that are incorporated into the environmental document and should satisfy technical reviewers who wish to assess the validity of the noise study, including methods and assumptions. Sufficient information should be presented to allow any trained noise analyst to reach the same conclusions.

As with all technical environmental studies, the level of effort to be spent on the noise study report needs to correspond to the size and complexity of the project, and degree of controversy surrounding it.

After completion of the noise study report, the noise abatement decision report (NADR) is prepared. The NADR is a design responsibility and is prepared to compile information from several sources. These sources include the noise study report, other relevant environmental studies, and design information. The NADR brings this information together into a single, comprehensive document that is completed before public review of the project. The NADR is prepared before publication of the draft environmental document.

The draft environmental document is the primary means of conveying information on noise impacts and abatement to the public, and reflects conclusions and information contained in the noise study report and NADR.

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6.1 Outline

Table 6-1 shows an outline for a typical noise study report. Not all reports will need this level of detail. Others may require more because of special circumstances. An annotated noise study report outline has been prepared by Caltrans and is available: <http://www.dot.ca.gov/ser/forms.htm>. This outline provide guidance on the contents of noise study reports and provides a template with standard language that can be used a starting point for those who are preparing noise study reports.

Table 6-1. Noise Study Report Outline

Summary (or Executive Summary)

Purpose of Noise Report
Brief Description of the Project
Brief Description of the Land Use and Terrain
Existing Noise Levels (Ambient and Background)
Future Predicted Noise Levels
Traffic Noise Impacts (if Any)
Noise Abatement/Mitigation Considered (Range of Heights, Lengths, Insertion Losses, and Number of Benefited Receivers)
Reasonable Monetary Allowances per Benefited Receiver for Abatement Considered
Areas Where Abatement/Mitigation Is Not Feasible
Construction Noise

Chapter 1. Introduction

1. Purpose of Report
2. Background

Chapter 2. Project Description

1. Detailed Description of All Project Alternatives
2. Maps Showing Alignment and Profiles

Chapter 3. Fundamentals of Traffic Noise

1. Decibels and Frequency
2. Noise Source Characteristics (Vehicles and Roadways)
3. Noise Propagation
4. Perception at the Receiver, A-Weighting, and Noise Descriptors
5. Decibel Scale

Chapter 4. Federal and State Policies and Procedures

1. Traffic Noise Analysis Protocol
2. Technical Noise Supplement

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Chapter 5. Study Methods and Procedures

1. Selection of Receivers and Measurement Sites
2. Field Measurement Procedures (Note: Field Data in Appendices):
   a. Instrumentation and Setups
   b. Noise Measurements
   c. Traffic Counts and Speeds
   d. Meteorology
   e. Data Reduction
3. Noise Prediction Method Used: TNM as mandated in 23 CFR 772

Chapter 6. Existing Noise Environment

1. Detailed Description of Noise-Sensitive Land Use
2. Maps Showing Receivers and Noise Measurement Sites
3. Table Showing Existing Noise Levels at Receivers:
   a. Field-Measured Results (Ambient and Background)
   b. Modeled Results
4. Discussion on Model Calibration (if Appropriate) for Adjusting Modeled Noise Levels (Existing or Future)

Chapter 7. Future Noise Environment, Impacts, and Considered Abatement/ Mitigation

1. Discuss Future Traffic Data Assumptions and Site Geometry
2. Table Showing Predicted Noise Levels and Identification of Traffic Noise Impacts, if Any
3. Discussion of Noise Abatement Options
4. Table Showing Future Noise Levels and Insertion Losses (Noise Reduction) for Various Noise Barrier Heights, Lengths, and Locations
5. Table showing top-of-wall elevations as a function of station number
6. Table Summarizing Data Necessary for "Reasonableness" Determination
7. Discussion of Areas Where Abatement/Mitigation Is Not Feasible

Chapter 8. Construction Noise

Chapter 9. References

Appendix A. Traffic Data

Appendix B. Predicted Future Noise Levels and Noise Barrier Analysis

Appendix C. Noise Barrier Reasonableness Analysis Worksheets

Appendix D. Noise Barrier Analysis

Appendix E. Supplemental Data

1. Instrumentation, Manufacturer, Model, Type, Serial Number, and Calibration
2. Measurement Site Details and Instrument Setups
3. Measurement Procedures, Duration, and Number of Repetitions
4. Measured Noise Data, Dates, and Times
5. Meteorological Conditions
6. Traffic Counts
7. Data Reduction and Measurement Results
8. Details of Computer Modeling Assumptions, Inputs, and Outputs

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6.2 Summary

The noise study findings and conclusions should be presented near the front of the noise study report in the form of a summary (sometimes called *Executive Summary*). The summary is extracted from the technical portion of the noise study report. This requires the technical portion to be written first.

The summary should target laypersons and managers who are interested in the findings and conclusions of the noise study but not concerned about all of the technical details. Because the author of the noise study report is usually not the author of the project's environmental document, the summary should be written in such a manner that it can be copied into the environmental document. This will help to reduce misinterpretations, inconsistencies, loss of vital information, and numerical transpositions. The summary should be short, usually no longer than a few pages. The elements mentioned in Table 6-1 should be described briefly. A table listing receivers, existing noise levels, future noise levels without noise barriers, future noise levels with noise barriers (various heights), and insertion loss should be sufficient to summarize the results of the noise study.

6.3 Noise Impact Technical Study

The noise impact technical study is the main body of the noise study report. It contains detailed descriptions of why and how the noise study was performed and how the conclusions were reached. Sufficient detail is needed for someone to be able to duplicate the study from the information included in report.

6.3.1 Introduction

The introduction should include the purpose of the noise study report, study objectives, background information such as the need for the project and study, and any other general information useful to the understanding of the noise study report.

6.3.2 Project Description

The project description should include a detailed description of all project alternatives. There should be enough information for the reader to

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understand the project and how it fits into the transportation system of the area. An appropriate location map that shows the alternative alignments studied and their spatial relationship with noise-sensitive receivers such as residences, schools, hospitals, churches, and parks should be included.

6.3.3 Fundamentals of Traffic Noise

A short review of the physical principles of traffic noise at the source and its propagation, as well as subjective human perception, will provide a link for laypersons to understand the technical information. The contents of this section may be in a standard format or tailored to specific studies.

The noise characteristics of vehicles should be described briefly. Vehicle noise emissions increase with speed, and increased traffic volumes increase traffic noise, but it takes a doubling of traffic to increase noise levels by only 3 dB.

Noise propagation (line vs. point source) over acoustically hard and soft ground, effects by meteorological factors such as wind and temperature gradients, and shielding by terrain or noise barriers should be discussed.

Human perception of noise is frequency-dependent, which leads to a discussion on A-weighting, its purpose, and its use. If the character of the noise is unchanged sound level increases or decreases generally are perceived as follows: 3 dBA as barely perceptible, 5 dBA as readily perceptible, and 10 dBA as a doubling or halving of noise. This should be followed with a discussion on commonly used noise descriptors, such as $L_{eq}(h)$.

Inclusion of a decibel scale that shows a link between everyday activities and associated noise levels will provide the reader with a scale by which to evaluate the severity of traffic noise.

This discussion does not need to be restricted to the above items. Other topics may be included as appropriate, some of which may be specifically tailored to the nature of the noise study. The information presented in this TeNS may be beneficial in explaining various phenomena. For instance, where controversies surrounding parallel or single noise barrier noise reflections are an issue, it may prove beneficial to include relevant selected text from Section 5.1.7 or 7.1. Text from Section 7.1 may be similarly useful in addressing concerns about the effects of noise barriers on distant receivers.

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6.3.4 Federal and State Standards and Policies

This section addresses the applicable federal and state standards and policies. Caltrans noise analysis policies are in the Protocol and *Highway Design Manual*. Federal requirements are identified in 23 CFR 772. State requirements are contained in Streets and Highways Code Section 216. Terms used in the policies and standards should be mentioned in this section including the NAC, definitions of appropriate noise descriptors, and traffic noise impact criteria.

6.3.5 Study Methods and Procedures

Study methods and procedures followed should be identified in the noise study report. This section should describe selecting receivers, noise measurement sites, field measurement procedures, and noise prediction methods (see Sections 3 and 4).

The discussion of selecting the receivers and noise measurement sites should focus on the reasons they were selected. Selections are based on expectations of worst noise impacts, geometry of the project, representativeness, acoustical equivalence, and human use (see Sections 3.2 and 4.3.1). The importance of selecting receivers outside the area of project influence must not be overlooked. These receivers are extremely useful for documenting background noise levels and, after the project is built, guarding against unsubstantiated public claims that noise barriers constructed as part of the project increased noise levels at distant receivers (see Section 7.1.1).

The discussion on field measurement procedures (see Section 3) should include descriptions of instrumentation, setups, noise measurement procedures, traffic counts and speeds, meteorological observations, and data reduction methods. Model calibration procedures (see Section 4.4) should also be discussed.

The appendices to the noise report should indicate the measurement equipment used, calibration information, dates and times of measurements, measured noise data, traffic counts and speeds, meteorological conditions, site topography, and detailed measurement locations. (As a general rule, the microphone locations should be retraceable within 3 feet horizontally, and 1 foot vertically.) If measurements were taken at a time different from the worst noise hour, the adjustment and procedure used (see Section 3.3.1.2), any receivers modeled and calibrated, and any inputs should be shown.

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Noise level predictions must be based on the methodology in the FHWA Traffic Noise Model. These and other documents pertinent to the noise study should be referenced as appropriate.

6.3.6 Existing Noise Environment

Before traffic noise impacts can be evaluated, detailed knowledge of the existing noise environment is required. A description of the project's surrounding land use (e.g., residential, commercial, undeveloped land, farmland) should be included in this section. The number and types of receptors involved should be reported so that the reader understands the size and characteristics of the area under study. Particularly sensitive land uses should also be pointed out. For undeveloped land, future uses should be included if they are known. For reporting purposes the Protocol requires that at least one receiver be included in an area that is undeveloped. The presence of any other stationary or mobile noise sources (e.g. arterials, airports, railyards) should also be noted.

The general topography surrounding the project and any issues in noise measurements or modeling should be pointed out in this section, especially for complicated or unusual situations. A discussion on background noise levels (i.e., noise levels unaffected by the existing highway) is also appropriate as well as a general description of traffic flow conditions (i.e., traffic level of service). The importance of selecting measurement sites to document background noise levels is discussed in Section 3.1.1.

For each receiver selected for the noise impact analysis, the following should be shown.

- Location or address.
- Type of development.
- Number of units represented by the receiver.
- Land use activity category and NAC.
- Existing noise level results (data logs should be included in the appendices).
- State whether existing noise level was measured or modeled (predicted).
  - If measured, whether measurement was adjusted to worst hour noise (see Section 3.3.1.2).

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- If predicted, whether prediction included model calibration (see Section 4.4) (details of the calibration, such as the calibration constant and explanations of why they were excessively large, should be in the appendices).

Table 6-2 suggests how the information might be displayed in tabular form. The format shown is only an example. The information may be presented in other ways as long as the result is clear, concise, and effective.

This section should only show a summary of the results. It is important to mention whether the existing noise levels reflect the worst noise hour or other time periods. The text should include brief discussions of meteorological conditions during measurements and meteorological criteria. Noise measurement data, traffic counts, speeds, meteorological conditions, site locations, and topography should be included in the appendices.

6.3.7 Future Noise Environment, Impacts, and Considered Abatement

This section of the noise study report addresses the future noise environment. A discussion of the assumptions and data used to model predicted noise levels is appropriate. The source of predicted future traffic volumes (e.g., traffic models, assumed level of service [LOS] C or D, design-hour traffic), vehicle mix, and speeds should be included. The actual input and output data should be presented in the appendices.

The predicted results for future noise levels, traffic noise impacts, and considered abatement, if any, should be presented clearly and concisely. It is usually best to display summary information in tables. Examples of presenting predicted noise levels and impacts are shown in Tables 6-3 and 6-4. The table shows receivers, receiver type, location or address, existing noise levels, predicted noise levels, noise increase or decrease, activity category, NAC, and impact type. A project map showing receivers and approximate locations of noise barrier locations considered should be included.

The table showing predicted noise and impact results provides information for discrete receivers. The information must be expanded to include the entire study area. Table 6-2 shows how many units were represented by each selected receiver. This information can be used to identify areas of traffic noise impacts and the acoustical design of noise barriers (e.g., insertion loss, length, and height). For projects where traffic noise impacts

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have been identified, heights and lengths of all feasible noise barriers or other abatement measures should be shown, as well as enough information to determine the reasonable noise abatement allowance per benefited residence for each noise barrier and height considered. This allowance is necessary to determine whether abatement measure costs are reasonable. Although noise barriers are normally considered for abatement, other measures may also be considered (see the Protocol) and in some instances might be a better option.

If noise barriers are be considered for the project, the future noise levels and noise insertion losses for various barrier heights or alternate locations should be provided in tabular form. As stated in Section 1102.3 of the Caltrans *Highway Design Manual* a noise barrier should intercept the line of sight from the exhaust stack of a truck to the receptor. The truck stack height is assumed to be 11.5 feet above the pavement. The receptor is assumed to be 5 feet above the ground and located 5 feet from the living unit nearest the roadway. Table 6-4 provides an example of how this information can be reported.

The procedures for determining the preliminary reasonableness of noise abatement (see the Protocol) require various inputs, most of which have been discussed. Table 6-5 is an example of how this information may be displayed. The fact that barrier heights and locations are preliminary and subject to change should be mentioned.

If appropriate, it should be mentioned that noise barriers under consideration can create their own impacts. Barriers may interfere with the passage of air, interrupt scenic views, or create shadows. They can also create maintenance access challenges, make it difficult to maintain landscaping, create drainage or snow removal issues, and provide pockets for trash to accumulate. In certain circumstances, they may raise concerns about safety by blocking areas from the view of patrolling police. Noise barriers can also raise concerns about traffic safety by reducing stopping or merging sight distance or by reducing errant vehicle recovery room.

It is not uncommon for roadway geometries to change between the time the noise study report is completed and final design. Because calculated barrier attenuation values are directly tied to the geometric relationship between the roadway, barrier, and receivers, it is important to document the top and bottom elevations of noise barriers relative to the elevation of the roadway. Then if geometries change in the final design, an assessment can be made as to the significance of the geometric change relative to calculated barrier attenuation. If the geometric change is large enough it may be necessary to re-run the noise model with the new geometries to ensure that predicted attenuation values are maintained or to re-assess cost reasonableness if attenuation values change significantly.

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To document the elevations used in the noise analysis a top-of-wall profile should be provided for each noise barrier evaluated. The elevation profile should be provided for the minimum height wall that breaks the truck stack line-of-sight and the wall height that meets the reasonableness design goal (7 dB noise reduction at one or more benefited receiver). It may also be useful to include the elevation of the base of the barrier and outside travel lane. Table 6-6 is an example of how roadway and barrier elevations can be reported.

6.3.8 Construction Noise

Construction noise impacts and likely abatement measures (if necessary) should be discussed briefly. Unless the project involves construction activities that are likely to generate unusually high noise levels such as pile driving or pavement breaking, the discussion should be concise. Detailed discussions of typical construction equipment noise levels are probably not necessary unless the project involves unusually sensitive receptors or nighttime work or if the project is controversial. Caltrans Standard Specification Section 14-8 should be discussed. It states the following.

- Do not exceed 86 dBA L_{max} at 50 feet from the job site activities from 9 p.m. to 6 a.m.

- Equip an internal combustion engine with the manufacturer-recommended muffler. Do not operate an internal combustion engine on the job site without the appropriate muffler.

Procedures for analysis, monitoring, and abatement of construction noise can be found in Section 7.5.

6.3.9 References

Typical references may include 23 CFR 772, *FHWA Highway Traffic Noise: Analysis and Abatement Guidance* (December 2011), the Protocol, *Highway Design Manual* Chapter 1100, FHWA-PD-96-009 and -010, DOT-VNTSC-FHWA-98-1 and -2, and other appropriate documents.

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Table 6-2. Existing Noise Levels (Example)

Receiver	Location or Address	Type of Development	Units Represented	Noise Abatement Category and Criterion	Existing Worst Hour Noise Level, (dBA-L_{eq}[h])	Noise Level Measured[a] or Modeled[b]?
1	1234 Elm Street, backyard, center of patio (first-row residence)	Residential	15	B (67)	74	Measured
2	4321 Main Street, 5 feet from façade (first-row residence)	Residential	9	B (67)	75	Measured
3	2336 Elm Street, center of backyard (first-row residence)	Residential	24	B (67)	73	Modeled
4	3538 Elm Street, center of backyard (first-row residence)	Residential	18	B (67)	74	Modeled
5	1212 Church Street, 10 feet north of bottom front step	Church	1	C (67)	68	Measured
6	1723 Oak Street, center of front lawn (0.25 mile from the freeway, background noise level)	Residential	24	B (67)	56	Measured
7	1052 Sycamore Drive, middle of cul-de-sac, (0.25 mile from the freeway, background noise level)	Residential	30	B (67)	55	Measured

[a] Unless otherwise indicated, all measurements shown reflect worst hour noise levels (i.e., they were either measured during the noisiest hour [see Section 3.3.1.1] or were adjusted to worst hour traffic characteristics [see Section 3.3.1.2]).

[b] Unless otherwise indicated, modeled receivers include a calibration constant (see Sections 3.1.2, 4.3.3, and 4.4).

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Table 6-3. Predicted Traffic Noise Impacts (Example)

Receiver	Type, Location, or Address	Existing Noise Level (dBA-L_{eq}[h])	Predicted Noise Level (dBA-L_{eq}[h])	Noise Increase (+) or Decrease (–)	Activity Category and NAC, (L_{eq}[h])	Impact Type[a]
1	1234 Elm Street, backyard, center of patio (first-row residence)	74	75	+1	B (67)	A/E
2	4321 Main Street, 5 feet from façade (first-row residence)	75	76	+1	B (67)	A/E
3	2336 Elm Street, center of backyard (first-row residence)	73	74	+1	B (67)	A/E
4	3538 Elm Street, center of backyard (first-row residence)	74	75	+1	B (67)	A/E
5	1212 Church Street, 10 feet north of bottom front step	68	69	+1	C (67)	A/E
6	1723 Oak Street, center of front lawn (0.25 mile from freeway, background noise level)	56	56	0	B (67)	None
7	1052 Sycamore Drive, middle of cul-de-sac (0.25 mile from freeway, background noise level)	55	55	0	B (67)	None

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Table 6-4. Noise Abatement Predicted Noise Levels and Insertion Loss (dBA) for Soundwall 1 at Right-of-Way (Example)

		With Wall											
		Height = 6 feet		Height = 8 feet		Height = 10 feet[a]		Height = 12 feet		Height = 14 feet		Height = 16 feet	
Receiver	Without Wall	$L_{eq}(h)$	Ins. Loss	$L_{eq}(h)$	Ins. Loss	$L_{eq}(h)$	Ins. Loss	$L_{eq}(h)$	Ins. Loss	$L_{eq}(h)$	Ins. Loss	$L_{eq}(h)$	Ins. Loss
1	75	70	5	69	6	68[a]	7	66	9	65	10	64	11
2	76	70	6	69	7	68[a]	8	67	9	65	11	64	12
3	74	70	4	69	5	68[a]	6	66	8	65	9	63	11
4	75	70	5	69	6	68[a]	7	66	9	65	10	64	11
5	69	65	4	64	5	63[a]	6	61	8	60	9	59	10
6	56	56	NA[b]	56	NA[b]	56	NA[b]	56	NA[b]	56	NA[b]	56	NA[b]
7	55	55	NA[b]	55	NA[b]	55	NA[b]	55	NA[b]	55	NA[b]	55	NA[b]

[a] Breaks line of sight between 11.5-foot truck stack and 5-foot-high receiver per Section 1102.3 of the *Highway Design Manual*..

[b] NA = not applicable (no barrier considered).

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Table 6-5. Data for Reasonableness Determination (Example)

	Predicted without Soundwall[a]	
Soundwall	Absolute Noise Level (L_{eq}[h], dBA)	Build vs. No Build (dBA)
SW-1	75	+1
SW-2	74	+1

[a] At critical receivers.

	Predicted with Soundwall[a]					
Soundwall	Height = 6 feet	Height = 8 feet	Height = 10 feet	Height = 12 feet	Height = 14 feet	Height = 16 feet
SW-1						
Insertion Loss (dBA)	5	6	7	9	10	11
Benefited Residences	24	24	24	48	72	96
Reasonable Allowance Per Benefited Residence	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000
SW-2						
Insertion Loss (dBA)	4	5	6	8	9	11
Benefited Residences	0	24	24	48	48	96
Reasonable Allowance Per Benefited Residence	Not Feasible	$55,000	$55,000	$55,000	$55,000	$55,000

[a] At critical receivers.

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Table 6-6. Roadway and Barrier Geometries (Example)

Barrier ID	Station	Elevation of Outside Lane (feet)	Elevation of Wall Base (feet)_	Elevation of Top of 6 ft Wall	Elevation of Top of 8 ft Wall	Elevation of Top of 10 ft Wall[a]	Elevation of Top of 12 ft Wall	Elevation of Top of 14 ft Wall	Elevation of Top of 16 ft Wall
SW-1	100+00	1255	1258	1264	1266	1268	1270	1272	1274
	100+25	1256	1259	1265	1267	1269	1271	1273	1275
	100+50	1258	1261	1267	1269	1271	1273	1275	1277
	100+75	1257	1260	1266	1268	1270	1272	1274	1276
	200+00	1255	1258	1264	1266	1268	1270	1272	1274
	200+25	1254	1257	1263	1265	1267	1269	1271	1273
	200+50	1252	1255	1261	1263	1265	1267	1269	1271
	200+75	1251	1254	1260	1262	1264	1266	1268	1270
SW-2	300+00	1251	1252	1258	1260	1262	1264	1266	1268
	300+25	1253	1254	1260	1262	1264	1266	1268	1270
	300+50	1254	1255	1261	1263	1265	1267	1269	1271
	300+75	1255	1256	1262	1264	1266	1268	1270	1272
	300+00	1256	1257	1263	1265	1267	1269	1271	1273
	300+25	1255	1256	1262	1264	1266	1268	1270	1272
	300+50	1254	1255	1261	1263	1265	1267	1269	1271
	300+75	1253	1254	1260	1262	1264	1266	1268	1270

[a] Breaks line of sight between 11.5-foot truck stack and 5-foot-high receiver per Section 1102.3 of the *Highway Design Manual*.

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6.4 Appendices

Any details that would support the conclusions of the noise study report should be included in the appendices, such as instrumentation used, calibration data, field measurement data (e.g., noise, traffic, weather, dates, times, personnel), site details (e.g., plan views, cross sections), computer modeling inputs, and model results. If the analysis includes model calibrations (see Section 4.4), they should be shown in simple table form (see Table 6-7 for an example). The appendices should fill in all details that are not in the main report so the analysis could be repeated by an independent analyst.

Table 6-7. Model Calibration (Example)

Receiver	Measured Noise Level (dBA-L_{eq}[h])	Calculated Noise Level* (dBA-L_{eq}[h])	Calibration Constant (dBA)
1	68	70	-2
2	66	69	-3
3	70	71	-1
4	69	72	-3

*Calculated noise level = noise model result (see Section 4.4.1.1)

If measurements were taken at a time different than the worst noise hour, the adjustment and procedure used (see Section 3.3.1.2), any receivers modeled and calibrated, and any inputs should be shown.

The appendices are a good place to describe issues encountered during the noise study, such as difficulties of site accessibility (include a map of the access route) or contaminating noise sources, such as barking dogs, air conditioners, pool equipment, children's playgrounds, nearby construction, and aircraft. Such information may be useful if additional study or analysis is required.

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Section 7

Non-Routine Considerations and Issues

Sections 2 to 6 address the routine phases of Caltrans highway noise fieldwork and analyses. The subjects in this section are considered non-routine. Because Caltrans is occasionally involved in these special situations, they are included to round out the knowledge base of the Caltrans noise analysts or other interested party. The subjects addressed in this section are listed below.

- 7.1: Noise Barrier Issues
- 7.2: Sound Intensity and Power
- 7.3: Pavement Noise
- 7.4: Insulating Facilities from Highway Noise
- 7.5: Construction Noise Analysis, Monitoring, and Abatement
- 7.6: Earthborne Vibrations
- 7.7: OSHA Noise Standards
- 7.8: Effects of Transportation and Construction Noise on Marine Life and Wildlife (Bioacoustics)

7.1 Noise Barrier Issues

This section discusses some challenging issues and non-routine considerations related to noise barriers. Noise barriers are generally considered beneficial for residents near a freeway. However, there have been claims about perceived noise increases at distances farther than those for which the noise barriers were designed. This issue involves complex relationships between highway and barrier configurations, intervening terrain, receiver location, and atmospheric influences. This section discusses what Caltrans and others have found about this issue and suggests ways to study the effects of noise barriers on distant receivers. Some elements of this discussion involve routine considerations addressed in Section 5.

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The effectiveness of vegetation typically used in highway landscaping in reducing noise is also discussed. This issue occasionally surfaces when trimming or removal of shrubs and trees by Caltrans maintenance personnel triggers complaints of perceived noise increases.

7.1.1 Effects of Noise Barriers on Distant Receivers

The public and media in California have on occasion raised concerns that noise barriers increase noise levels at distances of up to 3 miles. The alleged increases were attributed to certain site geometries, noise barrier configurations, intervening terrain, and interacting meteorology. Continuing research by Caltrans and others has provided some answers to these concerns. However, there is a continued need for field research to verify prediction algorithms in prediction models for distances more than 500 feet, alter them if needed, and investigate conditions that lead to any newly identified concerns. This section discusses what Caltrans and others have found.

7.1.1.1 Background

Normally, noise barriers are designed for residences and noise-sensitive receptors located adjacent to a highway, and their effects are generally limited to receivers within about 500 feet of the highway. With few exceptions, there is little disagreement that properly designed noise barriers reduce highway noise within this distance, except for the limited conditions described in Section 5.1.7. Noise prediction models have not been adequately validated for distances beyond 500 feet. Caltrans' *Distance Limits for Traffic Noise Prediction Models* (2002) discusses the reasons for the distance limits. However, if there is a reasonable expectation that noise impacts would extend beyond 500 feet those impacts must be evaluated. This may require engineering judgment and supplemental noise measurements to determine impacts.

With the proliferation of noise barriers in California, public concern has emerged that under certain conditions of topography and meteorology noise barriers can increase noise levels at receivers located from 0.25 to 2 miles from freeways. To date, the concerns have been based on subjective perception only. No objective evidence based on noise measurements has been advanced that noise barriers increase noise levels at any distance or under any conditions other than under the limited conditions described in Section 5.1.7. As indicated, present noise prediction models are not reliable to accommodate distances more than

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500 feet. In addition, noise prediction models are unable to predict meteorological effects, which play an increasingly important role in observed noise levels with distance, independent of the nature and strength of their source.

The concerns raised by the public, primarily in the San Francisco Bay Area and Los Angeles area, include all three possible categories of source, barrier, and receiver configurations.

- Reflective noise barriers on the sides of highways opposite from those of the receivers (i.e., highways between barriers and receivers).
- Parallel reflective noise barriers on each side of highways.
- Noise barriers between highways and receivers.

The first two issues involve reflective noise of single and parallel barriers, discussed in Section 5.1.7. The third, however, deals with diffracted noise. All three issues of concern involve long noise propagation distances, which are difficult to study because of the numerous variables in topography and meteorology. Caltrans' experience has been that atmospheric conditions can cause measured noise levels at those distances to fluctuate by more than 10 dBA, with or without noise barriers.

Atmospheric refraction is the principal atmospheric process responsible for these fluctuations. A vertical gradient of either temperature or wind velocity produces a corresponding vertical gradient of sound velocity. This causes sound waves to refract (bend) upward or downward. Upward refraction occurs during sound propagation in an upwind direction or temperature lapse conditions (air temperatures decreasing with height). This tends to send noise skyward, leaving a noise shadow near the ground and thereby reducing noise levels. Downward refraction occurs during sound propagation in a downwind direction or in temperature inversions (temperature increasing with height above the ground). Downward refraction tends to send skyward noise down, concentrating noise near the ground, thereby increasing noise levels. Both upward and downward refraction occurs with and without noise barriers. Atmospheric refraction of sound waves is discussed in Section 2.1.4.3.

7.1.1.2 Results of Completed Studies

Caltrans and its consultants and others have performed elaborate research-level studies concerning noise from highways at adjacent and distant receivers, with and without noise barriers for the three barrier configurations mentioned in Section 7.1.1.1 above. It is not the intent of this section to discuss these studies in detail, only to mention their

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combined results. The studies were performed along the following routes: Interstate (I-) 405 in Los Angeles, various locations on I-680 and I-80 in the Bay Area, and one along State Route (SR) 99 in Sacramento. These studies followed the general guidelines and criteria outlined in Caltrans' *General Guidelines for Studying the Effects of Noise Barriers on Distant Receivers* (1998). The John A. Volpe National Transportation Systems Center (VNTSC) in Cambridge, Massachusetts, performed two similar studies at Dulles International Airport near Washington, DC, and along I-495 near Baltimore for parallel noise barriers. In addition to the research studies, Caltrans has gathered numerous anecdotal data during routine project studies.

In each research study, before– and after–noise barrier measurements were carefully matched by wind speed, wind direction, temperature, relative humidity, and temperature gradients with height above the ground. All measurements were also normalized for traffic variations. Brief summaries of results of the studies are provided below.

Study Results for Single Barrier on the Opposite Side

The results of studies involving noise level increases for single barriers on the opposite side of a highway in simple terrain, as discussed in Section 5.1.7.2, agreed remarkably with the theoretical calculations shown in the same section, particularly in Figure 5-26. For distances of 50 to 100 feet, the increases were generally 0 to 1 dBA. At 400 feet, the measured results were a 2.4-dBA increase as calculated. For longer distances, the increases were difficult to discern with accuracy but never more than 3 dBA, even in complex terrain as discussed in Section 5.1.7.2.

Study Results for Parallel Barriers

The results of studies involving parallel noise barriers (i.e., one on each side of the highway), as discussed in Section 5.1.7.4, showed degradations in performance of each barrier because of multiple reflections between two reflective barriers. The degradations appeared to increase with distance from and height above the highway/barrier configuration. Degradations also appeared to be a function of the W/H ratio, discussed in Section 5.1.7.4 and depicted in Figure 5-33. The VNTSC study at Dulles International Airport concluded that the maximum degradation at a 6:1 W/H ratio was 6 dBA at distances for which noise barriers are typically designed. At another location near Baltimore, a maximum degradation of 2.8 dBA was measured by VNTSC for a 9:1 W/H ratio. Caltrans measured a maximum degradation of 1.4 dBA for a W/H ratio of 15:1 along SR 99.

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Almost all parallel barrier configurations in California have a W/H ratio of at least 10:1, and most are about 15:1. Based on the studies by VNTSC and Caltrans, Caltrans Highway Design Manual Chapter 1100 advises a minimum W/H ratio of 10:1 or more to avoid degradations of 3 dBA or more. Please note that degradation in barrier performance does not indicate an increase in noise level above that without a noise barrier. Instead, it reduces the effectiveness of each barrier on each side of the highway.

Studies along I-680 and I-80 in the Bay Area also showed no measurable noise increase at receivers 0.25 to 2 miles from the highway and barriers.

Study Results for Receiver behind Single Barrier

For receivers behind a single barrier, field studies indicate that barriers are effective within about 330 feet of a highway. Caltrans has collected an abundance of data in research and routine studies over the years to substantiate this claim.

Caltrans has also experienced, in the course of many measurements, that beyond 330 feet or so from a highway, traffic noise levels often approach background levels (the noise levels associated with normal day-to-day activities in the community). Although soundwalls cannot attenuate noise below these levels, Caltrans has never experienced noise increases (above no-barrier noise levels) at any distance behind noise barriers. However, some people continue to believe that noise barriers will increase noise levels at distant receivers behind a barrier.

Explanations have sometimes centered on noise waves "going over the wall and coming back to the ground." This is called diffraction and is actually responsible for noise attenuation, rather than an increase in noise, when compared to the direct noise received without a noise barrier, as explained in Sections 2, 4, and 5.

Another popular "explanation" for perceived noise increase from soundwalls is that the soundwall "lifts" the noise over tiers of homes that normally would shield the receiver. A soundwall will elevate the noise source over tiers of homes no more than the intervening homes do. Soundwalls in California are generally limited in height to 16 feet, approximately equal to the average height of residential development.

There generally is a loss of "ground effect" behind a noise barrier. Without a noise barrier, the direct path of the traffic noise to the receiver travels closer to the ground than after a noise barrier is built. Noise waves close to the ground are subject to excess attenuation because of absorption

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by the ground. Therefore, when a noise barrier is built, there is a trade-off between barrier attenuation (a decrease in noise) and a loss of excess attenuation.

The net reduction of noise from barrier attenuation and loss of excess attenuation is called barrier insertion loss (see Section 5.1.5). Close to a barrier, the barrier attenuation benefit far outweighs the loss of excess attenuation. At farther distances, however, barrier attenuation diminishes while the cumulative effects of the loss of excess attenuation increase. Caltrans acoustical design procedures for noise barriers take these factors into consideration by applying different noise dropoff rates to with– and without–noise barrier cases. If these drop-off rates were kept constant and applied to long distances, there would be a distance at which the loss in ground effect would eventually exceed the barrier attenuation.

Extensive amounts of field data gathered during a Caltrans noise propagation research project show that differences between excess attenuation rates of elevated sources (e.g., truck stacks, noise diffracted over a noise barrier) and those close to the ground (e.g., tire noise) diminish after few hundred feet or so. The findings can be applied to noise barriers, which in essence "elevate" the source. The cumulative effect of decreasing differences in elevated and near-ground excess attenuation rates with distance appear to be at a maximum at about 200 to 300 feet behind the barrier, where the effect of the differences is the greatest. At greater distances, the differences in elevated and near-ground noise levels appear to become smaller until they disappear at some distance beyond about 400 feet.

Questions have also been raised at times about whether noise "redirected" by noise barriers "bounces off" temperature inversion layers. Redirections on the scale being discussed involve a maximum of 16-foot-high noise barriers and a distance of 0.25 mile or more, are less than 1 degree, and therefore are negligible. Studies under these conditions have confirmed that the difference between barrier and no barrier was not measurable although the noise levels were considerably higher.

After years of research and field measurements under controlled conditions, Caltrans has found no objective evidence that noise levels increase perceptibly because of noise barriers. It is widely accepted by acousticians that normal human ears can barely perceive 3-dBA changes in traffic noise levels when the frequency content of the noise has not changed. Such an increase in noise levels from noise barriers has never been measured.

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7.1.1.3 Studying the Effects of Noise Barriers on Distant Receivers

Allegations of noise barriers increasing noise levels at distant receivers based on perception only are unreliable at best. With possible noise fluctuations of more than 10 dBA from meteorological factors alone, people making such claims must not only remember the noise levels before the barrier, but also have knowledge of the meteorological conditions associated with those noise levels. To confirm whether noise barriers do increase noise levels in some instances, a complex before- and after-barrier field study must be undertaken.

Before– and after–noise barrier noise measurements do not adequately address the previous issues unless the measurements are carefully matched by before- and after-barrier conditions of meteorology, traffic, and topography. These types of studies are not routine. Technical Advisory, Noise, TAN-98-01-R9701 *General Guidelines for the Effects of Noise Barriers on Distant Receivers*, November 30, 1998, provides guidelines and criteria for conducting such studies. The advisory is available on the website of Caltrans Division of Environmental Analysis, Noise and Vibration Studies (http://www.dot.ca.gov/hq/env/noise/index.htm).

Procedures for measuring the performance of noise barriers including parallel barriers are provided in the 2009 version of TeNS.

7.1.2 Shielding Provided by Vegetation

No discussion on noise barriers is complete without mentioning the shielding effectiveness of trees, shrubs, and other vegetation typically used for landscaping along highways. Caltrans research on the shielding effectiveness of such vegetation at three different sites in late 1980s and early 1990s concluded that the mean noise reduction was less than 1 dBA, and ranged from 0 dBA to less than 3 dBA (California Department of Transportation 1995). The research further concluded that such vegetative barriers were not an effective measure to reduce highway traffic noise on a routine basis.

However, Caltrans receives complaints of noise increases when Caltrans maintenance personnel trim shrubs and bushes along highways. The most likely explanation for the increase in noise complaints is more related to visual aspects than noise. When shrubs shield traffic from the view of residences, the awareness of the traffic is reduced (i.e., “out of sight, out of mind”). When the vegetation is trimmed or eliminated, the adjacent residents will be able to see the traffic and will be reminded of the noise.

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In some cases, residents complaining about ineffective noise barriers have been satisfied when noise barriers have been combined with trees, shrubs, or ivy. Although noise did not noticeably decrease in those cases, the aesthetics of the barriers were improved. Early community acceptance studies have indicated a correlation between barrier acceptance and perceived effectiveness in reducing noise. Therefore, the use of vegetation with noise barriers can be beneficial by improving community acceptance and perceived effectiveness.

As discussed above wind can cause sound waves to refract (bend) upward or downward. When wind is blowing from a source to a receiver downward refraction can increase the sound energy received at the receiver. When a barrier is located between the source and the receiver downward wind refraction can reduce the affective noise reduction provided by the barrier. Research conducted by University Ghent in Belgium (Renterghem and Botteldooren 2008) studied how a tree canopy between the barrier and the receiver affects the degredation of barrier performance from downwind refraction. The study concluded that the presences of a row of trees between a barrier and receiver can provide an important improvement in downwind noise barrier performance up to a distance of 30 times the noise barrier height. Coniferous trees were found to the most effective in this regard. Other references indicate that 100 horizontal feet of tall grass and thick shrubbery can provide up to 5 dB of additional attenuation and 100 feet of dense woods can provide up to 2 dB of additional attenuation (Hoover & Keith 2000).

7.2 Sound Intensity and Power

This document has consistently described the amplitude of sound at a specific location in terms of sound pressure level or noise level. This is also the case for all noise standards, criteria, and descriptors mentioned in this document. In fact, SPL is used in virtually all environmental noise studies for two primary reasons: 1) it is easiest to measure, and 2) it best describes the impact at the receiver.

However, it is important for the noise analyst to know that there are other ways to express sound amplitude. Although considerably more difficult to measure, sound intensity and sound power often provide more useful information about noise sources than sound pressure level. Caltrans has begun using sound intensity in pavement noise studies, and future plans call for other uses to locate and map specific locations of vehicle noise subsources. This section briefly discusses sound power and intensity to broaden the knowledge of noise analysts who may in the future be involved with sound intensity or sound power studies.

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7.2.1 Sound Power

Sound pressure level describes a local condition. When the noise from a certain source is measured, such as a truck, in terms of sound pressure level, the information is incomplete without knowing the distance, nature, and radiation pattern of the source, intervening terrain, obstacles, reflections, and atmospheric conditions. A change in one or more of these factors will probably change the sound pressure level.

Sound power is a property of the noise source and is independent of the factors influencing sound pressure. Knowing the sound power of a noise source, the sound pressure level can be calculated under a variety of conditions and at different locations. The sound power of a source is a constant. Power is a rate of energy, or the amount of energy produced each second. Energy is force times distance, most commonly expressed as newton meters (Nm), with newton (N) being the unit of force. A force of 1 N is the force required to accelerate 1 kilogram 1 meter per second per second. If sound power is the rate of energy flow, the units are Nm/s, or watts (W).

Sound power may be visualized as the wattage of a light bulb and sound pressure level as the amount of light received by a reader in a room. The latter would depend on many factors, such as the power of the light bulb, distance from the light bulb, shadows from obstacles between the light bulb and reader, and reflections from walls.

From Section 2.1.3.2, sound pressure level is expressed in decibels, and 1 dB is defined as follows:

$$10\log_{10}(P_1 / P_0)^2 \qquad \textbf{(7-1)}$$

Where:

P_1 = the sound pressure

P_0 = a reference pressure of 20 μPa

Pascal is the unit of pressure (force per unit area); 1 Pa = 1 N/m^2. Sound power may similarly be expressed in decibels. The definition of a sound power level (L_W) is:

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$$L_W = 10\log_{10}(W_1 / W_0) \quad \textbf{(7-2)}$$

Where:
$W_0 = 10^{-12}$ W
W_1 = total acoustic power
L_W = sound power level in decibels

Sound pressure level should actually be referred to as L_P, although in environmental noise just L (e.g., L_{eq}) has normally been used. Using decibels in both sound power and sound pressure levels can be confusing. To avoid confusion, the international standard ISO 9296 requires documentation of sound power ratings in units of bels (B) rather than decibels. However, in the United States, decibels are often also used for sound power levels. In any case, the descriptors should be clearly noted whether they are sound power level or sound pressure level units. If a quantity is expressed in bels, 1 B = 10 dB.

Sound power cannot be measured directly. However, it can be calculated from sound intensity, which can be measured. One practical use of sound power level is rating product noise from hair dryers to refrigerators.

7.2.2 Sound Intensity

Sound intensity is a measure of a directional rate of energy flowing through a unit of area. The units of sound intensity are watts per square meter (W/m^2) and can be expressed in decibels RE: 1 picowatt (pW) per m^2 (1 pW = 10^{-12} W). This implies that if the entire measurement area around a source is known, its sound power can be calculated if the mean sound intensity for the measurement area is known. The measurement area (usually hemispherical) around a source increases with distance, and because sound intensity decreases with increasing area, sound power remains constant at any distance. To reduce the influence of background noise, sound intensity measurements are taken close to the source. Caltrans commonly uses on-board sound intensity (OBSI) measurements to characterize sound generated by various types of pavement. OBSI measurements are discussed in more detail in Section 7.3 below.

The sound intensity level (L_I) is calculated as follows:

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$$L_I = 10\log_{10}(I_1 / I_0) \quad \textbf{(7-3)}$$

Where:

L_I = sound intensity level in decibels

I_1 = sound intensity of interest in W/m^2

I_0 = reference intensity of 10^{-12} W/m^2

The sound intensity of interest (I_1) in W/m^2 can be calculated as follows:

$$I_1 = I_0 * 10^{(L_I/10)} \quad \textbf{(7-4)}$$

Sound intensity (I) is the product of sound pressure (P) and particle velocity (v):

$$I = P * v \quad \textbf{(7-5)}$$

Sound pressure is measured in pascals (N/m^2). Particle velocity is measured in meters per second (m/s). Therefore, the product of sound pressure and particle velocity yields W/m^2 (N/m^2 * m/s). In Section 2.1.3.1, it is explained briefly that particle velocity is the (back and forth) movement of air molecules. In Figure 2-2, it was shown that the motion is 90° out of phase with the fluctuating sound pressure. When the sound pressure is 0, the particle velocity is at its maximum either in a positive (away from the source) or negative (toward the source) direction.

A sound field includes both sound pressure and particle velocity and is therefore described by sound intensity, which includes amplitude and direction. Where sound pressure fluctuations are easy to measure with a sound level meter, the measurement of particle velocity requires more sophisticated instrumentation.

Sound intensity is most commonly measured with a pair of phase-matched microphones facing each other at a fixed distance apart (Figure 7-1). This two-microphone sound intensity probe measures only the total sound intensity traveling parallel to the microphones' axis and is therefore highly directional. If the probe is pointed at the source (Microphone 1 toward the source and Microphone 2 away from the source) the sound intensity is positive. If the probe is pointed away from the source, the sound intensity will be negative. Because of this directional characteristic, sound intensity is useful in measuring and mapping sound fields around sound sources. The reference point of a sound intensity probe is halfway between the diaphragms of the two microphones facing each other, and the reference direction is along the axis of the microphones.

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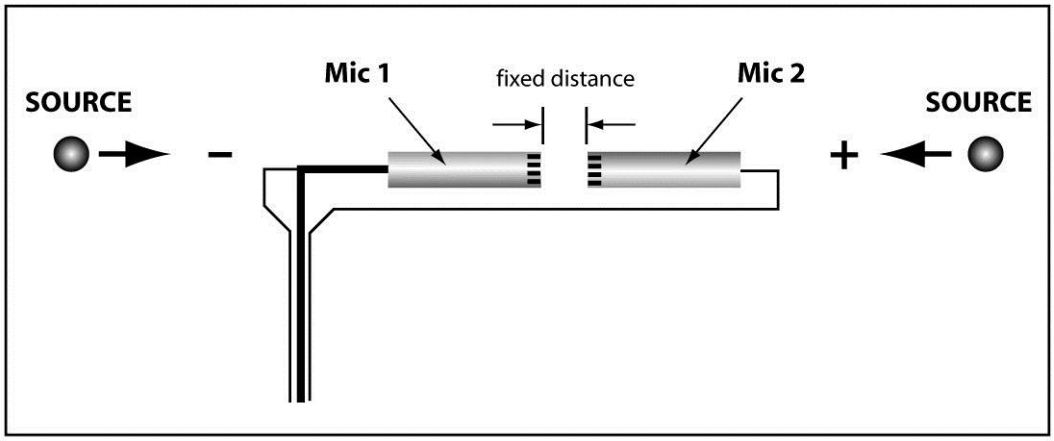

Figure 7-1. Schematic of a Sound Intensity Probe

Other sound intensity probes include a two-microphone, side-by-side system. This type of probe is aimed at 90° to the source and relies on "grazing" type microphones, which are sensitive to sound pressures directed parallel to the membranes, instead of perpendicular (Figure 7-2).

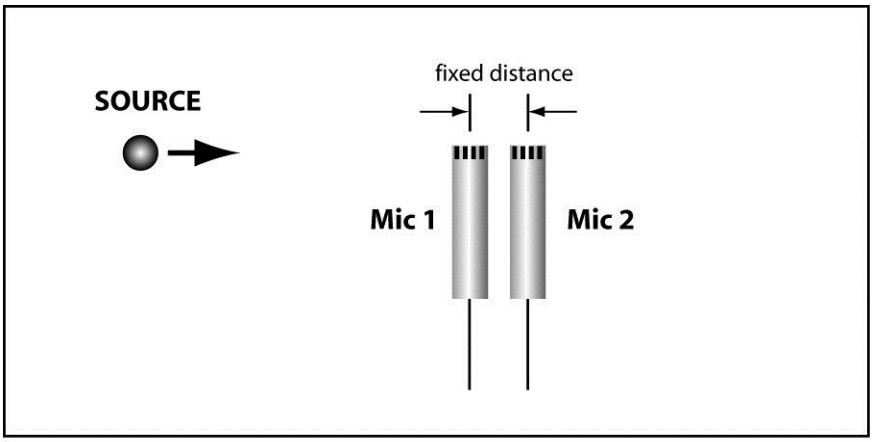

Figure 7-2. Side-by-Side Microphone Probe

To determine the total sound power of a source in watts, the sound intensity (I_k) must be first measured perpendicular to the unit area (A_k) (Figure 7-3). The power for that unit area (W_k) is then the product of I_k and A_k. Therefore, the total power (W_{total}) is calculated as follows:

$$W_{total} = \sum_1^K (A_k \times I_k) \quad \textbf{(7-6)}$$

The result in units of decibel can be calculated from Equation 7-2, or shown in B by dividing the decibel result by 10.

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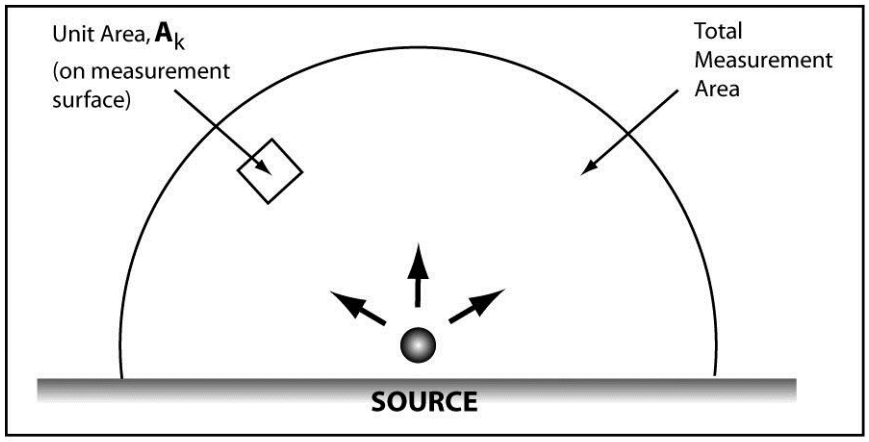

Figure 7-3. Sound Power Measurement Area

7.3 Tire/Pavement Noise

In Section 2, noise is discussed in terms of source, path, and receiver. All three components must be present before noise impacts can occur. Strategies involving quieting the source, disrupting the path, or insulating the receiver may conceptually be used to achieve noise abatement. Using a common analogy of a loud stereo set in a room, there are three options open to lowering the sound to a listener in an adjacent room. The first is lowering the volume at the stereo, quieting the source. The second option is to close the door between the two rooms, disrupting the path. As a third option, the listener can wear earplugs, insulating the receiver.

Although quieting the source would conceptually be the simplest and most effective method of noise abatement, Caltrans has so far dealt with noise abatement by disrupting the path by constructing noise barriers between the highway source and resident receivers. This approach is used because Caltrans has limited options at quieting the highway noise source. For instance, Caltrans has no control over quieting vehicles. This has been the responsibility of the U.S. Environmental Protection Agency, which over the years, through regulatory and legislative action, has mandated stricter new vehicle noise standards, especially for trucks. The only control Caltrans has at the source is highway design. Highway alignments could be selected away from sensitive receivers, and new highways could be depressed. Unfortunately, many factors other than noise dictate highway design. In addition, new development often occurs along existing highways, further limiting noise abatement options.

One detail of highway design that affects noise at the source is the type and texture of pavement used. There are two major types of pavement:

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flexible asphalt concrete (AC) which is black in color and rigid PCC which is white in color. Historically, new AC generally tends to be quieter than new PCC, but aggregate size, surface texture, and age/condition can cause wide variations in tire pavement noise levels. The differences in noise reducing characteristics between AC and PCC are narrowing as new construction techniques are being developed. It has been well known for at least a decade that OGAC produces less noise from tire/pavement interaction than DGAC. It is also known that longitudinal (parallel to direction of travel) texturing, tining, or grooving in PCC is much less noisy than transverse (perpendicular to direction of travel) texturing, tining, or grooving. What is least understood is the longevity of the lower noise benefits associated with "quieter" pavement. There are many regional variables that affect pavement performance, such as road base condition, environment, traffic loads, mix design, and quality of construction material and methods. In general as pavements age and wear, the acoustic characteristics change and tire/pavement noise becomes louder.

Caltrans has gathered increasing evidence that OGAC retains its noise reduction benefits throughout the years in typical applications at lower elevations on snow-free highways. The longest-running quiet pavement noise study to date, being conducted on I-80 near Davis, California, demonstrates that after over 13years of operation, OGAC continues to yield 4- to 5-dBA lower noise levels than the previous DGAC pavement. Other studies have shown the same trend. The pavement noise results are based on actual traffic streams, wayside noise measurements carefully controlled for the effects of meteorology, and supplemental OBSI measurements.

Studies using innovative approaches such as sound-intensity measurements of tire/pavement interactions have been employed to study the relative noise benefits of various pavement mixes and textures. In all cases, the sound-intensity measurements are augmented and correlated with wayside noise measurements. This is important because vehicle noise consists of four primary subsources: mechanical noise, exhaust noise (stack exhaust on heavy trucks), tire/pavement noise, and aerodynamic noise (at high speeds). The stricter EPA standards initiated in the 1970s have lowered mechanical and exhaust noise subsources. At highway speeds, tire/pavement noise affects total vehicle noise to a greater extent than all the other vehicle noise subsources combined. Tire/pavement noise on a passenger car operating at a steady freeway speed may account for as much as 75% to 90% of the vehicle noise energy, but these percentages may not be the same on louder, more acoustically complex heavy trucks. It is possible to perceptively lower overall traffic noise levels by careful pavement selection and design. Future Caltrans-sponsored research will include the relative contribution of subsources of vehicles to help confirm

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the validity of the importance of tire/pavement noise through the use of complex microphone arrays and multi-channel signal processors.

FHWA policy does not allow quieter pavement to be considered as a noise abatement measure. Caltrans practice of calibrating noise prediction models allows for optional calibration adjustments for various pavement types (California Department of Transportation 2003). This practice does not mean that quieter pavement is to be used as a noise abatement measure. Rather, the process is used to account for an otherwise unexplained portion of differences between measured and predicted noise results. Without the adjustment for pavement, this difference would have been added anyway, without explaining the cause.

The following studies and reports provide useful and relevant information related to tire/pavement noise.

Determining End Limits of Quieter Pavement Projects (Rymer and Donavan 2011).

Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method (American Association of State Highway and Transportation Officials 2012)

I-80 Davis OGAC Pavement Noise Study (Illingworth & Rodkin 2011a)

Eight Year Evaluation of the Noise Performance of the Caltrans Asphalt Research Pavements on LA 138 (Illingworth & Rodkin 2011b)

Initial and Long-Term Evaluation of the Tire-Pavement Noise Produced by Various Portland Cement Concrete Surface Textures Measurements on the State Route KN 58 Mojave Bypass 2003 to 2010 (Illingworth & Rodkin 2011c)

Comparative Measurements of Tire/Pavement Noise in Europe and the United States Noise Intensity Testing in Europe (NITE) Study (Illingworth & Rodkin 2006)

Caltrans Thin Lift Study: Effects of Asphalt Pavements on Wayside Noise (Rochat et al. 2010)

Caltrans Memorandum—Quieter Pavement Bulletin (Shatnawi 2009)

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NCHRP Report 635 Acoustic Beamforming: Mapping Sources of Truck Noise (National Cooperative Highway Research Program 2009)

NCHRP Project 1-44: Measuring Tire-Pavement Noise at the Source (National Cooperative Highway Research Program 2011a)

NCHRP Project 1-44 (1) Measuring Tire-Pavement Noise at the Source: Precision and Bias Statement (National Cooperative Highway Research Program 2011b)

The Little Book of Quieter Pavement (Federal Highway Administration 2007)

Rumble strips and expansion joints can be the source of impulse noise when vehicle tires strike the strips or joints. Locations of rumble strips or expansion joints relative to noise sensitive receptors should be considered to minimize community noise impacts. Alternative rumble strip and expansion joint designs that reduce noise are currently being explored by Caltrans.

7.4 Insulating Facilities from Highway Noise

Revisions to 23 CFR 772 that occurred in 2011 eliminated the interior noise abatement criterion for residential uses and eliminated noise insulation of private residences as a fundable form of noise abatement. 23 CFR 772 does however include an interior noise abatement criterion for Activity Category D land use facilities (auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.) Noise insulation of Activity Category D land use facilities is listed in 23 CFR 772 as a fundable form of noise abatement.

If a situation arises where interior noise at Activity Category D land use facilities must be evaluated as part of a noise study report, the normal procedure is to determine exterior noise levels using standard modeling methods and then to apply building noise reduction factors recommended by FHWA based on the building construction type and window condition. Table 7-1 summarizes building noise reduction factors recommended by FHWA (Federal Highway Administration 2011).

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Table 7-1. FHWA Building Noise Reduction Factors

Building Type	Window Condition	Noise Reduction Due to Exterior of Building
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
	Double Glazed	30 dB
The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.		

Source: Federal Highway Administration 2011.

If interior noise impacts are identified the first course of action is to consider the use of an exterior barrier to reduce noise. If an exterior barrier is not feasible or does not provide sufficient noise reduction, insulation of the facility can be considered. This would require a detailed evaluation of existing building noise reduction and potential methods for improving the noise reduction. The 2009 version of TeNS provides detailed methods for measuring existing building noise reduction which are consistent with ASTM E966-02, "Standard Guide for Field Measurements of Airborne Sound Insulation of Building Facades and Façade Elements."

7.5 Construction Noise Analysis, Monitoring, and Abatement

Construction noise is usually a concern only in exceptional cases, such as when pile driving and crack-and-seat pavement rehabilitation operations are planned. Ground vibration generated by pile driving and crack-and-seat operation also increase concern by the public. Caltrans Standard Specifications Sections 14-8 and the Caltrans Standard Special Provisions Section 5-1 discuss construction noise levels. Caltrans Standard Specifications are applied to all construction projects. The Standard

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Special Provisions provide a menu of special provisions that can be selectively applied to a project based on the specific needs of the project.

Section 14-8 of the Caltrans standard specifications addresses noise and states:

> Do not exceed 86 dBA L_{max} at 50 feet from the job site activities from 9 p.m. to 6 a.m.
>
> Equip an internal combustion engine with the manufacturer-recommended muffler. Do not operate an internal combustion engine on the job site without the appropriate muffler.

Section 5-1, *Noise Control*, of the Standard Special Provisions states the following.

General

This section applies to equipment on the project or associated with the project, including trucks, transit mixers, stationary equipment, and transient equipment. Do not exceed 86 dBA L_{max} at 50 feet from the job site activities from _____ p.m. to _____ a.m. except you may perform the following activities during the hours and for the days shown in the following table:

Noise Restriction Exceptions

Activity	Hours		Days	
	From	To	From	Through

Do not operate construction equipment or run the equipment engines from 7:00 p.m. to 7:00 a.m. or on Sundays except you may operate equipment within the project limits during these hours to:

1. Service traffic control facilities.
2. Service construction equipment.

Noise Monitoring

Provide one Type 1 sound level meter and one acoustic calibrator to be used by the Department until contract acceptance. Provide training by a person trained in noise monitoring to one Department employee designated by the Engineer. The sound level meter must be calibrated and certified by the manufacturer or other independent acoustical laboratory before delivery to the Department. Provide annual recalibration by the manufacturer or other independent acoustical laboratory. The sound level meter must be capable of taking measurements using the A-weighting network and the slow response settings. The measurement microphone must be fitted with a windscreen. The Department returns the equipment to you at contract acceptance. Use if a sound meter is required. The contract lump sum

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price paid for noise monitoring includes full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all work involved in noise monitoring.

As a state agency, Caltrans is not required to comply with local noise ordinances. However, as a matter of practice, it is Caltrans' intent to comply with 23 CFR 771.105 which states that it is FHWA policy that:

> [t]o the fullest extent possible all environmental investigations, reviews, and consultation be coordinated as a single process, and compliance with all applicable environmental requirements shall be reflected in the environmental documentation.

If construction noise on any highway project is anticipated to be a substantial concern, further analysis is recommended. The following items are to be examined.

- Land uses or activities that may be affected by construction noise.
- Level, timing (scheduling), and duration of construction.
- Measures to reduce adverse construction noise impacts on the community that could be included in the project's plans and specifications.

Caltrans does not routinely analyze construction noise during the project development phase. However, as is discussed in Section 6.3.2, construction noise impacts and likely abatement measures (if necessary) should be discussed briefly in the noise study report for all projects. Generally, Caltrans will only consider construction noise and its abatement in greater detail during the project impact analysis if the project is large, is controversial, or has a prolonged construction phase with extensive pile driving or other loud operations. Construction noise impacts on wildlife may also need to be considered in some special situations. An example would be where pile driving will occur near nesting birds that are on the endangered species list. The effects of noise on wildlife are discussed in more detail in Section 7.8.

Caltrans construction or environmental personnel are sometimes asked to monitor construction noise levels during the construction phase to ensure the contractor's compliance with the Caltrans Standard Specifications, project-specific Special Provisions, or other construction noise limits that may be imposed on the project. The monitoring is usually performed in response to complaints from adjacent residents, but there may also be situations where the contractor must demonstrate compliance with a specific limit on noise.

In January 2006, the FHWA published the FHWA Roadway Construction Noise Model Users guide, which provides guidance on how to use the

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FHWA Windows-based construction noise model. It provides useful information on construction noise analysis, equipment noise source levels, and impact criteria.

In addition to noise, construction activities can potentially generate earthborne vibrations that may disturb, damage, or interfere with activities at vibration-sensitive receivers. Section 7.6 briefly discusses earthborne vibrations.

7.5.1 Consideration of Construction Noise during Project Development Phase

If the project is large, is controversial, or has a prolonged construction phase with extensive pile driving or other loud operations, construction noise should be analyzed during the project development phase, along with routine noise analyses, and the analysis should be included in the environmental documentation. Details of construction operations are frequently lacking or minimal in this phase. Therefore, the analysis will usually be qualitative rather than quantitative, and addressed in the environmental document only in general terms, with references to the Standard Specification, Standard Special Provisions, and other appropriate directives. A qualitative discussion may include information on the following topics.

- Residences or land use activities to be impacted most by construction noise.
- Principal types of equipment to be used.
- Noise characteristics (impact noise, continuous noise, etc.) and range of noise levels of equipment used at reference distances.
- Duration of construction and the loudest operations.
- Appropriate specifications, special provisions, and regulations by which the contractor must abide.
- Noise monitoring for compliance during construction.
- Abatement strategies that can potentially be provided, such as one or more of the following.
  - Temporary walls, earth berms, or noise curtains.
  - Alternative, less noisy construction methods.
  - Restricted hours of operation.
  - Planning and routing haul roads away from residences.

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- Building soundwalls required for traffic noise abatement for the project first.

If some details about the types and numbers of construction equipment, types of operations, duration, and scheduling are available during the project development phase, a quantitative analysis may be performed. A quantitative analysis may include all of the factors for the qualitative analysis and the following.

- Calculating expected noise levels at the affected receivers or at a standard distance (usually 50 feet) as dictated by criteria.
- Comparisons of calculated noise levels to specifications, special provisions, and other pertinent criteria.

Caltrans construction noise criteria are typically expressed using the L_{max} descriptor at a reference distance. As stated above, an L_{max} of 86 dBA at 50 feet is commonly used by Caltrans as a maximum construction noise limit. Equipment and operations are usually at or less than that level, except for blasting, pile drivers (impact or vibratory), hoe rams, pavement breakers for crack-and-seat operations, and other impact equipment. Table 7-2 summarizes typical construction noise levels identified in the FHWA Roadway Construction Noise Model User's Guide (Federal Highway Administration 2006). These noise levels come directly from data developed during the construction of the Central Artery Tunnel Project in Boston completed December 2007.

Table 7-2. Typical Construction Equipment Noise

Equipment Description	L_{max} Noise Limit at 50 feet, dB, Slow	Usage Factor	Impact Device?
All other equipment more than 5 horsepower	85	50	No
Auger drill rig	85	20	No
Backhoe	80	40	No
Bar bender	80	20	No
Blasting	94	N/A	Yes
Boring jack power unit	80	50	No
Chain saw	85	20	No
Clam shovel	93	20	Yes
Compactor (ground)	80	20	No
Compressor (air)	80	40	No
Concrete batch plant	83	15	No
Concrete mixer truck	85	40	No
Concrete pump truck	82	20	No
Concrete saw	90	20	No

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Equipment Description	L_{max} Noise Limit at 50 feet, dB, Slow	Usage Factor	Impact Device?
Crane (mobile or stationary)	85	16	No
Dozer	85	40	No
Dump truck	84	40	No
Excavator	85	40	No
Flat bed truck	84	40	No
Front end loader	80	40	No
Generator (25 kilovolt-amperes [kVA] or less)	70	50	No
Generator (more than 25 kVA)	82	50	No
Gradall	85	40	No
Grader	85	40	No
Horizontal boring hydraulic jack	80	25	No
Hydra break ram	90	10	Yes
Impact pile driver (diesel or drop)	95	20	Yes
Jackhammer	85	20	Yes
Mounted impact hammer (hoe ram)	90	20	Yes
Paver	85	50	No
Pickup truck	55	40	No
Pneumatic tools	85	50	No
Pumps	77	50	No
Rock drill	85	20	No
Scraper	85	40	No
Slurry plant	78	100	No
Slurry trenching machine	82	50	No
Soil mix drill rig	80	50	No
Tractor	84	40	No
Vacuum street sweeper	80	10	No
Vibratory concrete mixer	80	20	No
Vibratory pile driver	95	20	No
Welder/Torch	73	40	No

Source: Federal Highway Administration 2006.

Table 7-2 also provides a typical usage factor for each equipment type. The usage factor is an estimate of the fraction of time each piece of equipment operates at full power. The usage factor can be used to estimate L_{eq} from the L_{max} values listed in Table 7-2 in those cases where the impact criteria is expressed in terms of L_{eq}. Equation 7-10 can used to estimate L_{eq} from L_{max}. It also includes a term for estimating noise at distances other than 50 feet.

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$$L_{eq}(h), \text{dBA} = L_{max} \text{ at 50 feet} - 20\log(D / 50) + 10\log(UF) \quad \textbf{(7-7)}$$

Where:

L_{max} at 50 feet can be looked up in Table 7-2 or similar table

D = distance of interest

UF = usage factor or fraction of time period of interest equipment is in use

If more than one piece of equipment is in operation in the same location, Equation 7-7 can be used for each piece of equipment and the results can be summed to give a combined noise level at the location of interest. Typically, only noise levels from the two or three loudest pieces of equipment are summed. The FHWA Roadway Construction Noise Model automates most of this process.

7.5.2 Noise Monitoring during Construction

Construction noise monitoring may be part of a program called for in the environmental document, in regulatory permits, or in response to noise complaints. Noise monitoring requirements may be in response to effects on both humans and wildlife. Refer to Section 7.8 for more discussion on the effects of construction noise on wildlife. In most cases, the noise measurements are used to ensure compliance with the appropriate criteria specified in construction contract specifications or other applicable regulations. In the case of complaints, measurements may be conducted to identify the source of the complaints and to develop solutions for reducing the noise. As discussed above, Caltrans is not required to comply with local noise ordinances. However, as a matter of practice, it is Caltrans intent to comply with all applicable environmental requirements per 23 CFR 771.105.

If construction noise monitoring is necessary, the districts' environmental units or trained construction personnel will usually perform the measurements. In some cases, the contractor or subcontractor may perform noise monitoring as part of the construction contract.

The manner in which construction noise measurements are taken depends on the applicable criteria. If the criterion calls for a certain L_{max} at a reference distance, the sound level meter must be placed at the requested distance from stationary equipment and the noise measured in the L_{max} mode during full operation of the equipment. Ideally, the noise level should be measured from four different directions, approximately 90° from each other (Figure 7-4). This may not be possible, however, and perhaps only two or three directions can be measured. A sufficient time period in each of the microphone positions should be allowed to permit the

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L_{max} to occur. Sound level meters usually have an L_{max}-hold button. In this mode, the recorded L_{max} only changes when a higher noise level than the previous maximum is recorded. If the noise is relatively constant and the L_{max}-hold does not change for 30 seconds, the measurement is completed. If the noise is not constant, such as with pile driving, a longer time period of at least 2 minutes is recommended.

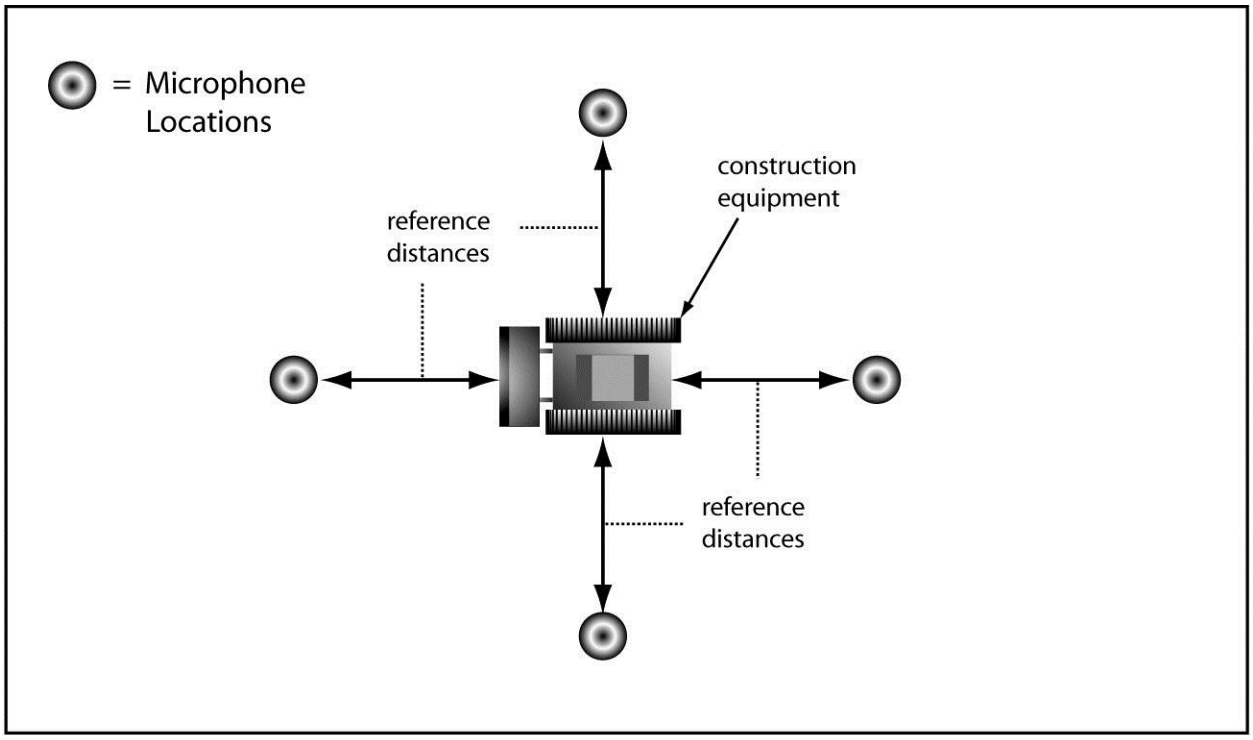

Figure 7-4. Measuring One Piece of Equipment

If more than one piece of stationary construction equipment is involved in the same operation, the reference distance should be measured from the nearest piece of equipment, preferably from various directions (Figure 7-5).

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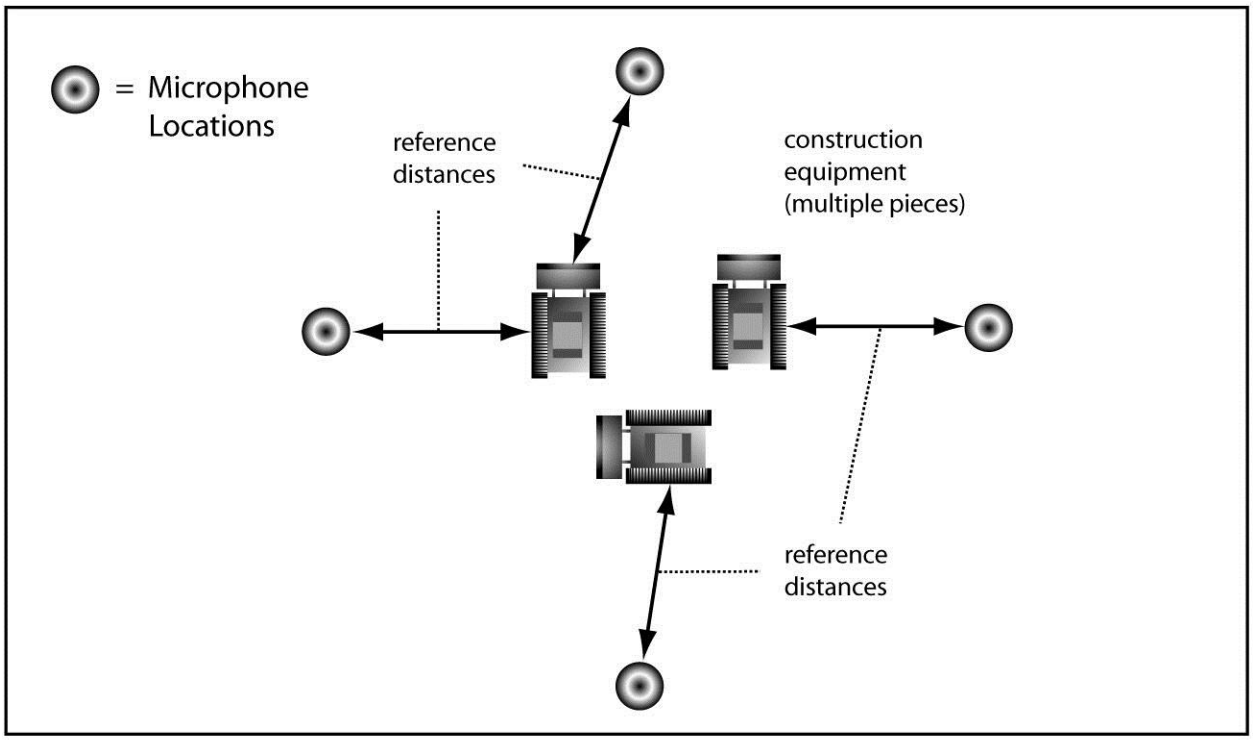

Figure 7-5. Measuring Multiple Pieces of Equipment Operating in Same Area

For mobile equipment, the reference distance is the closest distance at the point of passby. The equipment should be measured from two directions—equipment moving from left to right and from right to left.

If the response time setting of the meter is not specified in the criteria, the slow setting should be used for equipment producing continuous noise. For impact noise, such as pile driving, the response setting should be switched to impulse. In all cases, a minimum of three measurements should be taken at each microphone position. The highest L_{max} should be used for comparison with applicable standards or criteria.

In the less frequent cases where a construction noise criterion may call for a certain noise level at the project right-of-way line or a residence, the microphone locations must coincide with the locations called for in the criterion. In the event a criterion calls for a descriptor different from L_{max}, such as L_{eq}, the proper descriptor must be measured by the sound level meter. All previously mentioned provisions are applicable. Section 3 should be consulted for general noise measurement provisions.

Additional information on construction noise measurements can be found in "Measurement of Highway-Related Noise," Report FHWA-PD-96-046, May 1996, available through the National Technical Information Service

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in Springfield, Virginia, and in the FHWA Construction Noise Handbook which is available:

http://www.fhwa.dot.gov/environment/noise/construction_noise/handbook

7.5.3 Construction Noise Abatement

In the event that construction noise exceeds or is expected to exceed applicable standards and criteria, the following options are open to abate the noise at the source, in the path, and at the receiver.

7.5.3.1 Abatement at Source

Noise control at the source is the most sensible approach because it does not limit abatement for a single source-receiver pair, but instead lowers construction noise at all receivers. Caltrans Standard Specifications require all construction equipment to have adequate mufflers and be well maintained. If these specifications are not enough to reduce noise levels to less than the standards and criteria, other options can be used, including one or more of the following.

- Reroute haul routes away from residences.
- Require modern equipment.
- Plan noisiest operations for times of day when people are less sensitive to noise.
- Plan operations to minimize the use of backup warning devices.
- Set backup warning devices to lowest level without jeopardizing safety.
- Operate equipment at minimum power.
- Use quieter alternate methods or equipment.

7.5.3.2 Abatement in Path

There are several options open to abate construction noise in the source-to-receiver noise path. These usually include temporary enclosures around stationary equipment, temporary barriers, and noise curtains. If permanent noise barriers are part of the project, their construction should be scheduled first. Other strategies include effective use of temporary earth mounds as barriers, creating buffer zones between equipment and residences, or making use of existing structures as barriers.

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7.5.3.3 Abatement at Receiver

Abatement at the residence is usually done as a last resort. Strategies include window treatment or other insulation techniques. This is usually only cost-effective if relatively few residences are involved. Another strategy is temporary relocation of residents.

7.5.3.4 Community Awareness

Community awareness may be the most effective approach to reduce complaints of construction noise. Residents' tolerance toward construction noise is greatly increased if they are informed that the noise is temporary, that they have a telephone number to call for more information and to report specific noise concern, and that every effort will be made to address those concerns. Door-to-door personal contacts are the most effective, but this may be time-consuming. Other ways to relate the information are hotlines, project websites, automated phone calls, frequent community meetings, letters to the impacted residences, and local news coverage.

If construction noise is anticipated to be a major issue, the community should have an opportunity to provide considerable input early in the project development stage. It is essential that communication channels between the Caltrans resident engineer and the community stay open during the construction phase as well. A real time monitoring and reporting system with posting of measured noise levels on a website can be an effective way to keep the public informed on the project noise conditions associated with large, long-term projects. Responsibilities for addressing noise complaints should be included in the construction contract documents.

7.6 Earthborne Vibration

Caltrans has been involved with vibration studies since 1958. Until 1992, the Caltrans Transportation Laboratory in Sacramento conducted all vibration studies. Since then, most vibration studies have been contracted out. However, the Caltrans Division of Environmental Analysis does perform some vibration monitoring to investigate complaints.

Earthborne vibrations generated by construction activities or by traffic once a transportation facility is in operation can under certain circumstances be a serious concern. This section emphasizes the awareness and early recognition of potential vibration issues. When vibration-sensitive receptors or activities are located near a proposed new

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alignment or near an existing facility scheduled for heavy reconstruction, potential vibration impacts should be addressed during the project development phase with assistance of the Caltrans Division of Environmental Analysis. Caltrans' *Transportation- and Construction-Induced Vibration Guidance Manual* (2004) provides a wealth of information on vibration, including summaries of Caltrans experiences, and should be consulted.

During construction, pile driving, pavement breaking for crack-and-seat operations, demolition of old structures, and blasting are among the worst vibration offenders. Concerns may include annoyance, interference with activities, and structural damage. Therefore, construction activities involving generation of high-level vibrations must be carefully planned.

Although construction activities potentially generate the highest vibration levels and most damage, they are temporary in nature. Long-term effects of vibration may be caused by the transportation facility after it is completed. Normally, highway traffic does not generate high enough levels to cause damage to residences or other structures, even at very close distances. However, vibrations caused by heavy trucks can interfere with vibration-sensitive activities or equipment. Laboratories using sensitive electronic equipment, laser surgery, or close-tolerance machining are a few examples of operations that can be affected by nearby highway traffic.

In addition trains can produce some of the highest vibrations on a transportation facility. Caltrans has needed to consider cases involving train vibrations where a new highway or light-rail facility necessitated realignment of railroad tracks closer to residences or sensitive operations.

Potential vibration issues should be recognized as early as possible, and strategies to address the concerns should be coordinated with the Caltrans Division of Environmental Analysis. Potentially impacted vibration-sensitive receptors should be considered early in the design development process so that effective mitigation design strategies can be identified.

7.7 Occupational Hearing Loss and OSHA Noise Standards

This section does not pertain to environmental noise standards or NAC. Occupational hearing loss is a concern in certain occupations where workers are exposed to high noise levels. These occupations could be relevant to Caltrans operations, such as construction, maintenance, and materials laboratories. OSHA has set standards for permissible noise exposures. When the limits of these permissible exposures are approached,

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OSHA requires the employer "to administer a continuing, effective hearing conservation program" to prevent hearing loss. When the maximum allowable noise exposure is exceeded, the employer must take certain steps to control the noise. OSHA occupational noise exposure standards are addressed by 29 CFR 1910.95 and should be consulted if excessive noise exposure is suspected. For general reference, the most relevant information in 29 CFR 1910.95 is summarized below.

7.7.1 Noise-Induced Hearing Loss

Occupational noise-induced hearing loss develops slowly over a period of time when exposed to high continuous or intermittent noise levels. This should not be confused with traumatic hearing loss, which is caused by a single transient high-level noise event, such as a gunshot or explosion. The most important aspects of occupational noise-induced hearing loss are listed below.

- It is always sensory-neural (affects the hair cells in the inner ear).
- It typically affects both ears equally.
- The first sign of hearing loss is a *notching*, or reduced hearing sensitivity at 3,000, 4,000, or 6,000 Hz, with normal sensitivity in higher or lower frequencies. This is in contrast to age-related hearing loss, which also begins at 3,000 to 6,000 Hz but continues into higher frequencies.
- Noise-induced hearing loss due to chronic noise exposure is greatest during the first 10 years or so of exposure and slows down afterward. Age-related hearing loss, however, accelerates over time.
- Noise-exposed ears are not more sensitive to future noise exposure and do not progress beyond the added normal age-related hearing loss once the noise exposure is discontinued.

7.7.2 OSHA Noise Standards

Occasionally, the exposure of Caltrans personnel or contractors to noise is a concern. 29 CFR 1910.95(a) requires the employer to protect the employee against the effects of noise exposure when the permissible noise exposures in Table 7-3 are exceeded. The noise levels must be measured on the A-scale with the sound level meter at slow response.

29 CFR 1910.95(b)(1) requires that when the permissible noise exposure levels are exceeded, "feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of

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Table [7-3], personal protective equipment shall be provided and used to reduce sound levels within the levels of the table."

29 CFR 1910.95(b)(2) considers variations in noise level involving maxima at intervals of 1 second or less to be continuous.

Table 7-3. Table G-16 Permissible Noise Exposure

Duration per Day (Hours)	Sound Level (dBA, Slow Response)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Notes: When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions [C(1) / T(1)] + [C(2) / T(2)] + ……[C(n) / T(n)] exceeds 1, the mixed exposure should be considered to exceed the limit value. C(1), C(2), etc. indicate the times of exposure at a specific noise level. T(1), T(2), etc. indicate the times permissible for that specific exposure. Exposure to impulsive or impact noise should not exceed 140 dB peak (as opposed to rms) sound pressure level.

Two simple examples of the calculation shown in the footnote of the above table are provided below.

- C(1) = 3 hours at 95 dBA and C(2) = 5 hours at 90 dBA. The corresponding T(1) and T(2) values from the permissible noise exposure table are T(1) = 4 hours and T(2) = 8 hours. Using the calculation in the footnote, the exposure is:

  3/4 + 5/8 = 0.75 + 0.625 = **1.375 (>1)**.

  The maximum allowable exposure has been exceeded.

- C(1) = 1 hour at 100 dBA and C(2) = 3 hours at 90 dBA. The corresponding T(1) and T(2) values from the permissible noise exposure table are T(1) = 2 hours and T(2) = 8 hours. Using the calculation in the footnote, the exposure is:

  1/2 + 3/8 = 0.50 + 0.375 = **0.875 (<1).**

  The maximum allowable exposure has not been exceeded.

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The fractions may also be expressed as percentages, with 100% the maximum allowable exposure level. The first example would result in 137.5% and the second in 87.5%.

29 CFR 1910.95(c)(1–2) requires the employer to "administer a continuing, effective hearing conservation program…whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level…of 85 decibels, measured on the A-scale (slow response). Or equivalently, a dose of fifty percent." The 85-dBA noise level or dose of 50% is also referred to as the action level. The hearing conservation program is fully described in 29 CFR 1910.95(c–o).

7.8 Effects of Transportation and Construction Noise on Marine Life and Wildlife (Bioacoustics)

The effects of highway and construction noise on marine life and wildlife is generally referred to as bioacoustics. Concerns regarding these effects generally arise in response to requirements of the federal Endangered Species Act, National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and other resource agencies that have jurisdiction in the project area.

Caltrans biologists routinely address environmental issues related to all of the effects of transportation and construction on animals. Noise is only one of the issues, but it can be an important factor in the overall impact assessment. Underwater noise from pile driving can affect some fish within close range. In the San Diego area, Caltrans has built earth berms and soundwalls to protect nesting areas for Least Bell's Vireo, an endangered bird species. The task of addressing noise impacts on marine and terrestrial wildlife rests primarily with the biologists. However, noise analysts provide a supporting role to the biologists in providing technical noise expertise. Accordingly, it is critical that biologists coordinate directly with the project noise analyst when evaluating noise impacts on wildlife.

Addressing the effects of noise on marine and terrestrial animal species provides an exceptionally difficult challenge and requires specialized expertise. With marine life, the acoustical environment is vastly different than on land. In both marine and terrestrial environments, there is a great variety of animal species, each with different tolerances to noise. The nature of the adverse effects on the different species can also differ. On land, some birds may be flushed from their nesting areas, which may

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interfere with reproduction. Songbirds, which depend on their songs to find a mate, may be unable to communicate with each other in a noisy environment, therefore missing the opportunity to reproduce. Other animals may be temporarily or permanently driven from their habitat. The hearing frequency response to noise is also different in each species. For example the hearing range for humans is 20 to 20kHz whereas the hearing range for bats is 10 Hz to 200 kHz and the range for birds is 1KHz to 5 KHz. Accordingly, the use of the human response A-scale when evaluating noise impacts on other species may not be appropriate in some cases.

The Caltrans' document *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* (Guidance Manual) provides detailed guidance on the process for evaluating underwater noise impacts on fish from pile driving (2009). This document is available:
<http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm>.

National Cooperative Highway Research Program Research Results Digest 363- Hydroacoustic Impacts on Fish from Pile Installation (National Cooperative Highway Research Program 2011c) provides additional on pile driving noise impacts on fish. This document is available:
<http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_363.pdf>.

Specific guidance on how to address airborne noise effects on terrestrial wildlife has not yet been developed by Caltrans. Caltrans has however commissioned a report entitled *The Effects of Highway Noise on Birds* (Dooling and Popper 2007) which provides background on the effects of noise on birds and provides recommended criteria for impact assessment. This document is available:
<http://www.dot.ca.gov/hq/env/bio/avian_bioacoustics.htm>

Another useful resource is the FHWA document *Synthesis of Noise Effects on Wildlife Populations* (Federal Highway Administration 2004).

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Section 8
Glossary

The terms and definitions in this glossary are either used in this TeNS or are commonly found in environmental noise literature. To make this glossary more useful to the highway traffic noise analyst, these definitions are generally oriented toward highway traffic noise and abatement, not general acoustics.

Absorption: The attenuation of sound caused by conversion of sound energy into other forms of energy, usually heat, within a medium. Absorption is a property of the medium. In noise barrier material, absorption can be considered the complement of reflection. A perfectly absorptive material does not reflect any sound energy, and a non-absorptive (i.e., reflective) material reflects almost all sound energy. In either case, a small portion of sound energy is transmitted through the barrier and continues in roughly the same direction as the incident noise propagation. In typical highway traffic noise barriers, the sound energy passing through is less than 1% of the incident noise energy. See also "Transmission Loss."

Absorption Coefficient: A term that approximately equals the ratio of sound energy absorbed by a material to the energy incident on the material. Absorption coefficients range from 0 (no absorption) to 1 (perfect absorption). In highway noise barriers, material with an absorption coefficient of 0 will reflect back almost all incident noise energy, and material with a coefficient of 1 will not reflect back any sound energy. The absorption coefficient depends on material, sound frequency, and angle of incidence.

Absorptive Grounds: Types of ground, such as normal earth and most grounds with vegetation, that are absorptive to sound energy and that reverse the phase of reflected energy at grazing angles of incidence. See also "Soft Sites" and "Ground Effects."

Acoustics: The broad field of science that deals with the production, propagation, reception, effects, and control of sound, both audible and inaudible to the human ear, and occurring in all media.

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Airborne Sound: Sound that reaches the point of interest primarily by propagation through the air.

Ambient Noise: All-encompassing noise at a given place and time. This is usually a composite of sounds from all sources near and far, including any specific sources of interest.

Amplitude: The strength or magnitude of the pressure of a sound wave.

Anechoic Chamber: A room that has boundaries designed to absorb nearly all of the sound incident on them, producing a test room that is essentially free from reflected sound, and simulates free field conditions for the limited space defined by the room's boundaries.

Angle of Diffraction: The angle through which sound energy is diffracted as it passes over the top of a noise barrier and proceeds toward the receiver. Receivers deeper into the shadow zone have larger angles of diffraction and therefore higher barrier attenuation. See also "Diffraction" and "Shadow Zone."

Angle of Incidence: The angle formed by the radial line of sound waves striking a surface at a specific location and the plane of that surface. See also "Angle of Reflection."

Angle of Reflection: The angle formed by the radial line of sound waves reflecting off a surface at a specific location and the plane of that surface. See also "Angle of Incidence."

Atmospheric Effects: Sound absorption by air molecules and water vapor, sound refraction caused by temperature and near-ground wind gradients, and air turbulence are collectively called atmospheric effects. Although atmospheric effects are mostly responsible for substantial noise fluctuations at distant receivers, they also can have a significant effect at distances within 330 feet.

Audible Spectrum: The frequency range normally associated with human hearing, usually considered between 16 and 20,000 Hz. For noise control purposes, the audible spectrum of interest usually lies between 20 and 10,000 Hz.

Audiogram: A graph showing hearing loss as a function of frequency.

Audiometer: An instrument for measuring hearing sensitivity or loss.

Automobile: A vehicle classification for the purpose of noise prediction modeling, defined as all vehicles with two axles and four wheels designed

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primarily for transportation of nine or fewer passengers (automobiles) or transportation of cargo (light trucks). Generally, the gross weight is less than 10,000 pounds.

Average Level: Typically the energy-averaged noise level in decibels, wherein the contributing levels are first converted to relative energies or energy ratios, and added and divided by the number of contributing levels. The result is then converted back to decibels.

A-Weighted Sound Level: Expressed in dBA or dB(A). Frequency-weighted sound pressure level approximating the frequency response of the human ear. It is defined as the sound level in decibels measured with a sound level meter having the metering characteristics and a frequency weighting specified in the American National Standards Institute Specification for Sound Level Meters, ANSI S 1.4–1983. The A-weighting de-emphasizes lower frequency sound sounds below 1,000 Hz (1 kHz) and higher frequency sounds above 4 kHz. It emphasizes sounds between 1 and 4 kHz. A-weighting is the most commonly used measure for traffic and environmental noise throughout the world.

Background Noise: The total noise in a system or situation independent of the presence of (i.e., without) the noise source of interest.

Baffle: A shielding structure or series of partitions used to increase the effective external transmission path length between two points in an acoustic system.

Band: See "Frequency Band."

Band Center Frequency: The designated geometric mean frequency of a band of noise.

Band Pressure Level: The SPL contained within a specified band.

Barrier Attenuation: The noise reduction from barrier diffraction only.

Broadband Noise: Noise with components over a wide range of frequencies.

Calibrator: A device used to calibrate or properly adjust for valid measurement results a sound level meter and microphone system. Calibration must be performed before and after the sound level measurement sequence.

Community Noise Equivalent Level: A noise level that accounts for all the A-weighted noise energy from a source during 24 hours, and weights

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the evening (7 p.m. to 10 p.m.) and night (10 p.m. to 7 a.m.) noise by adding 5 and 10 dBA, respectively, during these periods.

Compression: The portion of a sound wave in which the air molecules are slightly compressed with respect to the barometric air pressure. The opposite of rarefaction.

Cylindrical Divergence: Sound waves generated by a line source, such as approximated by a highway, tend to form cylindrical wavefronts that propagate by radiating outward from their original line source in cylindrical pressure waves of ever-increasing areas. This process is referred to as cylindrical divergence or spreading. The same sound energy distributed over an ever-increasing cylindrical area is responsible for reducing the sound's energy per unit area (i.e., intensity) by half for each doubling of distance. This corresponds with a noise level decrease of 3 dB per doubling of distance.

Cycles per Second: See "Hertz."

Day-Night Level: See "L_{dn}."

Decibel: A decibel is one-tenth of a bel. It is a measure on a logarithmic scale that indicates the squared ratio of sound pressure to a reference sound pressure (unit for sound pressure level) or the ratio of sound power to a reference sound power (unit for sound power level). See also "Sound Pressure Level" and "Sound Power Level."

Descriptor: A generic term for a noise indicator such as L_{eq}, L_{max}, or L_{dn}.

Diffuse Sound Field: A sound field in which the time average of the mean square sound pressure is the same everywhere and the flow of acoustic energy in all directions is equally probable. For example, a sound source in a reverberation room, where many reflected sound waves are present and the sound level is equal at any location in the room.

Diffraction: The bending of sound pressure waves around an obstacle. The ease with which the pressure waves diffract around an obstacle depends on the ratio of wavelength to the size of the obstacle. Pressure waves with a given wavelength diffract more readily around a small object than a large one. Pressure waves with longer wavelengths diffract more easily around an object of a given size than pressure waves with a shorter wavelength. Because of the above principles, highway traffic noise barriers provide a more defined noise "shadow" behind the barrier and more noise attenuation for higher-frequency noise than lower-frequency noise. See also "Angle of Diffraction" and "Shadow Zone."

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Doppler Effect: The change in observed frequency of a sound wave caused by a time rate of change in the effective path length between the sound source and receiver. If the path length rate of change causes the source and receiver to approach each other, the observed frequency shifts upward. If the source and receiver recede relative to each other, the frequency shifts downward. The frequency shift is called the Doppler shift, and the unit is hertz.

Dosimeter: An instrument measuring noise exposure for compliance with OSHA standards.

Dynamic Range: The range in sound levels, in decibels, through which a source or receiver can emit or receive sound. For example, the dynamic range of a sound level meter typically ranges from 20 to 140 dB.

Emission Level: A measure of the noise output of a single vehicle. It is the maximum noise level, in dBA, observed during a passby of the vehicle at 50 feet. See also "Reference Energy Mean Emission Level."

Energy Average: The result of energy averaging or a method of averaging various SPLs based on their squared pressures. This method involves the conversion of decibels to equivalent relative energy or energy ratios, averaging the values**,** and changing the values back to decibels.

Energy Ratio: See "Relative Energy."

Equivalent Distance: The distance to a specific receiver from an imaginary single lane that acoustically represents a multilane highway or a group of lanes, such as directional lanes.

Equivalent Level: See "L_{eq}."

Excess Attenuation: Sound attenuation in addition to that caused by geometric spreading. It is usually meant to be the attenuation from ground effects and sometimes atmospheric effects. See also "Geometric Spreading," "Ground Effects," and "Atmospheric Effects."

Existing Noise Levels: The noise resulting from the natural and mechanical sources and human activity considered to be usually present in a particular area.

Far Field: The region beyond the near field, where the effects of source dimensions are less important and noise propagates with a simple relationship between sound level and distance.

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Filter: A device for separating components of a signal based on their frequency. It allows components in one or more frequency bands to pass relatively unattenuated and attenuates components in other frequency bands.

Flanking Noise: Refers to noise energy that arrives at an observer by an unexpected or unexamined pathway. For example, in the design of noise barriers, the calculations predict the energy that diffracts over the top of the barrier. If significant amounts of noise energy reach the observer by passing around its ends far up and down the roadway, this energy has flanked the barrier along unexpected "flanking paths."

Flow Resistivity: A measure of the acoustical absorption of the ground located between a sound source and receiver. As applied in the FHWA TNM the units of flow resistivity are cgs rayls. Water and hard pavement are highly acoustically reflective and are assigned a flow resistivity value of 20,000 cgs rayls. At the other extreme is power snow which is assigned a value of 10 cgs rayls.

Free Field: A sound field that is free from enclosures or boundaries, and in which there are no reflections and accompanying interference and reverberation effects such as found in auditoriums.

Frequency: The number of oscillations per second of a periodic wave sound and of a vibrating solid, expressed in units of hertz, formerly cycles per second (cps). 1 Hz = 1 cps = 1 oscillation per second. The value is the reciprocal (1/x) of the period of oscillations in seconds. The symbol for frequency is *f*.

Frequency Band: An interval of the frequency spectrum defined between an upper and lower cutoff frequency. The band may be described in terms of these two frequencies or (preferably) by the width of the band and the geometric mean frequency of the upper and lower cutoff frequencies (e.g., an octave band "centered" at 500 Hz).

Frequency Response: The response to an oscillating phenomenon (e.g., sound pressure) by an object (e.g., microphone or ear) measured in decibels as a function of frequency. For example, the A-weighting curve corresponds closely to the frequency response of human hearing at a certain constant level of sound energy. See also "A-Weighted Sound Level."

Frequency Spectrum: The description of a sound wave's resolution into components of different frequency and usually different amplitude and phase.

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Fresnel Number: A dimensionless value used in predicting the attenuation of a noise barrier located between a noise source and receiver. In its simplest mathematical form, $N = 2\delta / \lambda$, where δ is the path length difference between the sound path from the source to receiver via the top of the barrier and the straight line between the source and receiver, and λ is the wavelength of the sound (the units of δ and λ must be the same). Generally, the larger the value of N, the greater the attenuation.

Fundamental Frequency: The frequency with which a periodic function (e.g., sound wave) reproduces itself, sometimes called the first harmonic. See also "Harmonic."

Geometric Divergence: Refers to the shape of sound pressure wavefronts and the manner in which they propagate. Geometric divergence or spreading is a generic term used for specific types of divergence, such as cylindrical or spherical divergence. See also "Cylindrical Divergence" and "Spherical Divergence."

Gradient: Variation of speed of sound, temperature, and wind velocity with height above the ground surface. A gradient in speed of sound can be caused by differences in temperature with height above the ground or differences in wind velocities with height above the ground. The speed of sound gradient in turn causes atmospheric refraction of sound which can create noise "shadows" (i.e., decreases) in certain areas and noise concentrations (i.e., increases) in others. See also "(Atmospheric) Refraction."

Ground Effects: The effects of sound grazing absorptive ground. See also "Absorptive Grounds."

Hard Site: Term used for reflective characteristics of the ground surface between a noise source and receiver. The term is most often used in traffic noise prediction models, where it is associated with a 3 dB per doubling of distance line source attenuation (because of geometric spreading only, without excess attenuation).

Harmonic: A sinusoidal (i.e., pure-tone) component whose frequency is a whole-number multiple of the fundamental frequency of the wave. If a component has a frequency twice that of the fundamental frequency, it is called the second harmonic.

Heavy Truck: A vehicle type for the purpose of noise prediction modeling defined as all vehicles with three or more axles designed for transportation of cargo. Generally, the gross weight is more than 26,500 pounds.

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Hertz: Unit of frequency, formerly called cycles per second. 1 Hz = 1 cps. See also "Frequency."

Hourly Equivalent Sound Level: See "$L_{eq}(h)$."

Incident Sound: Direct sound striking a surface. See also "Angle of Incidence."

Infrasound: A sound with a frequency less than the audible sound spectrum (i.e., generally lower than 16 to 20 Hz).

Insertion Loss: The actual noise level reduction at a specific receiver from construction of a noise barrier between the noise source (e.g., traffic) and the receiver. Generally, it is the net effect of the barrier attenuation and loss of ground effects.

Inverse First Power: The increasing of sound amplitude from the process of cylindrical divergence from a line source. See also "Cylindrical Divergence." For a line source, the sound pressure level SPL_1 at distance D_1 is related to the sound pressure level SPL_2 at a distance of D_2 as follows:

$$SPL_1 - SPL_2 = 10\log(D_1 / D_2)$$

Inverse Square: The increasing of sound amplitude from the process of spherical divergence from a point source. See also "Spherical Divergence." For a point source, the sound pressure level SPL_1 at distance D_1 is related to the sound pressure level SPL_2 at a distance of D_2 as follows:

$$SPL_1 - SPL_2 = 10\log(D_1 / D_2)^2$$

kHz: Abbreviation for kilohertz, or 1,000 Hz. See also "Hertz."

L_{dn}: Abbreviation for the day-night level noise descriptor. It is the energy average of the A-weighted sound levels occurring during a 24-hour period, with 10 dB added to the A-weighted sound levels occurring from 10 p.m. to 7 a.m.

L_{eq}: The equivalent steady-state sound level that in a stated period of time would contain the same acoustical energy as the time-varying sound level during the same period.

$L_{eq}(h)$: The energy-average of the A-weighted sound levels occurring during a 1-hour period in decibels (i.e., a 1-hour L_{eq}). See also "L_{eq}."

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Level: In acoustics, the value of a logarithm of the ratio or ratio squared of that quantity *t* a reference quantity of the same kind in decibels. The base of the logarithm is commonly 10. The reference quantity and kind of level must be specified (e.g., sound pressure level of 60 dB RE: 20 µPa, sound power level RE: 10^{-12} W).

Line of Sight: A straight line between the observer's location and a specific noise source.

Line Source: A source of noise spread out into a line, such as approximated by the combined traffic on a roadway.

L_{max}: The highest SPL in a specific time period.

Logarithm: A mathematical operation that, for values more than 1, condenses these values into smaller values through the reverse of y^x, where x is the number being operated on. Normally, the base, or value of y, is taken as 10 (common log). If the base is not specified, its value is usually considered 10. Therefore, if $10^x = a$, then $x = \log_{10}a$, or log a. If $a > 1$, x is positive. If $a = 1$, $x = 0$. If $0 < a < 1$, x is negative. Please note that *a* must never be 0. For example:

$10^2 = 100$; log100 = 2; x = 2, a = 100
$10^0 = 1$; log1 = 0; x = 0, a = 1
$10^{-2} = 0.01$; log0.01 = -2; x = -2, a = 0.01

Loudness: The judgment of intensity of a sound in terms of which sounds may be ranked on a scale from soft to loud. On this scale, a doubling of a reference sound energy is barely perceptible to the human ear, a tripling of the sound energy is readily perceptible, and 10 times the sound energy is about twice as loud. Decreasing the sound by the same factors has a reciprocal effect—reducing the reference sound energy to one-tenth of the original energy the sound is perceived as half as loud. Although loudness depends primarily on the intensity of the sound, it also depends on the sound's frequency and wave form.

Loudness Level: Defined as the median SPL in a specified number of trials of a 1,000-Hz tone that is judged equally loud to the listener as the sound in question. Described in units of phons. Please note that the calculated loudness level, *L*, in phons is related to loudness in sones as follows:

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$$L = 10\log_2 n_s$$

Where:

L = the loudness level in phons

n_s = loudness in sones

A twofold change in loudness corresponds to an interval of 10 phons. See also "Phon" and "Sone."

L_X: The sound pressure level exceeded *x* percent of a specific time period. For example, L_{10} is the level exceeded 10% of the time, and L_{50} is the level exceeded 50% of the time.

Masking: The action of bringing one sound, audible when heard by itself, to inaudibility or unintelligibility by the introduction of another sound.

Medium: A substance carrying a sound wave, such as air, water, or steel.

Medium Truck: A vehicle classification for the purpose of noise prediction modeling, defined as all vehicles with two axles and six wheels designed for transportation of cargo. Generally, the gross weight is more than 10,000 pounds and less than 26,500 pounds.

Meter Response: Measure of the quickness with which the needle of an analog sound level meter or the display of a digital sound level meter follows changes in the actual sound level.

Microphone: An electroacoustic transducer that transforms sound waves into equivalent electric waves.

Natural Frequency: Frequency of free oscillation of a system (i.e., the frequency at which a system vibrates when given an initial excitation and allowed to vibrate freely without constraints).

Near Field: The part of a sound field, usually within about two wavelengths of the lowest sound frequency from a sound source, in which the dimensions of the sound source have an important effect and where there is no simple relationship between sound level and distance. For traffic noise, the near field usually exists within 25 feet of the nearest traffic. Noise measurements or predictions should be avoided in the near field.

Noise: Sound that is loud, unpleasant, unexpected, or otherwise undesirable.

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Noise Barrier: A generic term for any feature that blocks or diminishes sound in its path from the source to receiver. Although the term can technically refer to any feature, manmade or natural, the two most common features included in noise barriers are soundwalls and earth berms. Almost all noise barriers in California are soundwalls; therefore, the terms "noise barrier" and "soundwall" are frequently interchanged, although soundwalls are a subset of noise barriers. See also "Soundwalls" and "Earth Berms."

Noise Contour: An imaginary line shown on a plan along which all sound levels are equal.

Noise Floor: The level of noise, in decibels, that represents the threshold of sensitivity for a sound level meter and below which the inherent (i.e., device's own) noise limits its detectability of low-level signals.

Noise Reduction Coefficient: A value representing the arithmetic average of the absorption coefficients in four octave bands with respective center frequencies of 250, 500, 1,000, and 2,000 Hz.

Octave: The interval between two sounds having a frequency ratio of 1:2; (e.g., 500 to 1,000 Hz; 440 to 880 Hz).

Octave Band: A frequency band in which the interval between the upper and lower cutoff frequency is one octave. As with all frequency bands, the octave band is usually described by its center frequency. Octave bands are centered by preferred frequencies described by ISO R 266. An example is the 500-Hz octave band. See also "Frequency Band."

One-Third Octave: The interval between two sounds having a frequency ratio of the cube root of 2 (approximately 1.26). Three contiguous one-third octaves cover the same frequency range as an octave.

One-Third Octave Band: A frequency band in which the interval between the upper and lower cutoff frequency is one-third of an octave. As with all frequency bands, the one-third octave band is usually described by its center frequency. Three contiguous octave bands make up one octave band. As with octave bands, one-third octave bands are centered by preferred frequencies described by ISO R 266. For example, three one-third octave bands centered at 400, 500, and 630 Hz make up the 500-Hz octave band. See also "Frequency Band."

Overall Level: The SPL that includes all the energy in all frequency bands of interest.

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Pascal: A unit of pressure (in acoustics, normally rms sound pressure) equal to 1 Newton per square meter (N/m^2). The pascal is abbreviated Pa. A reference pressure for a sound pressure level of 0 dB is 20 μPa.

Peak Sound Level: See "Peak Sound Pressure Level."

Peak Sound Pressure: The maximum instantaneous (i.e., non-rms) sound pressure for a transient or impulsive sound of short duration or in a specified time interval for a sound of long duration. The unit is pascals.

Peak Sound Pressure Level: Level of peak sound pressure. The unit is decibels with stated frequency weighting, if any. See also "Peak Sound Pressure" and "Sound Pressure Level."

Permanent Threshold Shift: Permanent hearing loss from frequent exposures to noise of high intensities. See also "Temporary Threshold Shift."

Phon: Unit of loudness judged or calculated in definition of loudness level. See also "Loudness Level."

Pink Noise: Broadband noise that yields the same energy for each octave band over its entire range of frequencies. Because, going from low to high frequencies, each subsequent octave band contains twice the frequency range as the previous band, the energy decreases with increasing frequency to maintain equal energy per octave band. Compare with white noise.

Point Source: A noise source essentially concentrated at a single point from which noise propagates outward in all directions. A single vehicle observed from some distance can be approximated as a point source. See also "Spherical Divergence" and "Spreading."

Propagation: The passage of sound energy from a noise source to receiver through a medium (e.g., air).

Pure Tone: A sound wave whose waveform is a sine wave (single frequency).

Random Incidence: Refers to sound waves that strike the receiver randomly from all angles of incidence. Such waves are common in a diffuse sound field.

Random Noise: Noise that has random characteristics in both time and amplitude (i.e., any occurrence of any amplitude is as likely to occur at any one moment as any other).

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Rarefaction: The portion of a sound wave in which the air molecules are rarefied or in a slight vacuum with respect to the barometric air pressure. The opposite of compression.

Rate of Decay: The time rate at which SPL decreases at a given receiver after the sound source is turned off. The commonly used unit is decibels per second (dB/s). It is used in measuring reverberation time of a room. See also "Reverberation" and "Reverberation Time."

Receiver: Most basically defined as any natural or artificial sensor that can perceive, register, or be affected by sound (e.g., human ear, microphone). When modeling noise, a receiver is a point in the model that represents a single receptor or multiple receptors (defined below). For example if three single-family residences are in an area where acoustic conditions are the same, each residence is a receptor. For more modeling purposes the three residences can be represented by a single receiver in the model.

Receptor: Most basically defined as any natural or artificial sensor that can perceive, register, or be affected by sound (e.g., human ear, microphone). In the context of a noise analysis under the requirements of 23 CFR 772 a receptor is a single specific dwelling unit or the equivalent of a single dwelling unit. For example in a park with three baseball fields, each field is considered to be equivalent to a single dwelling unit for the purposes of noise analysis.

Reference Energy Mean Emission Level: The speed-dependent, energy-averaged maximum passby noise level generated by a defined vehicle type, as measured by a sound level meter at 50 feet from the centerline of travel at a height of 5 feet.

Reference Pressure: Any sound pressure to which a test pressure is being compared on a decibel scale, such as in the following expression:

$$dB = 10\log_{10}\left(\frac{p_1}{p_0}\right)^2$$

Where:

P_0 = reference pressure (usually defined as 20 μPa).

Also, the sound pressure at 1,000 Hz that normal young adults can just detect, taken as 20 μPa.

Reflection: Bouncing back of sound waves away from an object that is larger in exposed section than the wavelengths and of sufficient surface

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weight, density, and stiffness to present a very large increase in impedance compared to the surrounding air.

Reflective Ground: Grounds that do not absorb sound energy and reflect back most of the energy. Examples are paved surfaces (e.g., asphalt, concrete) and hard-packed soils. The opposite of absorptive ground.

Refraction: The bending of sound waves in arcing curves either downward or upward because of different velocities of sound with respect to height above the ground. The sound velocity differences are caused either by differences in near-ground wind velocity from wind shear, or vertical changes in temperature (sound velocity increases with air temperature). Downward refraction occurs for downwind sound propagation and during near-ground temperature inversions (temperature increases with height), and is responsible for noise increases. Upward refraction occurs for upwind sound propagation and during near-ground temperature lapses (temperature decreases with height), and is responsible for noise decreases.

Relative Energy: The energy ratio between a sound level and reference level. For example, the sound energy of 60 dB is 10^6, or 1,000,000 times larger than that of 0 dB. The sound energy of 67 dB is $10^{6.7}$, or 5,011,872 times larger than that of 0 dB.

To add or subtract sound levels, the relative energies (not the decibel levels) may be added directly. Therefore, for the case above, total relative energy is as follows:

60 dB + 67 dB = 1,000,000 + 5,011,872 = **6,011,872 (RE: 0 dB)**
10log(6,011,872) = **67.8 dB.**

The same result would be obtained if a reference of 50 dB were selected, as shown below.

50 dB + 10log[$10^{(6-5)}$ + $10^{(6.7-5)}$] =
50 dB + 10log(10^1 + $10^{1.7}$) =
50 dB + 10log(60.12) =
50 dB + 17.8 = **67.8 dB.**

Resonance: The relatively large amplitude of sound or vibration produced when the frequency of the source of the sound or vibration "matches" (i.e., synchronizes) with the natural frequency of vibration of an object. See also "Natural Frequency."

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Resonator: A device that resounds or vibrates in sympathy with a source of sound and vibration (i.e., the source frequency matches the natural frequency of the resonator).

Reverberant Field: The region in a room where the reflected sound dominates, as opposed to the noise source where the direct sound dominates.

Reverberation: The persistence of sound in an enclosed space, because of multiple reflections, after the sound source has stopped.

Reverberation Room: A room having a long reverberation time, especially designed to make a sound field inside it as diffuse as possible. Also called a live room. The opposite of an anechoic chamber. See also "Anechoic Chamber."

Reverberation Time: The time taken for the sound energy to decrease to one millionth (10^{-6}), corresponding to a drop of 60 dB in SPL, of its steady-state value when the sound source is suddenly stopped. It is a measure of the persistence of an impulsive sound in a room and of acoustical absorption present inside the room.

Root Mean Square Pressure: The square root of the mean of the squares of a set of instantaneous positive, negative, or zero pressure amplitudes. The rms value is calculated by squaring the pressure values at each instant, adding them, dividing the total by the number of values, and taking the square root of the result. The squaring of both the positive and negative values ensures a positive result. An rms sound pressure is directly correlated with sound energy. For a single-frequency sound or sine wave, there is a simple relationship between the peak sound pressure and rms value:

$$\text{Peak} = \sqrt{2} * \text{rms} \approx 1.414 * \text{rms}$$
$$\text{rms} = (1 / \sqrt{2}) * \text{Peak} \approx 0.707 * \text{Peak}$$

Shadow Zone: The area behind a noise barrier that is blocked from direct view of the source of noise on the roadway.

Shielding: A noise reduction at the receiver because of the placement or existence of natural or artificial barriers (e.g., walls, berms, rows of buildings, or trees, if thick and dense enough).

Sine Wave: A sound wave, audible as a pure tone, in which the sound pressure is a sinusoidal function of time.

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Soft Site: See "Absorptive Ground."

Sound: A vibratory disturbance created by a moving or vibrating source in the pressure and density of a gaseous, liquid medium or in the elastic strain of a solid that is capable of being detected by hearing organs. Sound may be thought of as mechanical energy of a vibrating object transmitted by pressure waves through a medium to the ears. The medium of main concern is air. Unless otherwise specified, sound will be considered airborne, not structureborne, earthborne, etc.

Sound Energy: See "Relative Energy."

Sound Insulation: The use of structures and materials designed to reduce the transmission of sound from one room or area to another, or from the exterior to interior of a building. Also, the degree by which sound transmission is reduced by means of sound-insulating structures and materials.

Sound Intensity: The average rate of sound energy transmitted in a specified direction through a unit area normal to this direction at a point considered.

Sound Level: Frequency-weighted SPL measured using metering characteristics and frequency weighting, such as A, B, or C, specified in the ANSI Specification for Sound Level Meters.

Sound Level Meter: An instrument used for measuring sound levels in a specified manner. It generally consists of a microphone, amplifier, output display, and frequency weighting networks.

Sound Power: The total amount of energy radiated into the atmosphere per unit time by a source of sound.

Sound Power Level: The level of sound power, averaged over a period of time, the reference being 10^{-12} watts.

Sound Pressure Level: Ten times the logarithm to the base 10 of the ratio of the time mean-square pressure of a sound, in a stated frequency band to the square of the reference sound pressure in gasses, of 20 μPa. SPL represents only unweighted rms levels. The unit is decibels. See also "Root Mean Square."

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$$SPL = 10\log_{10}\left(\frac{p_1}{p_0}\right)^2$$

Where:

P_0 = reference pressure of 20 μPa.

P_1 = sound pressure.

Source: A general term designating the sound energy generator. In transportation, noise sources are classified as point and line sources, which have different propagation characteristics. See also "Point Source" and "Line Source."

Source Heights: The effective acoustic height of vehicle noise sources. These heights have been determined from vehicle noise emission data, and are programmed in the appropriate computerized noise prediction models. The heights represent the energy average of all subsources (e.g., exhaust, tires, and engine noise) and are most important in evaluating noise barrier attenuation.

Sound Transmission Class: A single figure rating system designed to estimate sound insulation properties of a partition or a rank ordering of a series of partitions. It is intended for use primarily when speech and office noise constitutes the principal problem.

Spectrum: See "Frequency Spectrum."

Speed of Sound: The speed of sound for standard temperature of dry air at 32ºF and standard air pressure of 29.29 inches Hg standard is 1,087.3 feet per second. From these base values, the variation of speed of sound with temperature is described by the following equations:

$$\text{English Units: } c = 1051.3\sqrt{1+\frac{T_f}{459}}$$

Where:

c = speed of sound

T_f = temperature in ºF

Spherical Divergence: Sound waves generated by a point source, such as approximated by a single vehicle, tend to form spherical wavefronts that propagate by radiating outward from their original point source in spherical pressure waves of ever-increasing areas. This process is referred to as "spherical divergence" or "spreading." The same sound energy

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distributed over an ever-increasing spherical area is responsible for reducing the sound's energy per unit area (intensity) by one-quarter for each doubling of distance. This corresponds with a noise level decrease of 6 dB per doubling of distance. See also "Cylindrical Divergence."

Spherical Wave: A sound wave in which the surfaces of constant phase are concentric spheres. A small (point) source radiating into an open space produces a free sound field of spherical waves.

Steady-State Sound: Sounds for which average characteristics remain constant in time (e.g., sound of an air conditioner, fan, or pump).

Structureborne Sound: Sound that reaches the receiver over at least part of its path by vibration of a solid structure.

Temporary Threshold Shift: A temporary hearing loss, evidenced by an increase in the threshold of audibility (see "Threshold of Audibility") occurring after exposure to noise of high intensity. After a given time, usually up to several hours, the ear recovers to almost normal, but not quite so. After an excessive number of exposures of high intensity a hearing loss, or permanent threshold shift develops gradually.

Threshold of Audibility: The minimum SPL at which a person can hear a specific sound for a specified fraction of trials.

Transducer: A device capable of being actuated by waves from one or more transmission systems or media, and supplying related waves to one or more other transmission systems or media (e.g., microphones, loud speakers, accelerometers, seismometers).

Transient Sound: Transient sounds are those whose average properties do not remain constant over time (e.g., aircraft flyover, passing train, sonic boom, gunshot).

Transmission Loss: The loss in sound energy at a specific frequency, expressed in decibels, as sound passes through a barrier or a wall. It may be expressed mathematically as:

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$$10 \times Log\left[\frac{E_1}{E_2}\right]$$

Where:

E_1 = sound energy leaving the back of the wall

E_2 = sound energy as it strikes the front of the wall

Transmission loss is not a reduction in total energy, only a transformation from sound energy into heat. Almost all highway noise barriers provide a loss of at least 25 dBA, which means that less than 1/3 of a percent of the sound energy travels through the wall.

Wave: In acoustics, a propagation wave is a cyclic pressure variation in air. The waves move at a characteristic speed (e.g., the speed of sound) through the medium (e.g., air) as an elastic response to a pressure perturbation at a source.

Wave Front: A portion of any wave, whether in compression or rarefaction state, that can be followed as it propagates throughout the medium, analogous to the crest of a tidal wave as it crosses the ocean. At all points on the wave front, the wave has equal amplitude and phase.

Wavelength: For a non-periodic wave, such as sound in air, the normal distance between analogous points of any two successive waves. The wavelength of sound in air or water is inversely proportional to the frequency of the sound. Therefore, the lower the frequency, the longer the wavelength.

White Noise: Broadband noise, the energy of which is constant over a wide range of frequencies (i.e., energy/Hz = constant). Because each octave band range increases by a factor of two, from low to high frequencies, each subsequent octave band contains twice the acoustical energy as the previous one. This corresponds to an increase of 3 dB in energy for each subsequent octave band. Compare with “Pink Noise.”

Ultrasonic: Pertaining to sound frequencies above the audible sound spectrum (in general, more than 20,000 Hz).

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Appendix A

References Cited

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Appendix A
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Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
1	E	Ora/LA	12/7	I-5 SO San Juan Cap./Route 19 near Long Beach	Ora	0	LA	3.6			
1	E	LA/Ven	7	Route 187 near Santa Monica/Route 101 near El Rio	LA	32.2	Ven	21.1			
1	E	Santa Barbara	5	Route 101 at Las Cruces to Route 246 near Lompoc	SB	R 0.0	SB	19.3			
1	E	SLO	5	Route 227 SO Oceano/Route 101 near Pismo Beach	SLO	10.3	SLO	16.7			
1	E	SLO/Mon/SCr/SM/SF	5/4	Route 101 near San Luis Obispo/Route 35 near Daly City	SLO	16.7	SF	1.9			
1	E	SF	4	Route 35 in SF/Route 101 near Golden Gate Br in SF	SF	1.9	SF	7.1			
1	E	Mar/Son/Men	4/1	Route 101 near Marin City/Route 101 near Leggett	Marin	0.0	Men	105.6			
1	**OD**	**SANTA BARBARA**	**5**	**FR Route 101 NR LAS CRUCES TO NR LOMPOC**	**SANTA BARBARA**	**0**	**SANTA BARBARA**	**18.6**	**18.6**	**30**	December 14, 1971
1	**OD**	**SAN LUIS OBISPO**	**5**	**FR SAN LUIS OBISPO CIL TO MONTEREY CL**	**SAN LUIS OBISPO**	**17.73**	**SAN LUIS OBISPO**	**74.3**	**56.6**	**54**	August 13, 1999
1	**OD**	**MONTEREY**	**5**	**FR SAN LUIS OBISPO CL TO CARMEL RIVER**	**MONTEREY**	**0.0**	**MONTEREY**	**72.3**	**72.3**	**1**	June 7, 1965
1	**OD**	**MONTEREY**	**5**	**FR CARMEL RIVER TO Route 68**	**MONTEREY**	**72.3**	**MONTEREY**	**78.1**	**5.8**	**14**	May 21, 1970
1	**OD**	**SAN MATEO**	**4**	**FR SANTA CRUZ CL TO S CIL HALF MOON BAY**	**SAN MATEO**	**0.0**	**SAN MATEO**	**26.2**	**26.2**	**39**	June 25, 1976
2	E	LA/SBD	7/8	Route 210 in La Can. Flintridge/Route 138 Via Wrtwd	LA	22.9	SBD	6.36			
2	**OD**	**LOS ANGELES**	**7**	**FR 2.7 MI NO Route 210 @ LA CANADA TO SAN BERND CL**	**LOS ANGELES**	**27.2**	**LOS ANGELES**	**82.3**	**55.1**	**22**	March 12, 1971
3	E	Trinity	2	Route 36 near Peanut/Route 299 near Douglas City	Trinity	L0.0	Trinity	L30.9			
3	E	Tri/Sis	2	Route 299 near Weaverville/Montague	Trinity	30.9	Sis	54.2			
4	E	Contra Costa	4	Route 160 near Antioch/Route 84 near Brentwood	Contra Costa	31.1	Contra Costa	40.5			
4	E	Cal/Alp	10	Route 49 near Angel's Camp/Route 89	Cal	21.4	Alp	31.7			
4	**OD**	**CALAVERAS**	**10**	**FR EO ARNOLD TO ALPINE CL**	**CALAVERAS**	**41.6R**	**CALAVERAS**	**65.9**	**24.3**	**26**	**November 9, 1971**
4	**OD**	**ALPINE**	**10**	**FR CALAVERAS CL TO Route 89**	**ALPINE**	**0.0**	**ALPINE**	**31.7**	**31.7**	**18**	**September 14, 1970**
5	E	San Diego	11	Intl Bdry at Tijuana/Route 75 SO SD Bay	San Diego	0.0	San Diego	4.6			
5	E	SD/Ora	11/12	Opposite Coronado/Route 74 near San Juan Cap.	SD	R14.0	Ora	9.6			
5	E	LA	7	I-210 near Tunnel Station/Route 126 near Castaic	LA	R44.0	LA	R55.5			
5	E	Mer/San Joaq	10	Route 152 WO Los Banos/I-580 near Vernalis	Mer	17.6	San Joaq	0.7			
5	E	Shasta	2	Route 44 near Redding/Shasta Reservoir	Shasta	R15.5	Shasta	R28.2			
5	E	Siskiyou	2	Route 89 near Mt Shasta/Route 97 near Weed	Siskiyou	R8.5	Siskiyou	R19.1			
5	E	Siskiyou	2	Route 3 near Yreka/Oregon State Line near Hilt	Siskiyou	R48.2	Siskiyou	R69.3			
5	**OD**	**MERCED**	**10**	**FR Route 152 TO STANISLAUS CL**	**MERCED**	**17.6**	**MERCED**	**32.5**	**14.9**	**8**	October 25, 1968
5	**OD**	**STANISLAUS**	**10**	**FR MERCED CL TO SAN JOAQUIN CL**	**STANISLAUS**	**0**	**STANISLAUS**	**28.1**	**28.1**	**8**	October 25, 1968
5	**OD**	**SAN JOAQUIN**	**10**	**FR STANISLAUS CL TO I-580**	**SAN JOAQUIN**	**0.0**	**SAN JOAQUIN**	**0.7L**	**0.7**	**37**	June 7, 1974
8	E	SD/Imp	11	Sunset Cliffs Blvd/Route 98 near Coyote Wells	SD	T0.0	Imp	R10.0			
9	E	SCr	5	Route 1 near Santa Cruz/Route 236 near Boulder Creek	SCr	0.0	SCr	13			
9	E	SCr	5	Route 236 near Boulder Creek/Route 236 near Waterman	SCr	13.0	SCr	20.8			
9	E	SCr	5	Route 236 near Waterman Gap/Route 35	SCr	20.8	SCr	27.1			
9	E	SCl	4	Route 35/Route 17 near Los Gatos	SCl	0.0	SCl	11.5			
9	**OD**	**SANTA CLARA**	**4**	**FR SANTA CRUZ CL @ SARATOGA GAP TO BLANEY PLAZA**	**SANTA CLARA**	**0.0**	**SANTA CLARA**	**7.5**	**7.5**	**42**	October 18, 1979
9	**OD**	**SANTA CLARA**	**4**	**FR BLANEY PLAZA TO LOS GATOS CIL**	**SANTA CLARA**	**7.5**	**SANTA CLARA**	**10.8**	**3.4**	**4**	May 2, 1968
12	E	Sonoma	4	Route 101 near Santa Rosa/Route 121 near Sonoma	Sonoma	R16.0	Sonoma	41.4			
12	**OD**	**SONOMA**	**4**	**FR DANIELLI AVE EO SANTA ROSA TO LONDON WAY NR AQUA CALIENTE**	**SONOMA**	**22.5**	**SONOMA**	**34**	**11.5**	**38**	December 17, 1974
13	E	Alameda	4	From Route 24 to Route 580	Alameda	9.62	Alameda	4.26			
14	E	Kern	6	Route 58 near Mojave/Route 395 near Little Lake	Kern	16	Kern	64.5			

**Post Miles for eligible segments are approximate; legal limits of State Scenic Highways are described in the Streets Highways Code (For limits of federal byways, visit FHWA "America's Bways" or USFS Scenic Byway programs).*

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Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
15	E	SD/Riv	11/8	Route 76 near San Luis Rey River/Route 91 near Corona	SD	R46.5	Riv	41.5			
15	E	SBd	8	Route 58 near Barstow/Route 127 near Baker	SBd	76.9	SBd	R136.6			
16	E	Col/Yol	3	Route 20/Capay	Col	0.0	Yol	25.3			
17	E	SCr/SCl	5/4	Route 1 near Santa Cruz/Route 9 near Los Gatos	SCr	0.0	SCl	7.1			
18	E	SBd	8	Route 138 near Mt Anderson/Route 247 near Lucerne Vly	SBd	R17.7	SBd	73.8			
20	E	Men	1	Route 1 near Fort Bragg/Route 101 near Willits	Men	R0.0	Men	R33.2			
20	E	Men/Lak/Col	1/3	Route 101 near Calpella/Route 16	Men	33.2	Col	3.5			
20	E	Nevada	3	Route 49 near Grass Valley/I-80 near Emigrant Gap	Nevada	R12.2	Nevada	45.7			
20	**OD**	**NEVADA**	**3**	**FR SKILLMAN FLAT CAMPGROUND TO 1/2 MI EO LOWELL HILL RD**	**NEVADA**	**33**	**NEVADA**	**39.5**	**6.5**	**23**	March 12, 1971
24	E	Contra Costa	4	Alameda/Contra Costa CL to Rte 680 in Walnut Crk	Contra Costa	0.0	Contra Costa	9.1			
24	**OD**	**CONTRA COSTA**	**4**	**FR E PORTAL OF CALDECOTT TUNNEL TO I-680 NR WALNUT CREEK**	**CONTRA COSTA**	**R0.3**	**CONTRA COSTA**	**9.1**	**8.8**	**45**	October 22, 1982
25	E	Mon/SBt	5	Route 198/Route 156 near Hollister	Mon	0.0	SBt	51.4			
27	E	LA	7	Route 1/Mulholland Dr.	LA	0.0	LA	11.1			
27	**OD**	**LOS ANGELES**	**7**	**"TOPANGA CANYON STATE SCENIC HIGHWAY"**	**LOS ANGELES**	**1.0**	**LOS ANGELES**	**3.5**	**2.5**	**61**	March 22, 2017
28	E	Placer	3	Route 89 in Tahoe City/Nevada SL (All)	Placer	0.0	Placer	11.0			
29	E	Sol/Nap	4	Route 37 near Vallejo/Route 221 near Napa	Sol	4.7	Nap	R8.7			
29	E	Nap/Lk	4/1	Trancas St in Napa/Route 20 near Upper Lake	Nap	13.0	Lk	52.5			
30	E	SBd	8	Route 330 near Highland/Route 10 near Redlands (deleted)	SBd	T29.5	SBd	33.3			
33	E	Ventura	7	Route 101 near Ventura/Route l50	Ventura	0.0	Ventura	11.2			
33	E	Ven/SB/SLO	7/5	Route 150/Route 166 in Cuyama Valley	Ventura	11.2	SLO	11.5			
33	E	Fresno	6	Route 198 near Coalinga/Route 198 near Oilfields	Fresno	15.7	Fresno	24.3			
33	**OD**	**VENTURA**	**7**	**FR 6.4 MI NO Route 150 TO 23.3 MI NO Route 150**	**VENTURA**	**17.6**	**VENTURA**	**34.5**	**16.9**	**32**	February 18, 1972
33	**OD**	**VENTURA**	**7**	**FR 23.3 MI NO Route 150 TO 30.5 MI NO Route 150**	**VENTURA**	**34.5**	**VENTURA**	**41.7**	**7.2**	**50**	July 11, 1988
33	**OD**	**VENTURA**	**7**	**FR 30.5 MI NO Route 150 TO 36.8 MI NO Route 150**	**VENTURA**	**41.7**	**VENTURA**	**48.0**	**6.3**	**32**	February 18, 1972
33	**OD**	**VENTURA**	**7**	**FR 36.8 MI NO Route 150 TO SANTA BARBARA CL**	**VENTURA**	**48.0**	**VENTURA**	**57.5**	**9.5**	**50**	July 11, 1988
35	E	SCl/SCr/SM/SF	4/5	Route 17 To Route 92/I-280/Route 1 in SF (All)	SCl	0.0	SF	3.2			
35	**OD**	**SAN MATEO**	**4**	**FR SCRUZ CL TO SCLARA CL**	**SAN MATEO**	**0.0**	**SAN MATEO**	**2.1**	**2.1**	**7**	September 13, 1968
35	**OD**	**SAN MATEO**	**4**	**FR SCLARA CL TO HALF MOON BAY RD (Route 92)**	**SAN MATEO**	**2.1**	**SAN MATEO**	**23.0**	**20.9**	**2**	January 22, 1968
36	E	Hum/Tri	1/2	Route 101 near Alton/Route 3 near Peanut	Hum	0.0	Tri	R28.7			
36	E	Teh/Plu	2	Route 89 near Morgan Summit/Route 89 near Deer Crk	The	87.7	Plu	6.3			
37	E	Marin	4	Route 251 near Nicasio/Route 101 near Novato (unconstructed)	Marin	0.0	Marin	11.2			
37	E	Mrn/Son/Sol	4	Route 101 near Ignacio/Route 29 near Vallejo	Mrn	11.2	Sol	9.5			
38	E	SBd	8	Route 10 near Redlands/Route 18 near Fawnskin (All)	SBd	0.0	SBd	49.5			
38	**OD**	**SAN BERNARDINO**	**8**	**FR 0.1 MI EO SOUTH FORK CAMPGROUND TO 2.9 MI SO Route 18 @ STATE LANE**	**SAN BERNARDINO**	**31.0**	**SAN BERNARDINO**	**46.7**	**15.7**	**3**	March 19, 1968
39	E	LA	7	Route 210 near Azusa/Route 2	LA	14.1	LA	44.4			
40	E	SBd	8	Barstow/Needles	SBd	0.0	SBd	154.6			
41	E	SLO	5	Route 1 near Morro Bay/Route 101 near Atascadero	SLO	0.0	SLO	15.9			
41	E	SLO/Ker/Kin	5/6	Route 46 near Cholame/ Route 33	SLO	43.8	Kin	8.1			
41	E	Mad/Mpa	6	Route 49 near Oakhurst/Yosemite National Park	Mad	35.5	Mpa	4.9			
44	E	Shasta	2	I-5 near Redding/Route 89 near Old Station	Shasta	0.0	Shasta	62.7			
46	E	SLO	5	Route 1 near Cambria/Route 101 near Paso Robles	SLO	0.0	SLO	29.8			
46	E	SLO	5	Route 101 near Paso Robles/Route 41 near Cholame	SLO	29.8	SLO	55.1			

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EEC ORIGINAL PKG

Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
49	E	Mad/Mpa/Tuo	10/3	Route 41 near Oakhurst/Route 120 near Moccasin	Mad	0.0	Tuo	R8.8			
49	E	Tuo/Cal/Ama/ED/Pla/Nev	3	Route 120/Route 20 near Grass Valley	Tuo	R8.8	Nev	R14.5			
49	E	Nev/Yub/Sie	3	Route 20 near Nevada City/Route 89 near Sattley	Nevada	15.1	Sie	47.5			
49	**OD**	**SIERRA**	**3**	**FR YUBA CL TO YUBA SUMMIT**	**SIERRA**	**0.0**	**SIERRA**	**41.2**	**41.2**	**24**	July 14, 1971
50	E	El Dorado	3	Route 49 near Placerville/Nevada SL near Lake Tahoe	El Dorado	17.7	El Dorado	80.4			
50	**OD**	**EL DORADO**	**3**	**FR EASTERN LIMIT OF GOV CENTER IC IN PLACERVILLE TO ECHO SUMMIT**	**EL DORADO**	**16.8**	**EL DORADO**	**66.5**	**49.7**	**46**	April 2, 1985
50	**OD**	**EL DORADO**	**3**	**FR ECHO SUMMIT TO SOUTH LAKE TAHOE CIL**	**EL DORADO**	**66.5**	**EL DORADO**	**74.4**	**7.9**	**47**	April 1, 1986
52	E	San Diego	11	I-5 EO La Jolla/Route 67 near Santee (All)	San Diego	0.0	San Diego	17.1			
52	**OD**	**SAN DIEGO**	**11**	**FROM NEAR SANTO ROAD TO NEAR MAST BOULEVARD**	**SAN DIEGO**	**9.5**	**SAN DIEGO**	**13.0**	**3.5**	**59**	February 2, 2016
53	E	Lake	1	Route 29 near Lwr Lk/Route 20 EO Clr Lake Oaks (All)	Lake	0.0	Lake	7.5			
57	E	Ora/LA	12/7	Route 90/Route 60 near City of Industry	Ora	19.9	LA	R4.5			
58	E	Ker/SBd	6/8	Route 14 near Mojave/I-15 near Barstow	Ker	112.0	SBd	R4.5			
62	E	Riv/SBd	8	I-10 near Whitewater/Arizona SL (All)	Riv	0.0	SBd	142.7			
62	**OD**	**RIVERSIDE**	**8**	**FR I-10 TO SAN BERNARDINO CL**	**RIVERSIDE**	**0.0**	**RIVERSIDE**	**9.2**	**9.2**	**34**	September 14, 1972
68	E	Monterey	5	City of Monterey/Route 101 near Salinas	Monterey	0.0	Monterey	22.0			
68	**OD**	**MONTEREY**	**5**	**FR Route 1 IN MONTEREY TO SALINAS RIVER**	**MONTEREY**	**L4.3**	**MONTEREY**	**R17.8**	**13.5**	**6**	June 19, 1968
70	E	But/Plu	3/2	Route 149 near Wicks Corner/Route 89 near Blairsden	But	20.5	Plu	33.0			
71	E	Riverside	8	Route 91 near Corona/Route 83 NO Corona	Riverside	0.0	Riverside	G3.0			
74	E	Ora/Riv	12/8	I-5 near San Juan Capistrano/I-111 (All)	Ora	0.0	Riv	R96.0			
74	**OD**	**RIVERSIDE**	**8**	**FR W BDRY OF SAN BERND NAT'L FOREST TO Route 111 IN PALM DESERT**	**RIVERSIDE**	**48.3**	**RIVERSIDE**	**R96.0**	**47.7**	**25**	October 18, 1971
75	E	SD	11	I-5 in Palm City/I-5 in San Diego (All)	SD	9.0	SD	22.3			
75	**OD**	**SAN DIEGO**	**11**	**FR IMPERIAL BEACH CIL TO AVENIDA DEL SOL IN CORONADO**	**SAN DIEGO**	**11.2**	**SAN DIEGO**	**18.4**	**7.2**	**36**	March 4, 1974
75	**OD**	**SAN DIEGO**	**11**	**SAN DIEGO-CORONADO BRIDGE**	**SAN DIEGO**	**20.5**	**SAN DIEGO**	**21.9**	**1.4**	**11**	December 17, 1969
76	E	SD	11	I-5 near Oceanside/Route 79 near Lake Henshaw (All)	SD	0.0	SD	52.3			
78	E	SD/Imp	11	Route 79 near Santa Ysabel/Route 86 passing near Julian	SD	51.1	Imp	13			
78	**OD**	**SAN DIEGO**	**11**	**FR W BDRY OF ANZA BORREGO DESERT STATE PARK TO E BDRY**	**SAN DIEGO**	**71.9**	**SAN DIEGO**	**90.1**	**18.2**	**31**	December 14, 1971
79	E	SD	11	Route 8 near Descanso/Route 78 near Julian	SD	0.0	SD	20.2			
79	E	SD/Riv	11/8	Route 78 near Santa Ysabel/Route 371 near Aguanga	SD	20.2	Riv	2.3			
80	E	SF/Ala	4	I-280 near First Street in SF/Route 61 in Oakland	SF	3.2	Ala	2.8			
80	E	Pla/Nev/Sie	3	Route 20 near Emigrant Gap/Nevada State Line	Pla	R59.5	Sie	1.6			
84	E	Ala	4	Route 238/I-680 near Sunol	Ala	10.8	Ala	18.0			
84	**OD**	**ALAMEDA**	**4**	**FR Route 238 (MISSION BLVD) EAST TO I 680**	**ALAMEDA**	**10.8**	**ALAMEDA**	**17.9**	**7.1**	**57**	July 7, 2007
88	E	Ama/Alp	10	Route 49 in Jackson/Nevada State Line	Ama	14.3	Alp	25.3			
88	**OD**	**ALPINE**	**10**	**FR AMADOR CL TO NEVADA SL**	**ALPINE**	**0.0**	**ALPINE**	**25.3**	**25.3**	**19**	September 14, 1970
88	**OD**	**AMADOR**	**10**	**FR DEW DROP RANGER STATION TO ALPINE CL**	**AMADOR**	**38.2**	**AMADOR**	**71.6**	**33.5**	**49**	July 30, 1986
89	E	Mono/Alp/ED/Pla/Nev/Sie/Plu/Teh/Sha/Sis	9/10/3	Route 395 near Coleville/I-5 near Mt Shasta (All)	Mono	0.0	Sis	R34.6			
89	**OD**	**EL DORADO**	**3**	**FR ALPINE CL TO PLACER CL**	**EL DORADO**	**0.0**	**EL DORADO**	**27.4**	**27.4**	**48**	April 1, 1986
89	**OD**	**MONO**	**9**	**FR 3.2 MILES WO Route 395 TO ALPINE CL**	**MONO**	**3.2**	**MONO**	**7.6**	**4.4**	**27**	November 9, 1971
89	**OD**	**ALPINE**	**10**	**FR MONO CL TO E JCT Route 88 & FR W JCT Route 88 TO EL DORADO CL**	**ALPINE**	**0.0**	**ALPINE**	**24.0**	**24**	**20**	September 14, 1970
91	E	Ora/Riv	12/8	Route 55 near Santa Ana Canyon/I-15 near Corona	Ora	R9.2	Riv	7.5			
91	**OD**	**ORANGE**	**12**	**FR Route 55 TO EAST CIL OF ANAHEIM**	**ORANGE**	**R9.2**	**ORANGE**	**R13.4**	**4.2**	**29**	November 15, 1971

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EEC ORIGINAL PKG

Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
92	E	San Mateo	4	Route 1 near Half Moon Bay/I-280 near Crystal Springs Lk	San Mateo	0.0	San Mateo	R7.3			
94	E	SD	11	Route 125 near Spring Valley/I-8 WO Jacumba	SD	10.1	SD	64.2			
96	E	Hum/Sis	1/2	Route 299 near Willow Creek/I-5 NO Yreka (All)	Hum	0.0	Sis	105.8			
97	E	Siskiyou	2	I-5 in Weed/Oregon SL NO Dorris (All)	Siskiyou	0.0	Siskiyou	54.1			
101	E	LA/Ven/SB/SLO	7/5	Route 27 (Topanga Cyn Blvd)/Route 46 near Paso Robles	LA	25.3	SLO	57.9			
101	E	Mon/SBt	5	Route 156 near Prunedale Northeasterly To Route 156	Mon	95.4	SBt	3.1			
101	E	Marin	4	Opposite San Francisco/Route 1 in Marin City	Marin	0.0	Marin	4.1			
101	E	Marin	4	Route 37 near Ignacio/Route 37 (unconstructed) near Novato	Marin	19.1	Marin	20.9			
101	E	Mendocino	1	Route 20 near Calpella/Route 20 near Willits	Men	30.8	Men	46.4			
101	E	Men/Hum/DN	1	Route 1 near Leggett/Route 199 near Crescent City	Men	T91.3	DN	R30.8			
101	E	Del Norte	1	Route 197 near Fort Dick/Oregon SL	Del Norte	36.3	Del Norte	46.5			
101	**OD**	**SANTA BARBARA**	**5**	**"GAVIOTA COAST STATE SCENIC HIGHWAY" FROM NEAR CITY OF GOLETA'S WESTERN BOUNDARY TO ROUTE 1 AT LAS CRUCES**	**SANTA BARBARA**	**27.5**	**SANTA BARBARA**	**48.9**	**21.4**	**60**	December 13, 2016
101	**OD**	**DEL NORTE**	**1**	**FR S BDRY DEL NORTE REDWOODS ST. PARK TO N BDRY NR CRESCENT CITY**	**DEL NORTE**	**11.0**	**DEL NORTE**	**23.1**	**12.1**	**12**	February 18, 1970
108	E	Tuo/Mno	10/9	Route 49 near Sonora/Route 395	Tuo	0.0	Mno	15.2			
111	E	Imp/Riv	8	Bombay Beach-Salton Sea SP/Route 195. near Mecca	Imp	57.6	Riv	18.4			
111	E	Riv	8	Route 74 near Palm Desert/I-10 near Whitewater	Riv	39.6	Riv	R63.4			
116	E	Sonoma	4	Route 1 near Jenner/Route 101 near Cotati	Sonoma	0.0	Sonoma	35.5			
116	**OD**	**SONOMA**	**4**	**FR Route 1 TO SOUTH CIL SEBASTOPOL**	**SONOMA**	**0.0**	**SONOMA**	**27.8**	**27.8**	**51**	September 20, 1988
118	E	Ven/LA	7	Route 23/Desoto Ave. near Browns Canyon	Ven	17.4	LA	R2.7			
120	E	Tuolumne	10	Route 49 near Chinese Camp/Route 49 near Moccasin	Tuolumne	15.5	Tuolumne	23.9			
120	E	Mono	9	E Bdry Yosemite/Route 395 near Mono Lake	Mono	0.0	Mono	13.4			
121	E	Sonoma	4	Route 37 near Sears Point/Route 12 near Sonoma	Sonoma	0.0	Sonoma	7.5			
121	E	Napa	4	Route 221 near Napa St. Hosp./near Trancas St in Napa	Napa	6.0	Napa	9.4			
125	**OD**	**SAN DIEGO**	**11**	**FR Route 94 NR SPRING VALLEY TO I-8 NR LA MESA**	**SAN DIEGO**	**13.5**	**SAN DIEGO**	**R15.3**	**1.8**	**21**	March 1, 1971
126	E	Ven/LA	7	Route 150 near Santa Paula/I-5 near Castaic	Ven	R12.0	LA	0R5.8			
127	E	SBd/Iny	8/9	I-15 near Baker/Nevada SL (All)	SBd	L0.0	Iny	49.4			
128	E	Men/Son/Napa/Sol/Yolo	1/4/3	Junction Route 1 /Junction Route 505 (entire route)	Men	0.00	Yolo	9.8			
138	E	SBd	8	Route 2 near Wrightwood/Route 18 near Mt Anderson	SBd	6.6	SBd	R37.9			
139	E	Mod/Sis	2	Route 299 near Canby/Oregon SL near Hatfield	Mod	0.0	Sis	5.0			
140	E	Mariposa	10	Route 49 at Mariposa/Yosemite Nat'l Park	Mariposa	21.2	Mariposa	51.8			
140	**OD**	**MARIPOSA**	**10**	**FR NO MARIPOSA TOWN PLNG AREA TO WO EL PORTAL TOWN PLNG AREA**	**MARIPOSA**	**22.8**	**MARIPOSA**	**49.9**	**27.1**	**52**	September 30, 1991
142	E	SBd	8	Orange CL/Peyton Dr.	SBd	0.0	SBd	4.4			
146	E	San Benito	5	Pinnacles Nat. Mon./Route 25 in Bear Valley	San Benito	G10.2	San Benito	15.2			
150	E	SB/Ven	5/7	Route 101 near Ven/SB CL/Route 126 near Santa Paula (All)	SB	0	Ven	34.4			
151	E	Shasta	2	Shasta Dam/I-5 near Project City (All)	Shasta	0.0	Shasta	R6.7			
151	**OD**	**SHASTA**	**2**	**FR SHASTA DAM TO NR LAKE BLVD**	**SHASTA**	**0.0**	**SHASTA**	**3.3**	**3.3**	**44**	September 9, 1981
152	E	SCr	5	Route 1/Santa Clara CL at Hecker Pass	SCr	0.0	SCr	8.3			
152	E	SCl/Mer	4/10	Route 156 near San Felipe/I-5	SCl	22.1	Mer	13.9			
152	**OD**	**MERCED**	**10**	**FR SANTA CLARA CL TO JUNCTION OF I-5**	**MERCED**	**0.0**	**MERCED**	**13.8**	**13.8**	**15**	June 19, 1970

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EEC ORIGINAL PKG

Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
154	E	SB	5	Route 101 near Los Olivos Via San Marcos Pass/Route 101 in Santa Barbara (All)	SB	0.0	SB	32.3			
154	**OD**	**SANTA BARBARA**	**5**	**FR Route 101 NR LOS OLIVOS VIA SAN MARCOS PASS TO Route 101 IN SANTA BARBARA**	**SANTA BARBARA**	**0.0**	**SANTA BARBARA**	**32.3**	**32.3**	**9**	November 22, 1968
156	E	Mon/SBt/SCl	5/4	Route 1 near Castroville/Route 152 NE of Hollister (All)	Mon	0.0	SCl	0.7			
156	**OD**	**MONTEREY**	**5**	**FR 1 MI EO CASTROVILLE TO Route 101 NR PRUNEDALE**	**MONTEREY**	**R1.0**	**MONTEREY**	**T5.3**	**4.3**	**35**	September 14, 1972
158	E	Mono	9	Route 395 near June Lk/Route 395 SO Lee Vining (All)	Mono	0.0	Mono	15.8			
160	E	CC/Sac	4/3	Route 4 near Antioch/Sacramento	CC	0.0	Sac	36.0			
160	**OD**	**SACRAMENTO**	**3**	**FR CONTRA COSTA CL TO S CIL SACRAMENTO**	**SACRAMENTO**	**L0.0**	**SACRAMENTO**	**35.0**	**45.8**	**10**	October 3, 1969
161	E	Sis	2	Route 97 near Dorris/Route 139 near Hatfield (All)	Sis	0.0	Sis	19.4			
163	E	San Diego	11	Ash Street in San Diego/I-8	San Diego	0.6	San Diego	3.8			
163	**OD**	**SAN DIEGO**	**11**	**FR S BDRY BALBOA PARK TO N BDRY**	**SAN DIEGO**	**0.9**	**SAN DIEGO**	**2.2**	**1.2**	**53**	April 24, 1992
166	E	SLO/SB/SLO	5	Route 101 near Santa Maria/Route 33 in Cuyama Valley	SLO	8.9	SLO	74.7			
168	E	Fresno	6	Route 65 near Clovis/Huntington Lake	Fresno	4.0	Fresno	49.7			
168	E	Inyo	9	Camp Sabrina/Route 395	Inyo	0.0	Inyo	18.3			
168	E	Iny/Mno	9	395 at Big Pine/ Route 266 at Oasis	Iny	18.3	Mno	1.4			
168	**OD**	**INYO**	**9**	**FR CMP SABRINA TO BROCKMN LN @ PAIUTE-SHOS IND RESV NR BISHOP**	**INYO**	**0.0**	**INYO**	**16.3**	**16.3**	**16**	June 19, 1970
173	E	SBd	8	Route 138 near Slvrwd Lk/Route 18 SO Lk Arwhd (All)	SBd	0.0	SBd	23.0			
174	E	Nevada	3	Bear River at Placer CL/Grass Valley CiL	Nevada	0.0	Nevada	10.2			
178	E	Inyo	9	E Bdry Dth Vly Nat'l Mon/Route 127 near Shoshone	Inyo	25.0	Inyo	43.0			
180	E	Fresno	6	Route 65 (unconstructed) near Minkler/Kings Canyon Nat'l Park Bdry near Cedar Grove	Fresno	77.3	Fresno	137.9			
180	**OD**	**FRESNO/TUL**	**6**	**FR (a) ALTA MAIN CANAL NEAR MINKLER TO NEAR THE GENERAL GRANT GROVE SECTION OF KINGS CANYON NAT'L PARK (KCNP) (b) GENERAL GRANT GROVE SECTION OF KCNP TO KCNP BDRY NEAR CEDAR GROVE**	**FRESNO**	**77.3**	**FRESNO**	137.9	**58**	**58**	October 15, 2015
190	E	Tul/Iny	6/9	Route 65 near Porterville/Route 127 near Death Valley Jct	Tul	R15.2	Iny	140.7			
190	**OD**	**INYO**	**9**	**FR W BDRY DEATH VALLEY NATIONAL MON TO E BDRY**	**INYO**	**68.9**	**INYO**	**124.4**	**55.5**	**5**	May 10, 1968
190	**OD**	**INYO**	**9**	**FR W BDRY DEATH VALLEY NATIONAL PARK TO E BDRY (EXTENSION)**	**INYO**	**42.4**	**INYO**	**68.9**	**26.5**	**56**	January 7, 2002
197	E	Del Norte	1	N Side of Smith River Fr Route 199/Route 101 (All)	Del Norte	0.0	Del Norte	7.1			
198	E	Mon/Fre	5/6	Route 101 near San Lucas/Route 33 near Coalinga	Mon	0.0	Fre	22.7			
198	E	Fresno	6	Route 33 near Oilfields/I-5	Fresno	22.6	Fresno	26.8			
198	E	Tulare	6	Route 99 near Goshen/Sequoia Nat'l Park	Tulare	R3.8	Tulare	44.2			
199	E	Del Norte	1	Route 101 near Crescent City/Oregon SL (All)	Del Norte	0.0	Del Norte	36.4			
203	E	Mono	9	Madera CL near Minaret Summit/Route 395 (All)	Mono	0.0	Mono	R8.6			
209	E	San Diego	11	Pt Loma/I-5 in San Diego (All)	San Diego	0.0	San Diego	R7.8			
210	E	LA	7	I-5 near Tunnel Station/Route 134	LA	R0.0	LA	R25.0			
215	E	Riverside	8	Route 74 near Romoland/Route 74 near Perris	Riverside	23.5	Riverside	26.3			
221	E	Napa	4	Route 29 at Suscol Rd/Route 121 in Napa (All)	Napa	0.0	Napa	2.7			
236	E	SCr	4	Route 9 near Bldr Ck/Route 9 NE of Big Basin SP (All)	SCr	0.0	SCr	17.7			
239	E	Ala/CC	4	I-580 WO Tracy/Route 4 near Brentwood (All) (unconstructed)	Ala	0.0	CC	7.0			
243	E	Riverside	8	Route 74 near Mountain Cntr/I-10 near Banning (All)	Riverside	0.0	Riverside	29.7			
243	**OD**	**RIVERSIDE**	**8**	**FR Route 74 TO BANNING CIL**	**RIVERSIDE**	**0.0**	**RIVERSIDE**	**28.2**	**28.2**	**33**	March 21, 1972
247	E	SBd	8	Route 62 near Yucca Valley/I-15 near Barstow (All)	SBd	0.0	SBd	78.1			

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EEC ORIGINAL PKG

Rte	Desig Status (OD= Officially Designated;	County	Caltrans Dist	"OD" or "E" State Scenic Highway Location (from/to)	Begin County	*Post Mile	End County	*Post Mile	Length Designated (miles)	Official Des #	Official Desig Date
251	E	Marin	4	Route 37 near Nicasio/Route 1 near Point Reyes (unconstructed)	Marin	0.0	Marin	5.1			
254	E	Humboldt	1	Route 101 near Sylvandale/0.1 Mi NO Jordan Creek (All)	Humboldt	0.0	Humboldt	47.0			
266	E	Mono	9	Nevada SL EO Oasis/Route 168 at Oasis	Mono	0.0	Mono	4.3			
280	E	SCl/SM/SF	4	Route 17/I-80 near First Street in San Francisco	SCl	L5.4	SF	T7.0			
280	**OD**	**SAN MATEO**	**4**	**FR SANTA CLARA CL TO NORTH CIL SAN BRUNO**	**SAN MATEO**	**R0.0**	**SAN MATEO**	**R21.8**	**21.8**	**43**	April 28, 1980
299	E	Humboldt	1	Route 101 near Arcata/Route 96 near Willow Creek	Humboldt	0.0	Humboldt	38.8			
299	E	Tri/Sha	2	Route 3 near Weaverville/I-5 near Redding	Tri	51.6	Sha	R25.9			
299	E	Sha/Las/Mod	2	Route 89 near Burney/Route 139 near Canby	Sha	80.1	Mod	21.8			
330	E	SBd	8	Route 30 near Highland/Route 18 near Running Springs (All)	SBd	29.5	SBd	44.1			
395	E	Ker/Iny/Mno	6/9	Route 14 near Little Lake/Route 89 near Coleville	Ker	29.7	Mno	117.0			
395	**OD**	**INYO**	**9**	**FR FORT INDEPENDENCE TO FISH SPRINGS RD**	**INYO**	**76.5**	**INYO**	**96.6**	**20.1**	**17**	July 30, 1970
395	**OD**	**MONO**	**9**	**FR INYO CL TO NEAR LONG VALLEY RESORT**	**MONO**	**R0.0**	**MONO**	**R18.0**	**18.0**	**55**	June 5, 2000
395	**OD**	**MONO**	**9**	**FR NR LONG VALLEY RESORT TO 1.1 MI NO Route 203**	**MONO**	**R18.0**	**MONO**	**R26.90**	**8.9**	**28**	November 9, 1971
395	**OD**	**MONO**	**9**	**FR 1.1 MI NO Route 203 TO Route 120**	**MONO**	**R26.9**	**MONO**	**50.7**	**23.8**	**55**	June 5, 2000
395	**OD**	**MONO**	**9**	**FR LEE VINING TO EVANS TRACT**	**MONO**	**52**	**MONO**	**74.5**	**22.5**	**55**	June 5, 2000
395	**OD**	**MONO**	**9**	**FR BRIDGEPORT TO SO WALKER**	**MONO**	**76.8**	**MONO**	**104.8**	**28.0**	**55**	June 5, 2000
580	E	SJ/Ala	4/10	I-5 SW of Vernalis/I-80	SJ	0.0	Ala	47.4			
580	**OD**	**ALAMEDA**	**4**	**FR SAN JOAQUIN CL TO Route 205**	**ALAMEDA**	**0.0**	**ALAMEDA**	**0.4**	**0.4**	**13**	February 18, 1970
580	**OD**	**ALAMEDA**	**4**	**FR SAN LEANDRO CIL TO Route 24 IN OAKLAND**	**ALAMEDA**	**R34.5**	**ALAMEDA**	**45.2**	**10.7**	**40**	June 25, 1976
580	**OD**	**SAN JOAQUIN**	**10**	**FR I-5 TO ALAMEDA CL**	**SAN JOAQUIN**	**0.0**	**SAN JOAQUIN**	**15.4R**	**15.4**	**37**	June 7, 1974
680	E	Ala/CC	4	Santa Clara CL/Route 24 in Walnut Creek	Ala	0.0	CC	14.4			
680	**OD**	**ALAMEDA**	**4**	**FR MISSION BLVD IN FREMONT TO BERNAL AVE NR PLEASANTON**	**ALAMEDA**	**R6.4**	**ALAMEDA**	**R16.8**	**10.4**	**41**	June 15, 1978
680	**OD**	**ALAMEDA**	**4**	**FR BERNAL AVE NR PLEASANTON TO CONTRA COSTA CL**	**ALAMEDA**	**R16.8**	**ALAMEDA**	**R21.9**	**5.1**	**45**	October 22, 1982
680	**OD**	**CONTRA COSTA**	**4**	**FR ALAMEDA CL TO Route 24**	**CONTRA COSTA**	**R0.0**	**CONTRA COSTA**	**14.4**	**14.4**	**45**	October 22, 1982

**Post Miles for eligible segments are approximate; legal limits of State Scenic Highways are described in the Streets Highways Code (For limits of federal byways, visit FHWA "America's Bways" or USFS Scenic Byway programs).*

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DEPARTMENT OF WATER RESOURCES

BULLETIN 118 - UPDATE 2003

CALIFORNIA'S GROUNDWATER

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Cover photograph:
A typical agricultural well with the water discharge pipe and the electric motor that drives the pump.

Inset photograph:
Groundwater recharge ponds in the Upper Coachella Valley near the Whitewater River that use local and imported water. Recharge ponds are also called spreading basins or recharge basins.

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State of California
The Resources Agency
Department of Water Resources

CALIFORNIA'S
GROUNDWATER

BULLETIN 118 *Update 2003*

October 2003

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Foreword

Groundwater is one of California's greatest natural resources. In an average year, groundwater meets about 30 percent of California's urban and agricultural water demands. In drought years, this percentage increases to more than 40 percent. In 1995, an estimated 13 million Californians, nearly 43 percent of the State's population, were served by groundwater. The demand on groundwater will increase significantly as California's population grows to a projected 46 million by the year 2020. In many basins, our ability to optimally use groundwater is affected by overdraft and water quality impacts, or limited by a lack of data, management, and coordination between agencies.

Over the last few years, California voters and the Legislature have provided significant funding to local agencies for conjunctive use projects, groundwater recharge facilities, groundwater monitoring, and groundwater basin management activities under Proposition 13 and the Local Groundwater Management Assistance Act of 2000. Most recently, the 2002 passage of Proposition 50 will result in additional resources to continue recent progress toward sustaining our groundwater resources through local agency efforts. We are beginning to see significant benefits from these investments.

The State Legislature recognizes the need for groundwater data in making sound local management decisions. In 1999, the Legislature approved funding and directed the Department of Water Resources (DWR) to update the inventory of groundwater basins contained in Bulletin 118 (1975), *California's Ground Water* and Bulletin 118-80 (1980), *Ground Water Basins in California.* In 2001, the Legislature passed AB 599, requiring the State Water Resources Control Board to establish a comprehensive monitoring program to assess groundwater quality in each groundwater basin in the State and to increase coordination among agencies that collect groundwater contamination information. In 2002, the Legislature passed SB 1938, which contains new requirements for local agency groundwater management plans to be eligible for public funds for groundwater projects.

Effective management of groundwater basins is essential because groundwater will play a key role in meeting California's water needs. DWR is committed to assisting local agencies statewide in developing and implementing effective, locally planned and controlled groundwater management programs. DWR is also committed to federal and State interagency efforts and to partnerships with local agencies to coordinate and expand data monitoring activities that will provide necessary information for more effective groundwater management. Coordinated data collection at all levels of government and local planning and management will help to ensure that groundwater continues to serve the needs of Californians.



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California Department of Pesticide Regulation
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California State Water Resources Control Board
California Regional Water Quality Control Boards
United States Geological Survey
United States Bureau of Reclamation

We also wish to thank numerous reviewers who provided valuable comments on the April 2003 public review draft of this bulletin.

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Acronyms and abbreviations

AB Assembly Bill
BMO Basin management objective
CAS California Aquifer Susceptibility
CVP Central Valley Project
DBCP Dibromochloropropane
DCE Dichloroethylene
DHS California Department of Health Services
DPR California Department of Pesticide Regulation
DTSC California Department of Toxic Substances Control
DWR California Department of Water Resources
DWSAP Drinking Water Source Assessment Program
EDB Ethylene dibromide
EC Electrical conductivity
EMWD Eastern Municipal Water District
EWMP Efficient water management
EPA U.S. Environmental Protection Agency
ESA Federal Endangered Species Act
ET Evapotranspiration
ETAW Evapotranspiration of applied water
EWA Environmental Water Account
GAMA Groundwater Ambient Monitoring and Assessment
GIS Geographic information system
GMA Groundwater Management Agency
gpm Gallons per minute
GRID Groundwater Resources Information Database
GRIST Groundwater Resources Information Sharing Team
H & S Health and Safety Code
HR Hydrologic region
ISI Integrated Storage Investigations
ITF Interagency Task Force
JPA Joint powers agreement
maf Million acre-feet
MCL Maximum contaminant level
mg/L Milligrams per liter
MOU Memorandum of understanding
MTBE Methyl tertiary-butyl ether
OCWD Orange County Water District
PAC Public Advisory Committee
PCE Tetrachloroethylene
PCA Possible contaminating activity
PPIC Public Policy Institute of California
ROD Record of Decision
RWQCB Regional Water Quality Control Board
SB Senate Bill
SGA Sacramento Groundwater Authority
SVOC Semi-volatile organic compound
SVWD Scotts Valley Water District
SWRCB State Water Resources Control Board

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taf Thousand acre-feet
TCE Trichloroethylene
TDS Total dissolved solids
UWMP Urban water management plan
USACE U.S. Army Corps of Engineers
USBR U.S. Bureau of Reclamation
USC United States Code
USGS U.S. Geological Survey
VOC Volatile organic compound
WQCP Water Quality Control Plan

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Findings

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Major Findings

1. **Groundwater provides about 30% of the State's water supply in an average year, yet in many basins the amount of groundwater extracted annually is not accurately known.**
   - In some regions, groundwater provides 60% or more of the supply during dry years.
   - Many small- to moderate-sized towns and cities are entirely dependent on groundwater for drinking water supplies.
   - 40% to 50% of Californians rely on groundwater for part of their water supply.
   - In many basins, groundwater use is indirectly estimated by assuming crop evapotranspiration demands and surveying the acreage of each crop type.

2. **Opportunities for local agencies to manage their groundwater resources have increased significantly since the passage of Assembly Bill 3030 in 1992. (Water Code § 10750 et seq.). In the past several years more agencies have developed management programs to facilitate conjunctive use, determine the extent of the resource, and protect water quality.**
   - The act provides the authority for many local agencies to manage groundwater.
   - The act has resulted in more than 200 local agencies adopting groundwater management plans to date.
   - The act encourages regional cooperation in basins and allows private water purveyors to participate in groundwater management through memoranda of understanding with public agencies.
   - Many local agencies are recognizing their responsibility and authority to better manage groundwater resources.

3. **Agencies in some areas have not yet developed groundwater management plans.**
   - Concerns about cooperative management, governance, and potential liabilities have kept some agencies from developing management plans.
   - Development of management programs to maintain a sustainable groundwater supply for local use has not been accomplished throughout the State.

4. **A comprehensive assessment of overdraft in the State's groundwater basins has not been conducted since Bulletin 118-80, but it is estimated that overdraft is between 1 million and 2 million acre-feet annually.**
   - Historical overdraft in many basins is evident in hydrographs that show a steady decline in groundwater levels for a number of years.
   - Other basins may be subject to overdraft in the future if current water management practices are continued.
   - Overdraft can result in increased water production costs, land subsidence, water quality impairment, and environmental degradation.
   - Few basins have detailed water budgets by which to estimate overdraft.
   - While the most extensively developed basins tend to have information, many basins have insufficient data for effective management or the data have not been evaluated.
   - The extent and impacts of overdraft must be fully evaluated to determine whether groundwater will provide a sustainable water supply.
   - Modern computer hardware and software enable rapid manipulation of data to determine basin conditions such as groundwater storage changes or groundwater extraction, but a lack of essential data limits the ability to make such calculations.
   - Adequate statewide land use data for making groundwater extraction estimates are not available in electronic format.

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5. **Surface water and groundwater are connected and can be effectively managed as integrated resources.**
   - Groundwater originates as surface water.
   - Groundwater extraction can affect flow in streams.
   - Changes in surface water flow can affect groundwater levels.
   - Legal systems for surface water and groundwater rights can make coordinated management complex.

6. **Groundwater quality and groundwater quantity are interdependent and are increasingly being considered in an integrated manner.**
   - Groundwater quantity and groundwater quality are inseparable.
   - Groundwater in some aquifers may not be usable because of contamination with chemicals, either from natural or human sources.
   - Unmanaged groundwater extraction may cause migration of poor quality water.
   - Monitoring and evaluating groundwater quality provides managers with the necessary data to make sound decisions regarding storage of water in the groundwater basin.
   - State agencies conduct several legislatively mandated programs to monitor different aspects of groundwater quality.
   - California Department of Water Resources (DWR) monitors general groundwater quality in many basins throughout the State for regional evaluation.

7. **Land use decisions affecting recharge areas can reduce the amount of groundwater in storage and degrade the quality of that groundwater.**
   - In many basins, little is known about the location of recharge areas and their effectiveness.
   - Protection and preservation of recharge areas are seldom considered in land use decisions.
   - If recharge areas are altered by paving, channel lining, or other land use changes, available groundwater will be reduced.
   - Potentially contaminating activities can degrade the quality of groundwater and require wellhead treatment or aquifer remediation before use.
   - There is no coordinated effort to inform the public that recharge areas should be protected against contamination and preserved so that they function effectively.

Additional Important Findings

8. **Funding to assist local groundwater management has recently been available in unprecedented amounts.**
   - Proposition 13 (Water Code, § 79000 et seq.) authorized $230 million in loans and grants for local groundwater programs and projects, almost all of which has been allocated.
   - The Local Groundwater Management Assistance Act of 2000 (Water Code, § 10795) has resulted in more than $15 million in grants to local agencies in fiscal years 2001, 2002, and 2003.
   - Proposition 50 (Water Code, § 79500 et seq) will provide funding for many aspects of water management, including groundwater management and groundwater recharge projects.
   - Funding for the California Bay-Delta program has provided technical and facilitation assistance to numerous local groundwater planning efforts.

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9. **Local governments are increasingly involved in groundwater management.**
   - Twenty-four of the 27 existing county groundwater management ordinances have been adopted since 1990.
   - Most ordinances require the proponents of groundwater export to demonstrate that a proposed project will not cause subsidence, degrade groundwater quality, or deplete the water supply before the county will issue an export permit.
   - While the ordinances generally require a permit for export of groundwater, most do not require a comprehensive groundwater management plan designed to ensure a sustainable water resource for local use.
   - Some local governments are coordinating closely with local water agencies that have adopted groundwater management plans.
   - Many local governments are monitoring and conducting studies in an effort to better understand groundwater resources.

10. **Despite the increased groundwater management opportunities and activities, the extent of local efforts is not well known.**
   - There is no general requirement that groundwater management plans be submitted to DWR, so the number of adopted plans and status of groundwater management throughout the State are not currently known.
   - There are no requirements for evaluating the effectiveness of adopted plans, other than during grant proposal review.
   - No agency is responsible for tracking implementation of adopted plans.
   - Unlike urban water management plans, groundwater management plans are not required to be submitted to DWR, making the information unavailable for preparing the California Water Plan.

11. **Despite the fact that several agencies often overlie each groundwater basin, there are few mechanisms in place to support and encourage agencies to manage the basin cooperatively.**
   - Some local agencies have recognized the benefits of initiating basinwide and regional planning for groundwater management and have recorded many successes.
   - Regional cooperation and coordination depends on the ability of local agencies to fund such efforts.
   - There is no specific State or federal program to fund and support coordination efforts that would benefit all water users in a region and statewide.

12. **The State Legislature has recognized the need to consider water supplies as part of the local land use planning process.**
   - Three bills—Senate Bill 221[1], SB 610[2], and AB 901[3]—were enacted in 2001 to improve the assessment of water supplies. The new laws require the verification of sufficient water supply as a condition for approving certain developments and compel urban water suppliers to provide more information on the reliability of groundwater as an element of supply.
   - The Government Code does not specifically require local governments to include a water resources element in their general plans.

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[1] Business and Professions Code Section 11010, Government Code Sections 65867.5, 66455.3, and 66473.7.
[2] Public Resources Code Section 21151.9, Water Code Sections 10631, 10656, 10657, 10910-10912, 10915.
[3] Water Code Sections 10610.2, 10631, 10634.

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13. **The need to monitor groundwater quality and contamination of groundwater continues to grow.**
    - As opportunities for developing additional surface water supplies become more limited, subsequent growth will increasingly rely on groundwater.
    - Human activities are likely the cause of more than half the exceedances of maximum contaminant levels in public water supply wells.
    - New contaminants are being regulated and standards are becoming more stringent for others, requiring increased monitoring and better management of water quality.

14. **Monitoring networks for groundwater levels and groundwater quality have not been evaluated in all basins to ensure that the data accurately represent conditions in the aquifer(s).**
    - Groundwater levels are monitored in about 10,000 active wells including those basins where most of the groundwater is used.
    - Groundwater levels are not monitored in approximately 200 basins, where population is sparse and groundwater use is generally low.
    - Groundwater quality monitoring networks are most dense near population centers and may not be representative of the basin as a whole.
    - Many of the wells being monitored are not ideally constructed to provide water level or water quality information that is representative of a specific aquifer.
    - Many wells are too deep to monitor changes in the unconfined (water table) portion of basins.

15. **The coordination of groundwater data collection and evaluation by local, State, and federal agencies is improving.**
    - The State Water Resources Control Board (SWRCB) recently formed the Groundwater Resources Information Sharing Team (GRIST) consisting of several State and federal agencies with groundwater-related programs.
    - DWR established a website in 1996 that has provided water-level data and hydrographs for more than 35,000 active and inactive wells monitored by DWR and cooperating agencies.
    - DWR collects and maintains water level data in part through partnerships with local agency cooperators.
    - DWR staff collaborated with many local, State, and federal agencies in developing this update of Bulletin 118.
    - SWRCB recently formed an interagency task force to develop a comprehensive groundwater quality monitoring program for assessing every groundwater basin in the State as required by the Groundwater Quality Monitoring Act of 2001 (AB 599; Water Code, § 10780 et seq.).
    - Water purveyors have concerns about balancing public access to data with water supply security.

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16. **Boundaries of groundwater basins have been determined using the best available geologic and hydrologic information. These boundaries are important in determining the availability of local water supplies.**
    - Basin boundaries were derived primarily by identifying alluvial sediments on geologic maps using the best available information, but are subject to change when new information becomes available.
    - The Water Code requires the use of basin boundaries defined in Bulletin 118 in groundwater management plans and urban water management plans.
    - The location of basin boundaries will become more critical as the demand for water continues to increase.
    - Subbasin boundaries may be delineated for management convenience rather than based on hydrogeologic conditions.

17. **Little is known about the stream-aquifer interaction in many groundwater basins.**
    - Groundwater and surface water are closely linked in the hydrologic cycle.
    - The relationship between streamflow and extraction of groundwater is not fully understood in most basins and is generally not monitored.
    - Groundwater extraction in many basins may affect streamflow.
    - Interaction of groundwater flow and surface water may affect environmental resources in the hyporheic zone.
    - An understanding of stream-aquifer interaction will be essential to evaluating water transfers in many areas of the State.

18. **Although many new wells are built in fractured rock areas, insufficient hydrogeologic information is available to ensure the reliability of groundwater supplies.**
    - Population is increasing rapidly in foothill and mountain areas in which groundwater occurs in fractured rock.
    - The cumulative effect of groundwater development may reduce the yield of individual wells, lower the flow of mountain streams, and impact local habitat.
    - Characterization of groundwater resources in fractured rock areas can be very expensive and complex.
    - Many groundwater users in these areas have no other water supply alternatives.
    - Recent dry years have seen many wells go dry in fractured rock areas throughout the State.
    - Groundwater management in these areas is beginning, but there is insufficient data to support quantitative conclusions about the long-term sustainable yield.

19. **When new wells are built, drillers are required to file a Well Completion Report with DWR. That report contains a lithologic log, the usability of which varies considerably from driller to driller.**
    - The Well Completion Reports are confidential and not available to the public, as stipulated by the Water Code, unless the owner's permission is obtained.
    - The usefulness of the information in Well Completion Reports varies but is not fully realized.
    - Public access to Well Completion Reports would increase understanding of groundwater conditions and issues.
    - There is no provision in the Water Code that requires submission of geophysical logs, which would provide an accurate log of the geologic materials within the aquifer.
    - Geophysical logs would provide a greatly improved database for characterization of aquifers.

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Recommendations

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Major Recommendations

1. **Local or regional agencies should develop groundwater management plans if groundwater constitutes part of their water supply. Management objectives should be developed to maintain a sustainable long-term supply for multiple beneficial uses. Management should integrate water quantity and quality, groundwater and surface water, and recharge area protection.**
   - Groundwater management in California is a local agency responsibility.
   - In basins where there is more than one management agency, those agencies should coordinate their management objectives and program activities.
   - A water budget should be completed that includes recharge, extraction and change in storage in the aquifer(s).
   - Changes in groundwater quality should be monitored and evaluated.
   - Stakeholders should be identified and included in development of groundwater management plans.

2. **The State of California should continue programs to provide technical and financial assistance to local agencies to develop monitoring programs, management plans, and groundwater storage projects to more efficiently use groundwater resources and provide a sustainable supply for multiple beneficial uses. DWR should:**
   - Post information about projects that have successfully obtained funding through various grant and loan programs.
   - Provide additional technical assistance to local agencies in the preparation of grant and loan applications.
   - Continue outreach efforts to inform the public and water managers of grant and loan opportunities.
   - Participate, when requested, in local efforts to develop and implement groundwater management plans.
   - Continue to assess, develop, and modify its groundwater programs to provide the greatest benefit to local agencies.
   - Develop grant criteria to ensure funding supports local benefits as well as Statewide priorities, such as development of the California Water Plan and meeting Bay-Delta objectives.

3. **DWR should continue to work with local agencies to more accurately define historical overdraft and to more accurately predict future water shortages that could result in overdraft.**
   - A water budget should be developed for each basin.
   - The annual change in storage should be determined for each basin.
   - The amount of annual recharge and discharge, including pumping, should be determined.
   - Changes in groundwater quality that make groundwater unusable or could allow additional groundwater to be used should be included in any evaluation of overdraft.

4. **Groundwater management agencies should work with land use agencies to inform them of the potential impacts various land use decisions may have on groundwater, and to identify, prioritize, and protect recharge areas.**
   - Local planners should consider recharge areas when making land use decisions that could reduce recharge or pose a risk to groundwater quality.
   - Recharge areas should be identified and protected from land uses that limit recharge rates, such as paving or lining of channels.

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- Both local water agencies and local governments should pursue education and outreach to inform the public of the location and importance of recharge areas.
- DWR should inform local agencies of the availability of grant funding and technical assistance that could support these efforts.

5. **DWR should publish a report by December 31, 2004 that identifies those groundwater basins or subbasins that are being managed by local or regional agencies and those that are not, and should identify how local agencies are using groundwater resources and protecting groundwater quality.**
   - Such information will be necessary to confirm whether agencies are meeting the requirements of SB 1938 (Water Code Section 10753.7).
   - Collection and summary of existing groundwater management plans will provide a better understanding of the distribution and coordination of groundwater management programs throughout the State.
   - Successful strategies employed by specific local agencies should be highlighted to assist others in groundwater management efforts.
   - Similarly, the impact of groundwater management ordinances throughout the State should be evaluated to provide a better understanding of the effect of ordinances on groundwater management.

6. **Water managers should include an evaluation of water quality in a groundwater management plan, recognizing that water quantity and water quality are inseparable.**
   - Local water managers should obtain groundwater quality data from federal, state, and local agencies that have collected such data in their basin.
   - Local agencies should evaluate long-term trends in groundwater quality.
   - Local agencies should work closely with the SWRCB and DWR in evaluating their groundwater basins.
   - Local agencies should establish management objectives and monitoring programs that will maintain a sustainable supply of good quality groundwater.

7. **Water transfers that involve groundwater (or surface water that will be replaced with groundwater) should be consistent with groundwater management in the source area that will assure the long term sustainability of the groundwater resource.**

8. **Continue to support coordinated management of groundwater and surface water supplies and integrated management of groundwater quality and groundwater quantity.**
   - Future bond funding should be provided for conjunctive use facilities to improve water supply reliability.
   - Funding for feasibility and pilot studies, in addition to construction of projects will help maximize the potential for conjunctive use.
   - DWR should continue and expand its efforts to form partnerships with local agencies to investigate and develop locally controlled conjunctive use programs.

9. **Local, State, and federal agencies should improve data collection and analysis to better estimate groundwater basin conditions used in Statewide and local water supply reliability planning. DWR should:**
   - Assist local agencies in the implementation of SB 221, SB 610, and AB 901 to help determine water supply reliability during the local land use planning process.
   - Provide and continue to update information on groundwater basins, including basin boundaries, groundwater levels, monitoring data, aquifer yield, and other aquifer characteristics.

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- Identify areas of rapid development that are heavily reliant on groundwater and prioritize monitoring activities in these areas to identify potential impacts on these basins.
- Evaluate the existing network of wells monitored for groundwater elevations, eliminate wells of questionable value from the network, and add wells where data are needed.
- Work cooperatively with local groundwater managers to evaluate the groundwater basins of the State with respect to overdraft and its potential impacts, beginning with the most heavily used basins.
- Expand DWR and local agency monitoring programs to provide a better understanding of the interaction between groundwater and surface water.
- Work with SWRCB to investigate temporal trends in water quality to identify areas of water quality degradation that should receive additional attention.
- Estimate groundwater extraction using a land use based method for over 200 basins with little or no groundwater budget information.
- Integrate groundwater budgets into the California Water Plan Update process.

10. **Increase coordination and sharing of groundwater data among local, State, and federal agencies and improve data dissemination to the public. DWR should:**
    - Use the established website to continually update new groundwater basin data collected after the publication of California's Groundwater (Bulletin 118-Update 2003).
    - Publish a summary update of Bulletin 118 every five years coincident with the California Water Plan (Bulletin 160).
    - Publish, in cooperation with SWRCB, a biennial groundwater report that addresses current groundwater quantity and quality conditions.
    - Coordinate the collection and storage of its groundwater quality monitoring data with programs of SWRCB and other agencies to ensure maximum coverage statewide and reduce duplication of effort.
    - Make groundwater basin information more compatible with other Geographic Information System-based resource data to improve local integrated resources planning efforts.
    - Compile data collected by projects funded under grant and loan programs and make data available to the public on the DWR website.
    - Encourage local agency cooperators to submit data to the DWR database.
    - Maximize the accuracy and usefulness of data and develop guidelines for quality assurance and quality control, consistency, and format compatibility.
    - Expand accessibility of groundwater data by the public after considering appropriate security measures.
    - State, federal and local agencies should expand accessibility of groundwater data by the public after considering appropriate security measures.
    - Local agencies should submit copies of adopted groundwater management plans to DWR.

Additional Important Recommendations

11. **Local water agencies and local governments should be encouraged to develop cooperative working relationships at basinwide or regional levels to effectively manage groundwater. DWR should:**
    - Provide technical and financial assistance to local agencies in the development of basinwide groundwater management plans.
    - Provide a preference in grant funding for groundwater projects for agencies that are part of a regional or basinwide planning effort.
    - Provide Proposition 50 funding preferences for projects that are part of an integrated regional water management plan.

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12. **Groundwater basin boundaries identified in Bulletin 118 should be updated as new information becomes available and the basin becomes better defined. DWR should:**
    - Identify basin boundaries that are based on limited data.
    - List the kind of information that is necessary to better define basin boundaries.
    - Develop a systematic procedure to obtain and evaluate stakeholder input on groundwater basin boundaries.

13. **Improve the understanding of groundwater resources in fractured rock areas of the State.**
    - DWR, in cooperation with local and federal agencies, should conduct studies to determine the amount of groundwater that is available in fractured rock areas, including water quality assessment, identification of recharge areas and amounts, and a water budget when feasible.
    - Local agencies and local governments should conduct studies in their areas to quantify the local demands on groundwater and project future demands.
    - The Legislature should consider expanding the groundwater management authority in the Water Code to include areas outside of alluvial groundwater basins
    - DWR should include information on the most significant fractured rock groundwater sources in future updates of Bulletin 118.

14. **Develop a program to obtain geophysical logs in areas where additional data are needed.**
    - DWR should encourage submission of geophysical logs, when they are conducted, as a part of the Well Completion Report.
    - The geophysical logs would be available for use by public agencies to better understand the aquifer, but would be confidential as stipulated by the Water Code.
    - DWR should seek funding to work with agencies and property owners to obtain geophysical logs of new wells in areas where additional data are needed.
    - Geophysical logs would be used to better characterize the aquifers within each groundwater basin.

15. **Educate the public on the significance of groundwater resources and on methods of groundwater management.**
    - DWR should continue to educate the public on statewide groundwater issues and assist local agencies in their public education efforts.
    - Local agencies should expand their outreach efforts during development of groundwater management plans under AB 3030 and other authority.
    - DWR should develop educational materials to explain how they quantify groundwater throughout the State, as well as the utility and limitations of the information.
    - DWR should continue its efforts to educate individual well owners and small water systems that are entirely dependent on groundwater.

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Introduction

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Introduction

Groundwater is one of California's greatest natural resources. In an average water supply year, groundwater meets about 30 percent of California's urban and agricultural demand. In drought years, this percentage increases to 40 percent or even higher (DWR 1998). Some cities, such as Fresno, Davis, and Lodi, rely solely on groundwater for their drinking water supply. In 1995, an estimated 13 million Californians (nearly 43 percent of the State's population) used groundwater for at least a portion of their public supply needs (Solley and others 1998). With a projected population of nearly 46 million by the year 2020, California's demand on groundwater will increase significantly. In many basins, our ability to optimally use groundwater is affected by overdraft and water quality, or limited by a lack of data, lack of management, and coordination between agencies.

In the last few years, California has provided substantial funds to local agencies for groundwater management. For example, the nearly $2 billion Water Bond 2000 (Proposition 13) approved by California voters in March 2000 specifically authorizes funds for two groundwater programs: $200 million for grants for feasibility studies, project design, and the construction of conjunctive use facilities; and $30 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies for recharge projects. Additionally, the Local Groundwater Management Assistance Act of 2000 (AB 303) resulted in $15 million in fiscal years 2001, 2002, and 2003 for groundwater studies and data collection intended to improve basin and subbasin groundwater management. These projects focus on improving groundwater monitoring, coordinating groundwater basin management, and conducting groundwater studies.

The State Legislature has increasingly recognized the importance of groundwater and the need for monitoring in making sound groundwater management decisions. Significant legislation was passed in 2000, 2001 and 2002. AB 303 authorizes grants to help local agencies develop better groundwater management strategies. AB 599 (2001) requires, for the first time, that the State Water Resources Control Board (SWRCB), in cooperation with other agencies, develop a comprehensive monitoring program capable of assessing groundwater quality in every basin in the State with the intent of maintaining a safe groundwater supply. SB 610 (2001) and SB 901 (2001) together require urban water suppliers, in their urban water management plans, to determine the adequacy of current and future supplies to meet demands. Detailed groundwater information is required for those suppliers that use groundwater. SB 221 (2001) prohibits approval of certain developments without verification of an available water supply. These bills are significant with respect to groundwater because much of California's new development will rely on groundwater for its supply.

Finally, SB 1938 (2002) was enacted to provide incentives to local agencies for improved groundwater management. The legislation modified the Water Code to require that specific elements be included in a groundwater management plan for an agency to be eligible for certain State funding administered by the Department of Water Resources for groundwater projects. AB 303 is exempt from that requirement.

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History of Bulletin 118

DWR has long recognized the need for collection, summary, and evaluation of groundwater data as tools in planning optimal use of the groundwater resource. An example of this is DWR's Bulletin 118 series. Bulletin 118 presents the results of groundwater basin evaluations in California. The Bulletin 118 series was preceded by Water Quality Investigations Report No. 3, *Ground Water Basins in California* (referred to in this bulletin as Report No. 3), published in 1952 by the Department of Public Works, Division of Water Resources (the predecessor of DWR). The purpose of Report No. 3 was to create a base index map of the "more important ground water basins" for carrying out DWR's mandate in Section 229 of the Water Code. Section 229 directed Public Works to:

> …investigate conditions of the quality of all waters within the State, including saline waters, coastal and inland, as related to all sources of pollution of whatever nature and shall report thereon to the Legislature and to the appropriate regional water pollution control board annually, and may recommend any steps which might be taken to improve or protect the quality of such waters.

Report No. 3 identified 223 alluvium-filled valleys that were believed to be basins with usable groundwater in storage. A statewide numbering system was created in cooperation with the State Water Pollution Control Board (now the State Water Resources Control Board) based on the boundaries of the nine Regional Water Quality Control Boards. In 1992, Water Code Section 229 was amended, resulting in the elimination of the annual reporting requirements.

In 1975, DWR published Bulletin 118, *California's Ground Water*, (referred to in this report as Bulletin 118-75). Bulletin 118-75 summarized available information from DWR, U.S. Geological Survey, and other agencies for individual groundwater basins to "help those who must make decisions affecting the protection, additional use, and management of the State's ground water resources."

Bulletin 118-75 contains a summary of technical information for 248 of the 461 identified groundwater basins, subbasins, and what were referred to as "areas of potential ground water storage" in California as well as maps showing their location and extent. The Bulletin 118-75 basin boundaries were based on geologic and hydrogeologic conditions except where basins were defined by a court decision.

In 1978, Section 12924 was added to the California Water Code:

> The Department shall, in conjunction with other public agencies, conduct an investigation of the State's groundwater basins. The Department shall identify the State's groundwater basins on the basis of geologic and hydrogeologic conditions and consideration of political boundary lines whenever practical. The Department shall also investigate existing general patterns of groundwater pumping and groundwater recharge within such basins to the extent necessary to identify basins which are subject to critical conditions of overdraft.

DWR published the report in 1980 as *Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924* (referred to in this report as Bulletin 118-80). The bulletin included 36 groundwater basins with boundaries different from Bulletin 118-75. The changed boundaries resulted by combining several basins based on geologic or political considerations and by dividing the San Joaquin Valley groundwater basin into many smaller subbasins based primarily on political boundaries. These changes resulted in the identification of 447 groundwater basins, subbasins, and areas of potential groundwater storage. Bulletin 118-80 also identified 11 basins as subject to critical conditions of overdraft.

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Box A Which Bulletin 118 Do You Mean?

Mention of an update to Bulletin 118 causes some confusion about which Bulletin 118 the California Department of Water Resources (DWR) has updated. In addition to the statewide Bulletin 118 series (Bulletin 118-75, Bulletin 118-80, and Bulletin 118-03), DWR released several other publications in the 118 series that evaluate groundwater basins in specific areas of the State. Region-specific Bulletin 118 reports are listed below.

- Bulletin 118-1. Evaluation of Ground Water Resources: South San Francisco Bay
  Appendix A. Geology, 1967
  Volume 1. Fremont Study Area, 1968
  Volume 2. Additional Fremont Study Area, 1973
  Volume 3. Northern Santa Clara County, 1975
  Volume 4. South Santa Clara County, 1981
- Bulletin 118-2. Evaluation of Ground Water Resources: Livermore and Sunol Valleys, 1974
  Appendix A. Geology, 1966
- Bulletin 118-3. Evaluation of Ground Water Resources: Sacramento County, 1974
- Bulletin 118-4. Evaluation of Ground Water Resources: Sonoma County
  Volume 1. Geologic and Hydrologic Data, 1975
  Volume 2. Santa Rosa Plain, 1982
  Volume 3. Petaluma Valley, 1982
  Volume 4. Sonoma Valley, 1982
  Volume 5. Alexander Valley and Healdsburg Area, 1983
- Bulletin 118-5. Bulletin planned but never completed.
- Bulletin 118-6. Evaluation of Ground Water Resources: Sacramento Valley, 1978

The Need for Bulletin 118 Update 2003

Despite California's heavy reliance on groundwater, basic information for many of the groundwater basins is lacking. Particular essential data necessary to provide for both the protection and optimal use of this resource is not available. To this end, the California Legislature mandated in the Budget Act of 1999 that DWR prepare:

> ...the statewide update of the inventory of groundwater basins contained in Bulletin 118-80, which includes, but is not limited to, the following: the review and summary of boundaries and hydrographic features, hydrogeologic units, yield data, water budgets, well production characteristics, and water quality and active monitoring data; development of a water budget for each groundwater basin; development of a format and procedures for publication of water budgets on the Internet; development of the model groundwater management ordinance; and development of guidelines for evaluating local groundwater management plans.

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The information on groundwater basins presented in Bulletin 118 Update 2003 is mostly limited to the acquisition and compilation of existing data previously developed by federal, State, and local water agencies. While this bulletin is a good starting reference for basic data on a groundwater basin, more recent data and more information about the basin may be available in recent studies conducted by local water management agencies. Those agencies should be contacted to obtain the most recent data.

Report Organization

Bulletin 118 Update 2003 includes this report and supplemental material consisting of individual descriptions and a Geographic Information System-compatible map of each of the delineated groundwater basins in California. The basin descriptions will be updated as new information becomes available, and can be viewed or downloaded at http://www.waterplan.water.ca.gov/groundwater/118index.htm (Appendix A). Basin descriptions will not be published in hard copy.

This report is organized into the following topics:

- Groundwater is one of California's most important natural resources, and our reliance on it has continued to grow (Chapter 1).
- Groundwater has a complex legal and institutional framework in California that has shaped the groundwater management system in place today (Chapter 2).
- Groundwater management occurs primarily at the local water agency level, but may also be instituted at the local government level. At the request of the Legislature, DWR has developed some recommendations for a model groundwater management ordinance and components for inclusion in a groundwater management plan (Chapter 3).
- Groundwater has had a flurry of activity in the Legislature and at the ballot box in recent years that will affect the way groundwater is managed in California (Chapter 4).
- Groundwater programs with a variety of objectives exist in many State and federal agencies (Chapter 5).
- Groundwater concepts and definitions should be made available to a wide audience (Chapter 6).
- Groundwater basins with a wide range of characteristics and concerns exist in each of California's 10 hydrologic regions (Chapter 7).

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Chapter 1
Groundwater – California's Hidden Resource

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Chapter 1
Groundwater – California's Hidden Resource

In 1975, *California's Ground Water – Bulletin 118* described groundwater as "California's hidden resource." Today, those words ring as true as ever. Because groundwater cannot be directly observed, except under a relatively few conditions such as at a spring or a wellhead, most Californians do not give much thought to the value that California's vast groundwater supply has added to the State. It is unlikely that California could have achieved its present status as the largest food and agricultural economy in the nation and fifth largest overall economy in the world without groundwater resources. Consider that about 43 percent of all Californians obtain drinking water from groundwater. California is not only the single largest user of groundwater in the nation, but the estimated 14.5 million acre-feet (maf) of groundwater extracted in California in 1995 represents nearly 20 percent of all groundwater extracted in the entire United States (Solley and others 1998).

California's Hydrology

California's climate is dominated by the Pacific storm track. Numerous mountain ranges cause orographic lifting of clouds, producing precipitation mostly on the western slopes and leaving a rain shadow on most eastern slopes (Figure 1 and Figure 2). These storms also leave tremendous accumulations of snow in the Sierra Nevada during the winter months. While the average annual precipitation in California is about 23 inches (DWR 1998), the range of annual rainfall varies greatly from more than 140 inches in the northwestern part of the State to less than 4 inches in the southeastern part of the State.

Snowmelt and rain falling in the mountains flow into creeks, streams, and rivers. The average annual runoff in California is approximately 71 maf (DWR 1998). As these flows make their way into the valleys, much of the water percolates into the ground. The vast majority of California's groundwater that is accessible in significant amounts is stored in alluvial groundwater basins. These alluvial basins, which are the subject of this report, cover nearly 40 percent of the geographic area of the State (Figure 3).

This bulletin focuses on groundwater resources, but in reality groundwater and surface water are inextricably linked in the hydrologic cycle. As an example, groundwater may be recharged by spring runoff in streams, but later in the year the base flow of a stream may be provided by groundwater. So, although the land surface is a convenient division for categorizing water resources, it is a somewhat arbitrary one. It is essential that water managers recognize and account for the relationship between groundwater and surface water in their planning and operations.

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Figure 1 Shaded relief map of California

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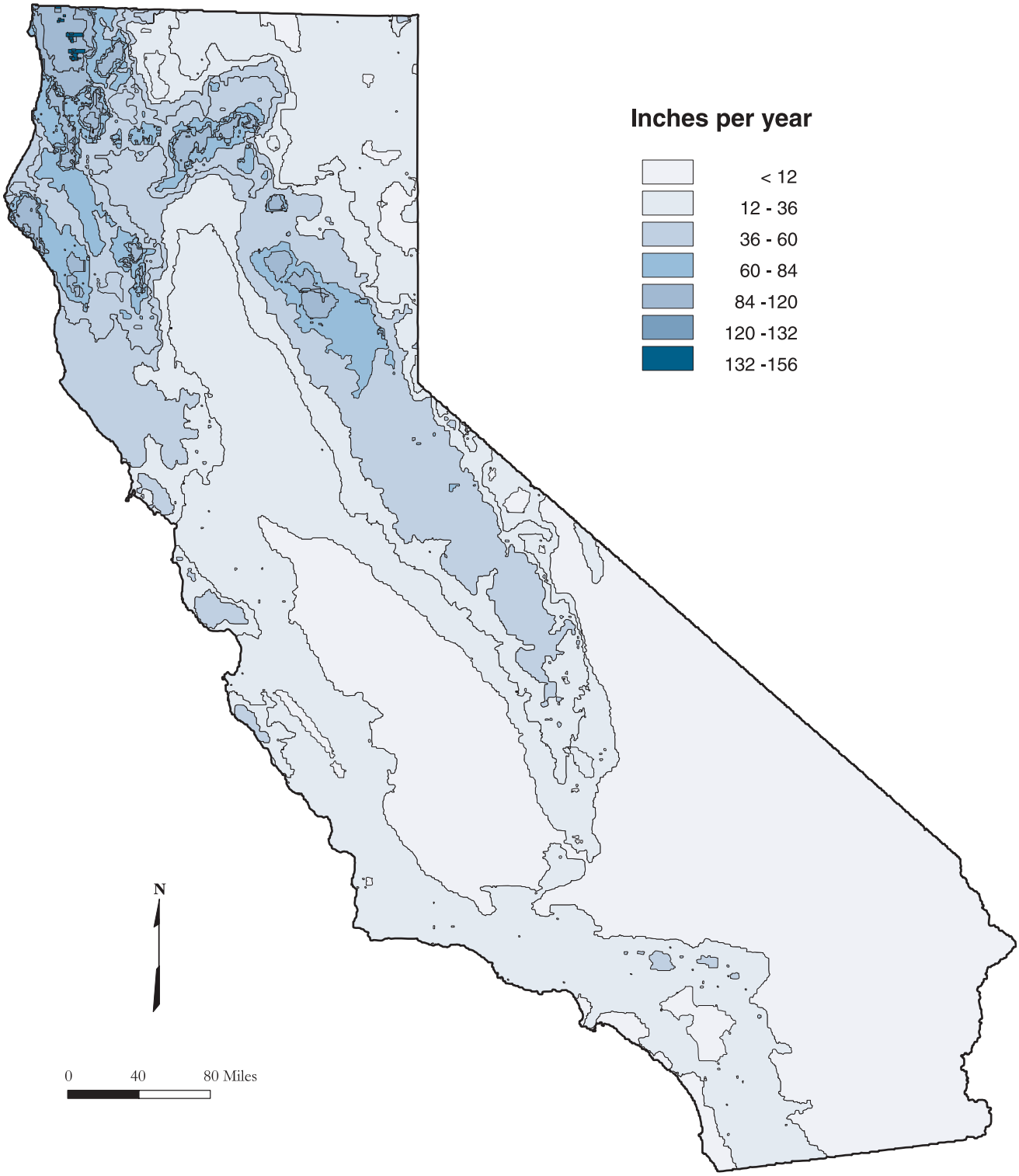

Figure 2 Mean annual precipitation in California, 1961 to 1990

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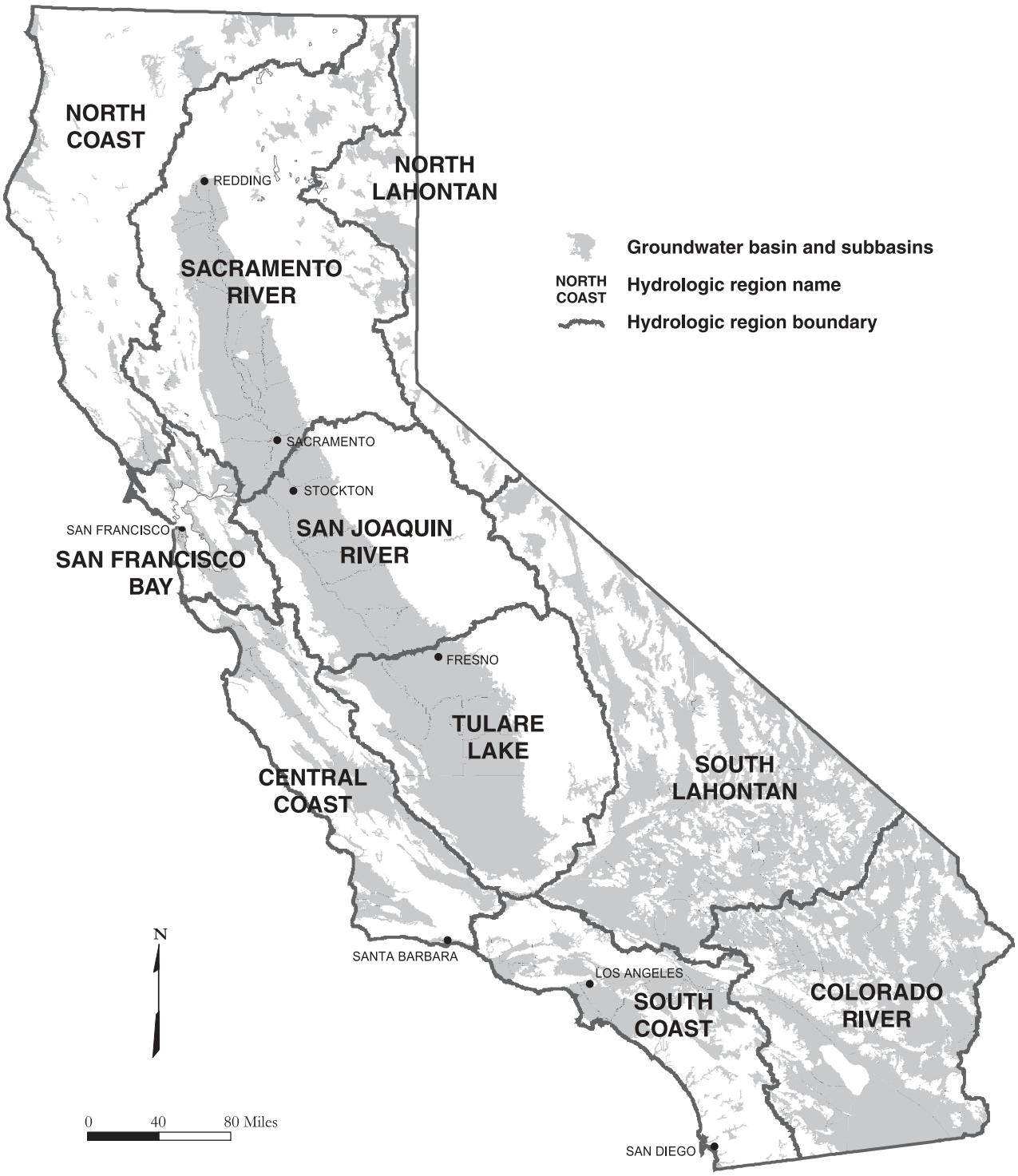

Figure 3 Groundwater basins, subbasins and hydrologic regions

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California's Water Supply System

The economic success achieved in California could not have been foreseen a century ago. California's natural hydrologic system appeared too limited to support significant growth in population, industry, and agriculture. The limitations revolved around not only the relative aridity of the State, but the geographic, seasonal, and climatic variability that influence California's water supply. Approximately 70 percent of the State's average annual runoff occurs north of Sacramento, while about 75 percent of the State's urban and agricultural water needs are to the south. Most of the State's precipitation falls between October and April with half of it occurring December through February in average years. Yet, the peak demand for this water occurs in the summer months. Climatic variability includes dramatic deviations from average supply conditions by way of either droughts or flooding. In the 20th century alone, California experienced multiyear droughts in 1912–1913, 1918–1920, 1922–1924, 1929–1934, 1947–1950, 1959–1961, 1976–1977, and 1987–1992 (DWR 1998).

California has dealt with the limitations resulting from its natural hydrology and achieved its improbable growth by developing an intricate system of reservoirs, canals, and pipelines under federal, State and local projects (Figure 4). However, a significant portion of California's water supply needs is also met by groundwater. Typically, groundwater supplies about 30 percent of California's urban and agricultural uses. In dry years, groundwater use increases to about 40 percent statewide and 60% or more in some regions.

The importance of groundwater to the State's development may have been underestimated at the beginning of the 20th century. At that time, groundwater was seen largely as just a convenient resource that allowed for settlement in nearly any part of the State, given groundwater's widespread occurrence. Significant artesian flow from confined aquifers in the Central Valley allowed the early development of agriculture. When the Water Commission Act defined the allocation of surface water rights in 1914, it did not address allocation of the groundwater resource. In the 1920s, the development of the deep-well turbine pump and the increased availability of electricity led to a tremendous expansion of agriculture, which used these high-volume pumps and increased forever the significance of groundwater as a component of water supply in California.

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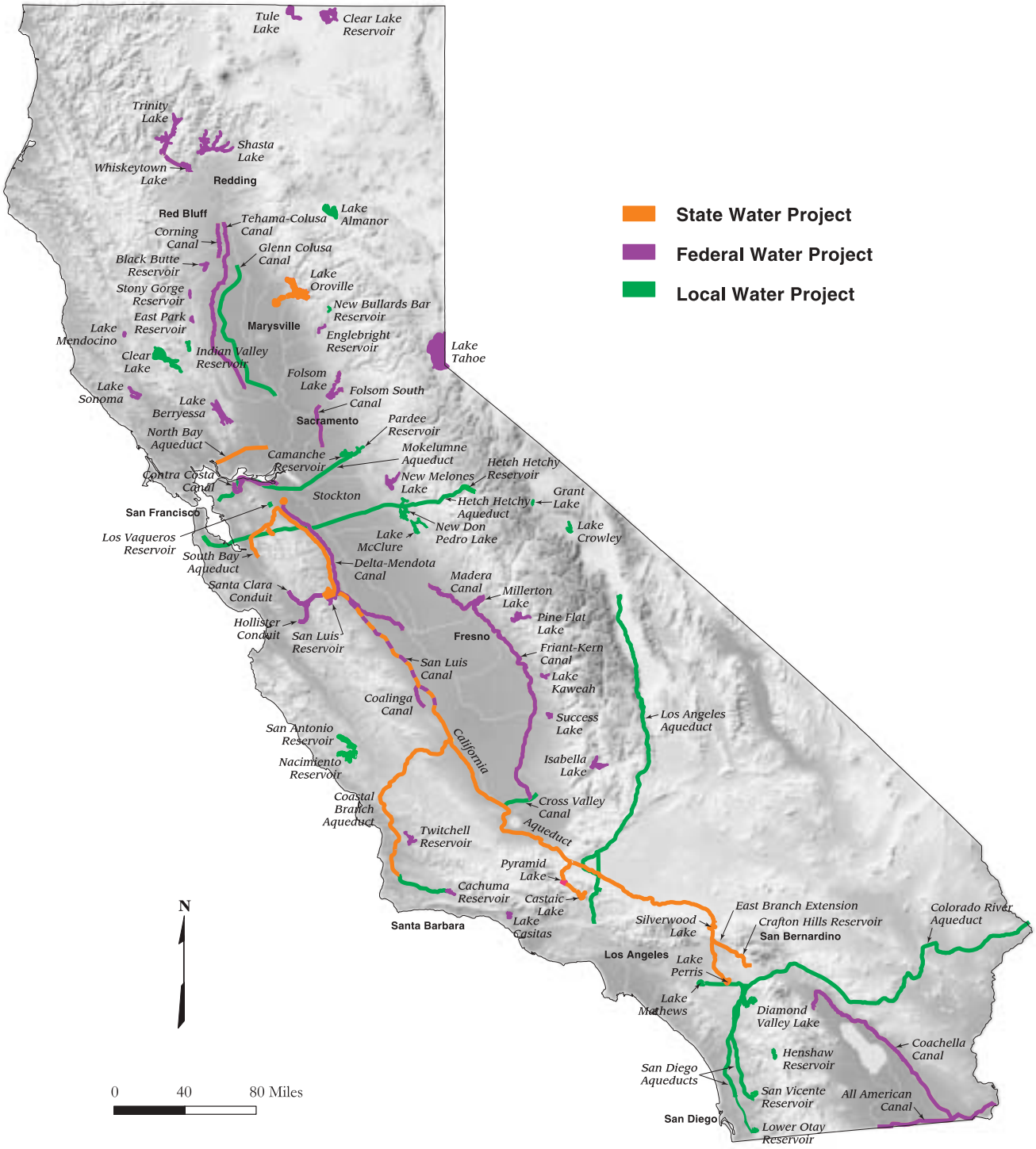

Figure 4 Water projects in California

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Box B Will Climate Change Affect California's Groundwater?

California's water storage and delivery system can be thought of as including three reservoir systems—the snowpack of the Sierra Nevada, an extensive system of dams, lakes, and conveyance systems for surface water, and finally the aquifers that store groundwater. Precipitation in the form of snow is stored in the Sierra in winter and early spring and under ideal conditions melts in a manner that allows dams to capture the water for use during California's dry season. When snow melts faster, the dams act as flood control structures to prevent high runoff from flooding lowland areas. Water storage and delivery infrastructure—dams and canals—has been designed largely around the historical snowpack, while aquifers have played a less formal and less recognized role.

What will be the effect of climate change on California's water storage system? How will groundwater basins and aquifers be affected?

The latest report of the Intergovernmental Panel on Climate Change (2001) reaffirms that climate is changing in ways that cannot be accounted for by natural variability and that "global warming" is occurring. Studies by the National Water Assessment Team for the U.S. Global Change Research Program's National Assessment of the Potential Consequences of Climate Variability and Change identify potential changes that could affect water resources systems. For California, these include higher snow levels leading to more precipitation in the form of rain, earlier runoff, a rise in sea level, and possibly larger floods. In addition to affecting the balance between storage and flood control of our reservoirs, such changes in hydrology would affect wildlands, resulting in faunal and floral displacement and resulting in changes in vegetative water consumption. These changes would also affect patterns of both irrigated and dryland farming.

A warmer, wetter winter would increase the amount of runoff available for groundwater recharge; however, this additional runoff in the winter would be occurring at a time when some basins, particularly in Northern California, are either being recharged at their maximum capacity or are already full. Conversely, reductions in spring runoff and higher evapotranspiration because of warmer temperatures could reduce the amount of water available for recharge and surface storage.

The extent to which climate will change and the impact of that change are both unknown. A reduced snowpack, coupled with increased seasonal rainfall and earlier snowmelt may require a change in the operating procedures for existing dams and conveyance facilities. Furthermore, these changes may require more active development of successful conjunctive management programs in which the aquifers are more effectively used as storage facilities. Water managers might want to evaluate their systems to better understand the existing snowpack-surface water-groundwater relationship, and identify opportunities that may exist to optimize groundwater and other storage capability under a new hydrologic regime that may result from climate change. If more water was stored in aquifers or in new or reoperated surface storage, the additional water could be used to meet water demands when the surface water supply was not adequate because of reduced snowmelt.

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Recent Groundwater Development Trends

While development of California's surface water storage system has slowed significantly, groundwater development continues at a strong pace. A review of well completion reports submitted to the California Department of Water Resources (DWR) provides data on the number and type of water wells drilled in California since 1987. For the 14-year period, DWR received 127,616 well completion reports for water supply wells that were newly constructed, reconditioned, or deepened—an average of 9,115 annually[1]. Of these, 82 percent were drilled for individual domestic uses; 14 percent for irrigation; and about 4 percent for a combined group of municipal and industrial uses (Figure 5). Although domestic wells predominate, individual domestic use makes up a small proportion of total groundwater use in the State.

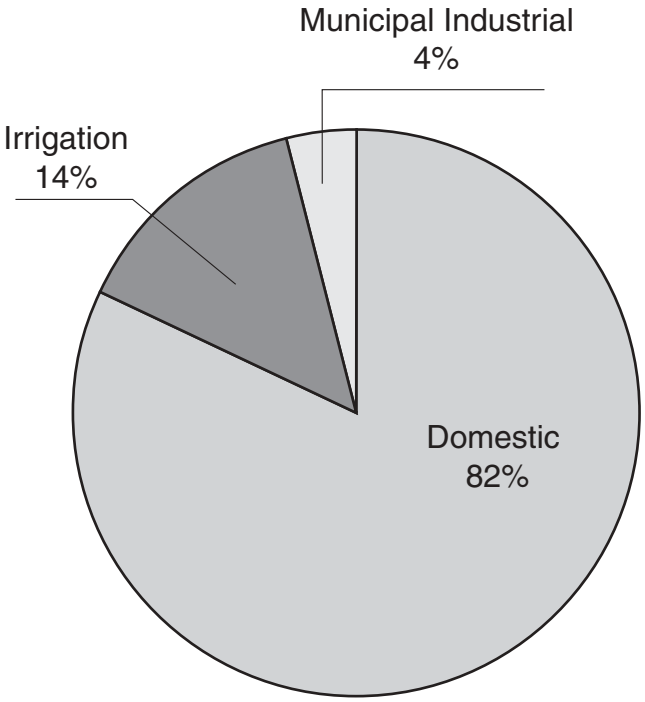

Figure 5 Well completion reports filed with DWR from 1987 through 2000

The most evident influence on the number of wells constructed is hydrologic conditions. The number of wells constructed and modified increases dramatically with drought conditions (Figure 6). The number of wells constructed and modified annually from 1987 through 1992 is more than double the annual totals for 1995 through 2000. Each year from 1987 through 1992 was classified as either dry or critically dry; water years 1995 through 2000 were either above normal or wet, based on measured unimpaired runoff in the Sacramento and San Joaquin valleys. In addition to providing an indication of the growth of groundwater development, well completion reports are a valuable source of information on groundwater basin conditions.

[1] DWR also received an average of 4,225 well completion reports for monitoring, which were not included above because they do not extract groundwater for supply purposes.

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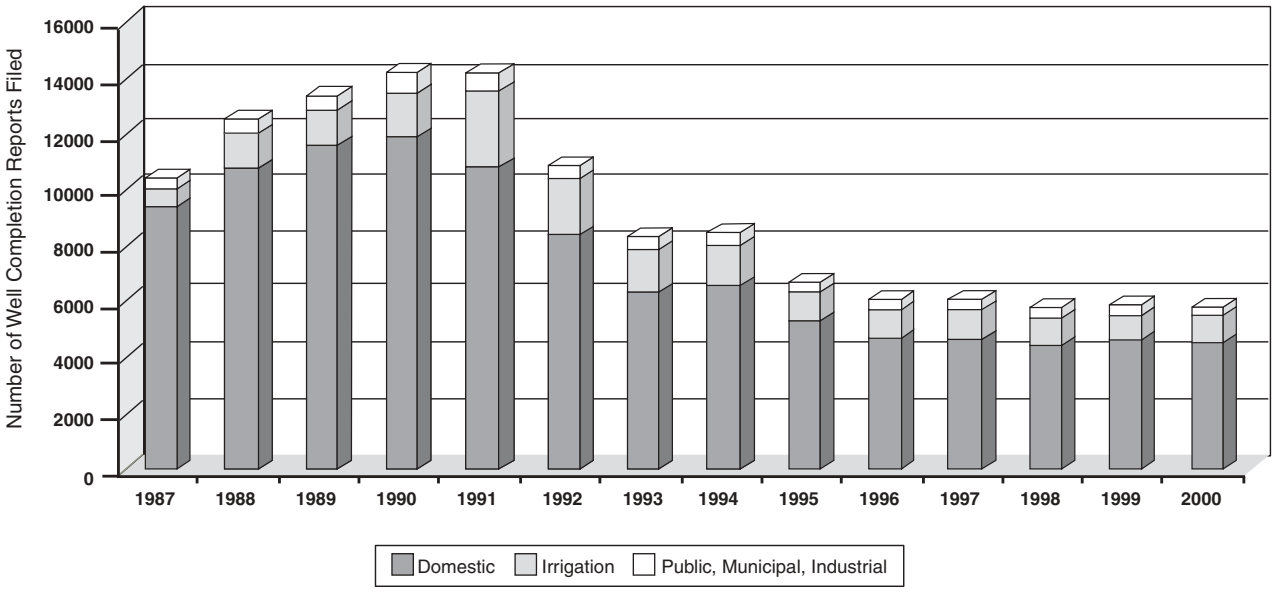

Figure 6 Well completion reports filed annually from 1987 through 2000

The Need for Groundwater Monitoring and Evaluation

Some 34 million people called California their home in the year 2000, and a population of nearly 46 million is expected by 2020. The increased population and associated commercial, industrial, and institutional growth will bring a substantially greater need for water. This need will be met in part by improved water use efficiency, opportunities to reoperate or expand California's surface water system, and increased desalination and recycling of water sources not currently considered usable. This need will also be met by storing and extracting additional groundwater. However, the sustainability of the groundwater resource, both in terms of what is currently used and future increased demand, cannot be achieved without effective groundwater management. In turn, effective groundwater management cannot be achieved without a program of groundwater data collection and evaluation.

Perhaps surprising to many, California does not have a comprehensive monitoring network for evaluating the health of its groundwater resource, including quantity and quality of groundwater. The reasons for this are many with the greatest one being that information on groundwater levels and groundwater quality is primarily obtained by drilling underground, which is relatively expensive. Given that delineated groundwater basins cover about 40 percent of the State's vast area, the cost of a dedicated monitoring network would be prohibitive. The other important reason for the lack of a comprehensive network is that, as will be discussed later in this report, groundwater is a locally controlled resource. State and federal agencies become involved only when a groundwater issue is directly related to the mission of a particular agency or if a local agency requests assistance. For these and other reasons, California lacks a cohesive, dedicated monitoring network.

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Box C What about Overdraft?

Overdraft is the condition of a groundwater basin in which the amount of water withdrawn by pumping over the long term exceeds the amount of water that recharges the basin. Overdraft is characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. Overdraft can lead to increased extraction costs, land subsidence, water quality degradation, and environmental impacts.

The California Water Plan Update, Bulletin 160-98 (DWR 1998) estimated that groundwater overdraft in California in 1995 was nearly 1.5 million acre-feet annually, with most of the overdraft occurring in the Tulare Lake, San Joaquin River, and Central Coast hydrologic regions. The regional and statewide estimates of overdraft are currently being revised for the 2003 update of Bulletin 160. While these estimates are useful from a regional and statewide planning perspective, the basin water budgets calculated for this update of Bulletin 118 clearly indicate that information is insufficient in many basins to quantify overdraft that has occurred, project future impacts on groundwater in storage, and effectively manage groundwater. Further technical discussion of overdraft is provided in Chapter 6 of this bulletin.

When DWR and other agencies involved in groundwater began to collect data in the first half of the 20th century, it quickly became evident that there were insufficient funds to install an adequate number of monitoring wells to accurately determine changes in the condition of groundwater basins. Consequently, to create a serviceable monitoring network, the agencies asked owners of irrigation or domestic wells for permission to measure water levels and to a lesser extent to monitor water quality. These have been called "wells of opportunity." In many areas, this approach has led to a network of wells that provide adequate information to gain a general understanding of conditions in the subsurface and to track changes through time. In some areas, groundwater studies were conducted and often included the construction of a monitoring well network. These studies have gradually contributed to a more detailed understanding of some of California's groundwater basins, particularly the most heavily developed basins.

Given the combination of monitoring wells of opportunity and dedicated monitoring wells, it might be assumed that an adequate monitoring network in California will eventually accumulate. However, several factors contribute to reducing the effectiveness of the monitoring network for data collection and evaluation: (1) The funding for data programs in many agencies, which was generally insufficient in the first place, has been reduced significantly. (2) When private properties change ownership, some new owners rescind permission for agency personnel to enter the property and measure the well. (3) The appropriateness of using these private wells is questionable because they are often screened over long intervals encompassing multiple aquifers in the subsurface, and in some cases construction details for the well are unknown. (4) Some wells with long-term records actually reach the end of their usefulness because the casing collapses or something falls into the well, making it unusable. In some cases, groundwater levels may drop below the well depth. (5) As water quality or water quantity conditions change, the monitoring networks may no longer be adequate to provide necessary data to manage groundwater.

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The importance of long-term monitoring networks cannot be overstated. Sound groundwater management decisions require observation of trends in groundwater levels and groundwater quality. Only through these long-term evaluations can the question of sustainability of groundwater be answered. For example, this report contains a summary of groundwater contamination in public water supply wells throughout the State collected from 1994 through 2000. While this provides a "snapshot" of the suitability of the groundwater currently developed for public supply needs, it does not address sustainability of groundwater for public uses. Sustainability can only be determined by observing groundwater quality over time. If conditions worsen, local managers will need to take steps to prevent further harm to groundwater quality. Long-term groundwater records require adequate funding and staff to develop groundwater monitoring networks and to collect, summarize, and evaluate the data.

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Chapter 2
Groundwater Management in California

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Groundwater Management in California

Groundwater management, as defined in this report, is the planned and coordinated monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of long-term sustainability of the resource. Throughout the history of water management in California, local agencies have practiced an informal type of groundwater management. For example, since the early 20th century, when excess surface water was available, some agencies intentionally recharged groundwater to augment their total water supply. In 1947, the amount of groundwater used was estimated at 9 million to 10 million acre-feet. By the beginning of the 21st century, the amount of groundwater used had increased to an estimated 15 million acre-feet. Better monitoring would provide more accurate information. This increased demand on California's groundwater resources, when coupled with estimates of population growth, has resulted in a need for more intensive groundwater management.

In 1914, California created a system of appropriating surface water rights through a permitting process (Stats 1913, ch. 586), but groundwater use has never been regulated by the State. Though the regulation of groundwater has been considered on several occasions, the California Legislature has repeatedly held that groundwater management should remain a local responsibility (Sax 2002). Although they are treated differently legally, groundwater and surface water are closely interconnected in the hydrologic cycle. Use of one resource will often affect the other, so that effective groundwater management must consider surface water supplies and uses.

Figure 7 depicts the general process by which groundwater management needs are addressed under existing law. Groundwater management needs are identified at the local water agency level and may be directly resolved at the local level. If groundwater management needs cannot be directly resolved at the local agency level, additional actions such as enactment of ordinances by local governments, passage of laws by the Legislature, or decisions by the courts may be necessary to resolve the issues. Upon implementation, local agencies evaluate program success and identify additional management needs. The State's role is to provide technical and financial assistance to local agencies for their groundwater management efforts, such as through the Local Groundwater Assistance grant program (see Chapter 4, AB 303).

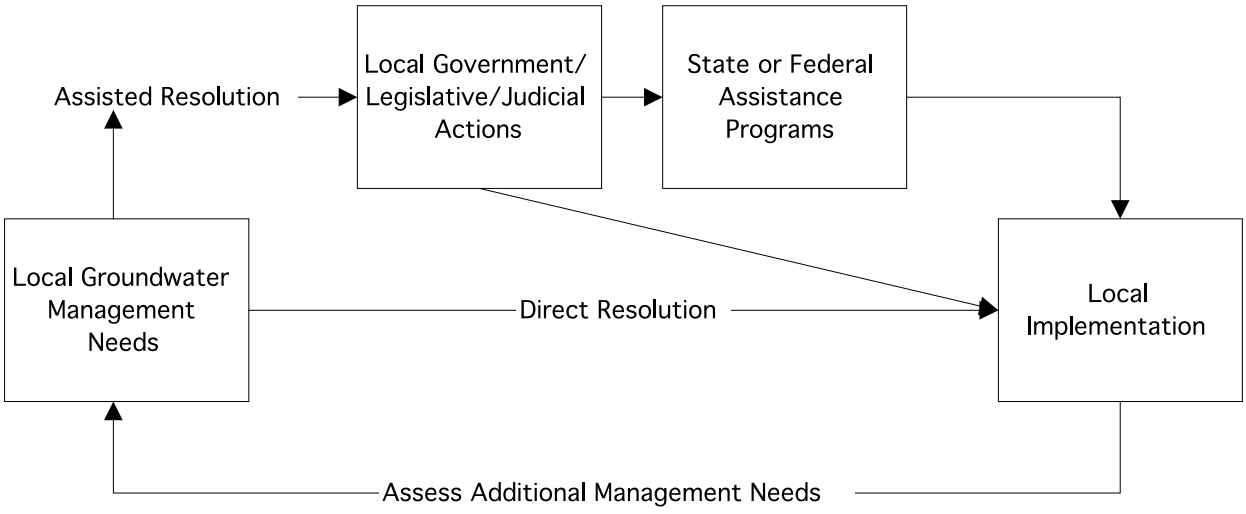

Figure 7 Process of addressing groundwater management needs in California

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How Groundwater is Managed in California

There are three basic methods available for managing groundwater resources in California: (1) management by local agencies under authority granted in the California Water Code or other applicable State statutes, (2) local government groundwater ordinances or joint powers agreements, and (3) court adjudications. Table 1 shows how often each of these methods has been used, and each method is discussed briefly below. No law requires that any of these forms of management be applied in a basin. Management is often instituted after local agencies or landowners recognize a specific groundwater problem. The level of groundwater management in any basin or subbasin is often dependent on water availability and demand.

Table 1 Groundwater management methods

Method	Frequency of use[a]
Local water agencies	Undetermined number of agencies with authority to manage some aspect of groundwater under general powers associated with a particular type of district. Thirteen agencies with specially legislated authority to limit or regulate extraction. Seven agencies with adopted plans under authority from Water Code Section 10750 et seq.[b] (AB 255 of 1991). More than 200 agencies with adopted plans under authority from Water Code Section 10750 et seq. (AB 3030 of 1992).
Local groundwater management ordinances	Currently adopted in 27 counties.
Court adjudication	Currently decided in 19 groundwater basins, mostly in Southern California. Three more basins are in court.

a. The numbers for some methods are unknown because reporting to the California Department of Water Resources is not required.
b. Section 10750 *et seq*. was amended in 1992.

Groundwater Management through Authority Granted to Local Water Agencies

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management. For example, a Water Replenishment District (Water Code, § 60000 et seq.) is authorized to establish groundwater replenishment programs and collect fees for that service. A Water Conservation District (Water Code, § 75500 et seq.) can levy groundwater extraction fees. Table 2 lists these and other types of local agencies that deliver water and may have authority to institute some form of groundwater management. Most of these agencies are identified in the Water Code, but their specific authority related to groundwater management varies. The Water Code does not require that the agencies report their activities to the California Department of Water Resources (DWR).

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Table 2 Local agencies with authority to deliver water for beneficial uses, which may have authority to institute groundwater management

Local agency	Authority	Number of agencies[a]
Community Services District	Gov. Code § 61000 et seq.	313
County Sanitation District	Health and Safety Code § 4700 et seq.	91
County Service Area	Gov. Code § 25210.1 et seq.	897
County Water Authority	Water Code App. 45.	30
County Water District	Water Code § 30000 et seq.	174
County Waterworks District	Water Code § 55000 et seq.	34
Flood Control and Water Conservation District	Water Code App. 38.	39
Irrigation District	Water Code § 20500 et seq.	97
Metropolitan Water District	Water Code App 109.	1
Municipal Utility District	Pub. Util. Code § 11501 et seq.	5
Municipal Water District	Water Code § 71000 et seq.	40
Public Utility District	Pub. Util. Code § 15501 et seq.	54
Reclamation District	Water Code § 50000 et seq.	152
Recreation and Park District	Pub. Resources Code § 5780 et seq.	110
Resort Improvement District	Pub. Resources Code § 13000 et seq.	-
Resource Conservation District	Pub. Resources Code § 9001 et seq.	99
Water Conservation District	Water Code App. 34; Wat. Code § 74000 et seq.	13
Water District	Water Code § 34000 et seq.	141
Water Replenishment District	Water Code § 60000 et seq.	1
Water Storage District	Water Code § 39000 et seq.	8

a. From State Controller's Office Special Districts Annual Report, 49th Edition.

Greater authority to manage groundwater has been granted to a small number of local agencies or districts created through special acts of the Legislature. For example, the Sierra Valley Groundwater Basin Act of 1980 (Water Code, App. 119) created the first two groundwater management districts in California. Currently, 13 local agencies have specific groundwater management authority as a result of being special act districts. The specific authority of each agency varies, but they can generally be grouped into two categories. Most of the agencies formed since 1980 have the authority to limit export and even control some in-basin extraction upon evidence of overdraft or the threat of overdraft. These agencies can also generally levy fees for groundwater management activities and for water supply replenishment. Agencies formed prior to 1980 do not have authority to limit extraction from a basin. However, the groundwater users in these areas are generally required to report extractions to the agency, and the agency can levy fees for groundwater management or water supply replenishment. Some of these agencies have effectively used a tiered fee

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structure to discourage excessive groundwater extraction in the basin. Table 3 lists the names of special act districts with legislative authority to manage groundwater.

Table 3 Special act districts with groundwater management authority in California

District or agency	Water Code citation[a]	Year agency established in Code[b]
Desert Water Agency	App. 100	1961
Fox Canyon Groundwater Management Agency	App. 121.	1982
Honey Lake Groundwater Management District	App. 129.	1989
Long Valley Groundwater Management District	App. 119.	1980
Mendocino City Community Services District	Section 10700 et seq.	1987
Mono County Tri-Valley Groundwater Management District	App. 128.	1989
Monterey Peninsula Water Management District	App. 118.	1977
Ojai Groundwater Management Agency	App. 131.	1991
Orange County Water District	App. 40.	1933
Pajaro Valley Water Management Agency	App. 124.	1984
Santa Clara Valley Water District	App. 60.	1951
Sierra Valley Groundwater Management District	App. 119.	1980
Willow Creek Groundwater Management Agency	App. 135.	1993

a. From West's Annotated California Codes (1999 update)
b. This represents the year the agency was established in the Water Code. Specific authorities, such as those for groundwater management activities, may have been granted through later amendments.

In 1991, AB 255 (Stats. 1991, Ch. 903) was enacted authorizing local agencies overlying basins subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish programs for groundwater management within their service areas. Water Code section 10750 et seq. provided these agencies with the powers of a water replenishment district to raise revenue for facilities to manage the basin for the purposes of extraction, recharge, conveyance, and water quality. Seven local agencies adopted plans under this authority.

The provisions of AB 255 were repealed in 1992 with the passage of AB 3030 (Stats. 1992, Ch. 947). This legislation was significant in that it greatly increased the number of local agencies authorized to develop a groundwater management plan and set forth a common framework for management by local agencies throughout California. AB 3030, which is codified in Water Code section 10750 et seq., provides a systematic procedure to develop a groundwater management plan by local agencies overlying the groundwater basins defined by Bulletin 118-75 (DWR 1975) and updates. Upon adoption of a plan, these agencies could possess the same authority as a water replenishment district to "fix and collect fees and assessments for groundwater management" (Water Code, § 10754). However, the authority to fix and collect these fees and assessments is contingent on receiving a majority of votes in favor of the proposal in a local election (Water Code, § 10754.3). More than 200 agencies have adopted an AB 3030 groundwater management plan. None of these agencies is known to have exercised the authority of a Water Replenishment District.

Water Code section 10755.2 expands groundwater management opportunities by encouraging coordinated plans and by authorizing public agencies to enter into a joint powers agreement or memorandum of understanding with public or private entities that provide water service. At least 20 coordinated plans have been prepared to date involving nearly 120 agencies, including cities and private water companies.

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Local Groundwater Ordinances

A second general method of managing groundwater in California is through ordinances adopted by local governments such as cities or counties. Twenty-seven counties have adopted groundwater ordinances, and others are being considered (Figure 8). The authority of counties to regulate groundwater has been challenged, but in 1995 the California Supreme Court declined to review an appeal of a lower court decision *Baldwin v. County of Tehama* (1994) that holds that State law does not occupy the field of groundwater management and does not prevent cities and counties from adopting ordinances to manage groundwater under their police powers. However, the precise nature and extent of the police power of cities and counties to regulate groundwater is uncertain.

The Public Policy Institute of California recently performed a study of California's water transfer market, which included a detailed investigation of the nature of groundwater ordinances by counties in California. The report found that 22 counties had adopted ordinances requiring a permit to export groundwater. In all but three cases, restricting out-of-county uses appears to be the only purpose (Hanak 2003). One ordinance, adopted recently in Glenn County (Box D, "Basin Management Objectives for Groundwater Management"), takes a comprehensive approach by establishing management objectives for the county's groundwater basins. Several other counties in Northern California are considering adopting similar management objective based ordinances.

Ordinances are mostly a recent trend in groundwater management, with 24 of the 27 ordinances enacted since 1990. Local ordinances passed during the 1990s have significantly increased the potential role of local governments in groundwater management. The intent of most ordinances has been to hold project proponents accountable for impacts that may occur as a result of proposed export projects. Because adoption of most of these ordinances is recent, their effect on local and regional groundwater management planning efforts is not yet fully known. However, it is likely that future groundwater development will take place within the constraints of local groundwater management ordinances. Table 4 lists counties with groundwater management ordinances and their key elements.

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Figure 8 Counties with groundwater ordinances

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Box D Basin Management Objectives for Groundwater Management

Most county groundwater management ordinances require that an export proponent prove the project will not deplete groundwater, cause groundwater quality degradation, or result in land subsidence. Although these factors could be part of any groundwater management plan, these ordinances do not require that a groundwater management plan be developed and implemented.

The only ordinance requiring development and adoption of objectives to be accomplished by management of the basin was adopted by the Glenn County Board of Supervisors in 2000. The action came after a citizens committee spent five years working with stakeholders. The process of developing a groundwater management ordinance for Glenn County began in 1995 when local landowners and county residents became concerned about plans to export groundwater or substitute groundwater for exported surface water. Control of exports was the focus of early ordinance discussions.

After long discussions and technical advice from groundwater specialists, the committee realized that goals and objectives must be identified for effective management of groundwater in the county. What did the county want to accomplish by managing groundwater within the county? What did groundwater management really mean?

The concept of establishing basin management objectives emerged (BMOs). BMOs would establish threshold values for groundwater levels, groundwater quality, and land surface subsidence. When a threshold level is reached, the rules and regulations require that groundwater extraction be adjusted or stopped to prevent exceeding the threshold.

The Glenn County Board of Supervisors has adopted BMOs, which were developed by an advisory committee, for groundwater levels throughout the county. While currently there are 17 BMOs representing the 17 management areas in the county, the goal is to begin managing the entire county in a manner that benefits each of the local agencies and their landowners, as well as landowners outside of an agency boundary. The committee is now developing BMOs for groundwater quality and land surface subsidence.

There is no single set of management objectives that will be successful in all areas. Groundwater management must be adapted to an area's political, institutional, legal, and technical constraints and opportunities. Groundwater management must be tailored to each basin or subbasin's conditions and needs. Even within a single basin, the management objectives may change as more is learned about managing the resource within that basin. Flexibility is the key, but that flexibility must operate within a framework that ensures public participation, monitoring, evaluation, feedback on management alternatives, rules and regulations, and enforcement.

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Table 4 Counties with ordinances addressing groundwater management

County	Year enacted	Key elements (refer to ordinances for exemptions and other details)
Butte	1996	Export permit required (extraction & substitute pumping), Water Commission and Technical Advisory Committee, groundwater planning reports (county-wide monitoring program)
Calaveras	2002	Export permit required (extraction & substitute pumping)
Colusa	1998	Export permit required (extraction & substitute pumping)
Fresno	2000	Export permit required (extraction & substitute pumping)
Glenn	1990 rev. 2000	Water Advisory Committee and Technical Advisory Committee, basin management objectives and monitoring network, export permit required (1990)
Imperial	1996	Commission established to manage groundwater, including controlling exports (permit required), overdraft, artificial recharge, and development projects
Inyo	1998	Regulates (1) water transfers pursuant to Water Code Section 1810, (2) sales of water to the City of Los Angeles from within Inyo Co., (3) transfer or transport of water from basins within Inyo County to another basin with the County, and (4) transfers of water from basins within Inyo Co. to any area outside the County.
Kern	1998	Conditional use permit for export to areas both outside county and within watershed area of underlying aquifer in county. Only applies to southeastern drainage of Sierra Nevada and Tehachapi mountains.
Lake	1999	Export permit required (extraction & substitute pumping)
Lassen	1999	Export permit required (extraction & substitute pumping)
Madera	1999	Permit required for export, groundwater banking, and import for groundwater banking purposes to areas outside local water agencies
Mendocino	1995	Mining of groundwater regulated for new developments in Town of Mendocino
Modoc	2000	Export permit required for transfers out of basin
Mono	1988	Permit required for transfers out of basin
Monterey	1993	Water Resources Agency strictly regulates extraction facilities in zones with groundwater problems
Napa	1996	Permits for local groundwater extractions; exemptions for single parcels and agricultural use
Sacramento	1952 rev. 1985	Water Agency established to manage and protect groundwater management zones; replenishment charges
San Benito	1995	Mining groundwater (overdraft) for export prohibited; permit required for off-parcel use, injecting imported water; influence of well pumping restrictions
San Bernardino	2002	Permit required for any new groundwater well within the desert region of the county
San Diego	1991	Provides for mapping of groundwater impacted basins (defined); projects within impacted basins require groundwater investigations
San Joaquin	1996	Export permit required (extraction & substitute pumping)
Shasta	1997	Export permit required (extraction & substitute pumping)
Sierra	1998	Export permit required or for off-parcel use
Siskiyou	1998	Permit required for transfers out of basin
Tehama	1992	Mining groundwater (overdraft) for export prohibited; permit required for off-parcel use; influence of well pumping restrictions
Tuolumne	2001	Export permit required (extraction & substitute pumping)
Yolo	1996	Export permit required (extraction & substitute pumping)

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Adjudicated Groundwater Basins

A third general form of groundwater management in California is court adjudication. In some California groundwater basins, as the demand for groundwater exceeded supply, landowners and other parties turned to the courts to determine how much groundwater can rightfully be extracted by each user. The courts study available data to arrive at a distribution of the groundwater that is available each year, usually based on the California law of overlying use and appropriation. This court-directed process can be lengthy and costly. As noted in Table 5, the longest adjudication took 24 years. Many of these cases have been resolved with a court-approved negotiated settlement, called a stipulated judgment. Unlike overlying and non-overlying rights to groundwater, such decisions guarantee to each party a proportionate share of the groundwater that is available each year. The intense technical focus on the groundwater supply and restrictions on groundwater extraction for all parties make adjudications one of the strongest forms of groundwater management in California.

There are 19 court adjudications for groundwater basins in California, mostly in Southern California (see Table 5). Eighteen of the adjudications were undertaken in State Superior Court and one in federal court. For each adjudicated groundwater basin, the court usually appoints a watermaster to oversee the court judgment. In 15 of these adjudications, the court judgment limits the amount of groundwater that can be extracted by all parties based on a court-determined safe yield of the basin. The basin boundaries are also defined by the court. The Santa Margarita Basin was adjudicated in federal court. That decision requires water users to report the amount of surface water and groundwater they use, but groundwater extraction is not restricted.

Most basin adjudications have resulted in either a reduction or no increase in the amount of groundwater extracted. As a result, agencies often import surface water to meet increased demand. The original court decisions provided watermasters with the authority to regulate extraction of the quantity of groundwater; however, they omitted authority to regulate extraction to protect water quality or to prevent the spread of contaminants in the groundwater. Because water quantity and water quality are inseparable, watermasters are recognizing that they must also manage groundwater quality.

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Box E Adjudication of Groundwater Rights in the Raymond Basin

The first basin-wide adjudication of groundwater rights in California was in the Raymond Basin in Los Angeles County in 1949 (*Pasadena v. Alhambra*). The first water well in Raymond Basin was drilled in 1881; 20 years later, the number of operating wells grew to about 140. Because of this pumping, the City of Pasadena began spreading water in 1914 to replenish the groundwater, and during the next 10 years the city spread more than 20,000 acre-feet.

Pumping during 1930 through 1937 caused water levels to fall 30 to 50 feet in wells in Pasadena. After attempting to negotiate a reduction of pumping on a cooperative basis, the City of Pasadena, on September 23, 1937, filed a complaint in Superior Court against the City of Alhambra and 29 other pumpers to quiet title to the water rights within Raymond Basin. The court ruled that the city must amend its complaint, making defendants of all entities pumping more than 100 acre-feet per year, and that it was not a simple quiet title suit but, a general adjudication of the water rights in the basin.

In February 1939, a court used the reference procedure under the State Water Code to direct the State Division of Water Resources, Department of Public Works (predecessor to the Department of Water Resources) as referee to review all physical facts pertaining to the basin, determine the safe yield, and ascertain whether there was a surplus or an overdraft. The study took 2-1/2 years to complete and cost more than $53,000, which was paid by the parties. The resulting Report of Referee submitted to the court in July 1943 found that the annual safe yield of the basin was 21,900 acre-feet but that the actual pumping and claimed rights were 29,400 acre-feet per year.

Most parties agreed to appoint a committee of seven attorneys and engineers to work out a stipulated agreement. In 1944, the court designated the Division of Water Resources to serve as watermaster for the stipulated agreement, which all but one of the parties supported. On December 23, 1944, the judge signed the judgment that adopted the stipulation.

The stipulation provided that (1) the water was taken by each party openly, notoriously, and under a claim of right, which was asserted to be, and was adverse to each and all other parties; (2) the safe yield would be divided proportionally among the parties; and (3) each party's right to a specified proportion of the safe yield would be declared and protected. It also established an arrangement for the exchange of pumping rights among parties.

Based on the stipulation, the court adopted a program of proportionate reductions. In so doing, the court developed the doctrine of mutual prescription, whereby the rights were essentially based on the highest continual amount of pumping during the five years following the beginning of the overdraft, and under conditions of overdraft, all of the overlying and appropriative water users had acquired prescriptive rights against each other, that is, mutual prescription.*

In 1945, one party appealed the judgment, and in 1947, the District Court of Appeals reversed and remanded *Pasadena v. Alhambra.* However, on June 3, 1949, the State Supreme Court overturned the appellate court's decision and affirmed the original judgment. In 1950, the court granted a motion by the City of Pasadena that there be a review of the determination of safe yield, and in 1955, the safe yield and the total decreed rights were increased to 30,622 acre-feet per year. In 1984, watermaster responsibilities were assigned to the Raymond Basin Management Board.

*In City of Los Angeles v. City of San Fernando (1975) the California Supreme Court rejected the doctrine of mutual prescription and held that a groundwater basin should be adjudicated based on the correlative rights of overlying users and prior appropriation among non-overlying users. For further discussion, see Appendix B.

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Table 5 List of adjudicated basins

Court name	Relationship to DWR Bulletin 118 basin name; county	Basin No.	Filed in court	Final decision	Watermaster and/or website
1—Scott River Stream System	Scott River Valley; Siskiyou	1-5	1970	1980	Two local irrigation districts
2—Santa Paula Basin	Subbasin of Santa Clara River; Ventura	4-4	1991	1996	Three-person technical advisory committee from United Water CD, City of Ventura, and Santa Paula Basin Pumpers Association; www.unitedwater.org
3—Central Basin	Northeast part of Coastal Plain of Los Angeles County Basin; Los Angeles	4-11	1962	1965	DWR—Southern District; wwwdpla.water.ca.gov/sd/watermaster/watermaster.html
4—West Coast Basin	Southwest part of Coastal Plain of Los Angeles County Basin; Los Angeles	4-11	1946	1961	DWR—Southern District; wwwdpla.water.ca.gov/sd/watermaster/watermaster.html
5—Upper Los Angeles River Area	San Fernando Valley Basin (entire watershed); Los Angeles	4-12	1955	1979	Superior Court appointee
6—Raymond Basin	Northwest part of San Gabriel Valley Basin; Los Angeles	4-13	1937	1944	Raymond Basin Management Board
7—Main San Gabriel Basin	San Gabriel Valley Basin, excluding Raymond Basin; Los Angeles	4-13	1968	1973	Water purveyors and water districts elect a nine-member board; www.watermaster.org/
Puente Narrows, *Addendum to Main San Gabriel Basin decision*			1972	1972	Two consulting engineers
8—Puente	San Gabriel Valley Basin, excluding Raymond Basin; Los Angeles	4-13	1985	1985	Three consultants
9—Cummings Basin	Cummings Valley Basin; Kern	5-2	1966	1972	Tehachapi-Cummings County Water District; www.tccwd.com/gwm.htm
10—Tehachapi Basin	Tehachapi Valley West Basin and Tehachapi Valley East Basin; Kern	5-28 6-45	1966	1973	Tehachapi-Cummings County Water District; www.tccwd.com/gwm.htm
11—Brite Basin	Brite Valley; Kern	5-80	1966	1970	Tehachapi-Cummings County Water District; www.tccwd.com/gwm.htm

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Table 5 List of adjudicated basins (continued)

Court name	Relationship to DWR Bulletin 118 basin name; county	Basin No.	Filed in court	Final decision	Watermaster and/or website
12—Mojave Basin Area Adjuducation	Lower, Middle & Upper Mojave River Valley Basins; El Mirage & Lucerne valleys; San Bernardino	6-40, 6-41, 6-42	1990	1996	Mojave Water Agency; www.mojavewater.org/mwa700.htm
13—Warren Valley Basin	Part of Warren Valley Basin; San Bernardino	7-12	1976	1977	Hi-Desert Water District; www.mojavewater.org
14—Chino Basin	Northwest part of Upper Santa Ana Valley Basin; San Bernardino and Riverside	8-2	1978	1978	Nine people, recommended by producers and appointed by the court; www.cbwm.org/
15—Cucamonga Basin	North central part of Upper Santa Ana Valley Basin; San Bernardino	8-2	1975	1978	Not yet appointed, operated as part of Chino Basin
16—San Bernardino Basin Area	Northeast part of Upper Santa Ana Basin; San Bernardino and Riverside	8-2	1963	1969	One representative each from Western Municipal Water District of Riverside County & San Bernardino Valley Municipal Water District
17—Six Basins	Six subbasins in northwest upper Santa Ana Valley; Upper & Lower Claremont Heights, Canyon, Pomona, Live Oak & Ganesha; Los Angeles. Small portions of Upper Claremont Heights and Canyon are in San Bernardino County	4-14, 8-2	1998	1998	Nine-member board representing all parties to the judgment
18—Santa Margarita River watershed	The Santa Margarita River watershed, including 3 groundwater basins: Santa Margarita Valley, Temecula Valley and Cahuilla Valley Basins; San Diego and Riverside.	9-4, 9-5, 9-6	1951	1966	U.S. District Court appointee
19—Goleta	Goleta Central Basin; judgment includes North Basin; Santa Barbara	3-16	1973	1989	No watermaster appointed; the court retains jurisdiction

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How Successful Have Groundwater Management Efforts Been?

This chapter describes the opportunities for local agencies to manage their groundwater resources. Many have questioned whether these opportunities have led to an overall successful system of groundwater management throughout California. How successful groundwater management has been throughout the State is a difficult question and cannot be answered at present. While there are many examples of local agency successes (see Box F, "Managing through a Joint Powers Agreement," Box G, "Managing a Basin through Integrated Water Management," and Box H, "Managing Groundwater Using both Physical and Institutional Solutions"), there are neither mandates to prepare groundwater management plans nor reporting requirements when plans are implemented, so a comprehensive assessment of local planning efforts is not possible. Additionally, many plans have been adopted only recently, during a period of several consecutive wet years, so many of the plan components are either untested or not implemented.

At a minimum, successful groundwater management should be defined as maintaining and maximizing long-term reliability of the groundwater resource, focused on preventing significant depletion of groundwater in storage over the long term and preventing significant degradation of groundwater quality. A review of some of the groundwater management plans prepared under AB 3030 reveals that some plans are simply brief recitations about continuing the agency's existing programs. Not all agencies that enacted groundwater management plans under AB 3030 are actively implementing the plan.

Despite this apparent lack of implementation of groundwater management plans prepared under AB 3030, the bill has certainly increased interest in more effective groundwater management. With more than 200 agencies participating in plans and more than 120 of those involved in coordinated plans with other agencies, AB 3030 has resulted in a heightened awareness of groundwater management. Additionally, annual reports published by a few water agencies indicate that they are indeed moving toward better coordination throughout the basin and more effective management of all water supplies. Given the history of groundwater management in California, these seemingly small steps toward better management may actually represent giant strides forward.

More recently, financial incentives have played a large role in driving groundwater management activities. For example, under grant and loan programs resulting from Proposition 13 of 2000 (see description in Chapter 4), local agencies submitted applications proposing a total increase in annual water yield of more than 300,000 acre-feet through groundwater storage projects. Additional projects and programs would be developed with sufficient funding for feasibility and pilot studies. Unfortunately, not enough funding exists for all of the proposed projects, and many other legal and institutional barriers remain (see Box I, "Impediments to Conjunctive Management Programs in California"). It is clear, however, that further incentives would help agencies move ahead more aggressively in their groundwater management planning efforts.

Additional progress in groundwater management is reflected by passage of amendments to the Water Code (§§ 10753.4 and 10795.4 as amended, §§ 10753.7, 10753.8, and 10753.9 as amended and renumbered, and §§ 10753.1 and 10753.7 as added) through SB 1938 of 2002. The amendments require that groundwater management plans include specific components for agencies to be eligible for some public funds for groundwater projects. The provisions of SB 1938 (2001) are fully described in Chapters 3 and 4.

This evaluation of groundwater management success has not really considered ordinances and adjudications. Adjudications have been successful at maintaining the groundwater basin conditions, often restricting pumping for all basin users. In some cases, adjudication provides the necessary framework for more proactive management as well. Ordinances have successfully restricted exports from basins, but have not

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Box F Managing through a Joint Powers Agreement

In 1993, representatives from business, environmental, public, and water purveyor interests formed the Sacramento Area Water Forum to develop a plan to protect the region's water resources from the effects of prolonged drought as the demand for water continues to grow. The Water Forum was founded on two co-equal objectives: (1) to provide a reliable and safe water supply for the region's economic health and planned development to the year 2030 and (2) to preserve the fishery, wildlife, recreational and aesthetic values of the lower American River.

After a six-year consensus-based process of education, analysis and negotiation, the participants signed a Water Forum agreement to meet these objectives. The agreement provides a framework for avoiding future water shortages, environmental degradation, groundwater contamination, threats to groundwater reliability, and limits to economic prosperity.

The Sacramento Groundwater Authority (SGA) was formed to fulfill a key Water Forum goal of protecting and managing the north-area groundwater basin. The SGA is a joint powers authority formed for the purpose of collectively managing the region's groundwater resources. This authority permits SGA to make contractual arrangements required to implement a conjunctive use program, and also provides potential partners with the legal and political certainty for entering into long-term agreements.

SGA's regional banking and exchange program is designed to provide long-term supply benefits for local needs, but also will have the potential to provide broader statewide benefits consistent with American River environmental needs. Water stored in Folsom Lake would be conjunctively used with groundwater in order to reduce surface water diversions in dry years and to achieve in-lieu recharge of the basin in wet years. The conjunctive use program participants include 16 water providers in northern Sacramento and southern Placer counties that serve water to more than half a million people.

Two of three implementation phases of the program are complete. In the first phase, program participants identified long-term water supply needs and conducted an inventory of existing infrastructure that could be used to implement the program. In the second phase, SGA completed two pilot banking and exchange projects, demonstrating the technical, legal, and institutional viability of a regional conjunctive use program. In the first pilot study, water agencies worked with the U.S. Bureau of Reclamation and the Sacramento Area Flood Control Agency to bank 2,100 acre-feet of groundwater, providing additional flood storage capacity in Folsom Lake. In the second pilot study, Citrus Heights and Fair Oaks water districts and the city of Sacramento extracted and used 7,143 acre-feet of groundwater, forgoing a portion of their rights to surface water, making this water available to the Environmental Water Account. The third phase of the SGA program is to further solidify the institutional framework and construct facilities to implement a full-scale regional conjunctive use program. These facilities, that will result in an average annual yield of 21,400 acre-feet, are currently under construction, funded in part by a $21.6 million grant under Proposition 13 of 2000.

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Box G Managing a Basin through Integrated Water Management

Orange County Water District (OCWD) was established in 1933 by an uncodified Act (Water Code App. 40) to manage Orange County's groundwater basin and protect the Santa Ana River rights of water users of north-central Orange County. The district manages the groundwater basin, which provides as much as 75 percent of the water supply for its service area. The district strives for a groundwater-based water supply with enough reserves to provide a water supply through drought conditions. An integrated set of water management practices helps achieve this, including the use of recharge, alternative sources, and conservation.

Recharge

The Santa Ana River provides the main natural recharge source for the county's groundwater basin. Increased groundwater use and lower-than-average rainfall during the late 1980s and early 1990s forced the district to rely on an aggressive program to enhance recharge of the groundwater basin. Programs used today to optimize water use and availability include:

- Construction of levees in the river channel to increase infiltration.
- Construction of artificial recharge basins within the forebay.
- Development of an underwater basin cleaning vehicle that removes a clogging layer at the bottom of the recharge basin and extends the time between draining the basin for cleaning by a bulldozer.
- Use of storm water captured behind Prado Dam that would otherwise flow to the ocean.
- Use of imported water from the State Water Project and Colorado River.
- Injection of treated recycled water to form a seawater intrusion barrier.

Alternative Water Use and Conservation

OCWD has successfully used nontraditional sources of water to help satisfy the growing need for water in Orange County. Projects that have added to the effective supply of groundwater are:

- Use of treated recycled water for irrigation and industrial use.
- In-lieu use to reduce groundwater pumping.
- Change to low-flow toilets and showerheads.
- Participation of 70 percent of Orange County hotels and motels in water conservation programs.
- Change to more efficient computerized irrigation.

Since 1975, Water Factory 21 has provided recycled water that meets all primary and secondary drinking water standards set by the California Department of Health Services. OCWD has proposed a larger, more efficient membrane purification project called the Groundwater Replenishment System (GWRS), which is scheduled to begin operating at 70,000 acre-feet per year in 2007. By 2020 the system will annually supply 121,000 acre-feet of high quality water for recharge, for injection into the seawater intrusion barrier, and for direct industrial uses.

This facility will use a lower cost microfiltration and reverse osmosis treatment process that produces water of near distilled quality, which will help reverse the trend of rising total dissolved solids (TDS) in groundwater caused by the recharge of higher TDS-content Santa Ana River and Colorado River waters. The facility will use about half the energy required to import an equivalent amount of water to Orange County from Northern California. The GWRS will be funded, in part, by a $30 million grant under Proposition 13 of 2000.

Source: Orange County Water District

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Box H Managing Groundwater using both Physical and Institutional Solutions

Four agencies share responsibility for groundwater management in Ventura County. Coordination and cooperation between these agencies focus on regular meetings, attendance at each other's board meetings, joint projects, watershed committees, and ongoing personal contacts to discuss water-related issues. The agencies and their areas of responsibility are:

- United Water Conservation District – physical solutions, monitoring, modeling, reporting, administering management plans and adjudication;
- Fox Canyon Groundwater Management Agency – pumping allocations, credits and penalties, abandoned well destruction, data for irrigation efficiency;
- County of Ventura – well permits, well construction regulations, tracking abandoned wells; and
- Calleguas Municipal Water District – groundwater storage of imported water.

In Ventura County 75% to 80% of the extracted groundwater is for agriculture; the remainder is for municipal and industrial use. Seawater intrusion into the aquifers was recognized in the 1940s and was the driving force behind a number of groundwater management projects and policies in the county's groundwater basins. As groundwater issues became more complicated at the end of the 20th century, these groundwater management projects and policies were useful in solving a number of problems.

Physical Solutions

Physical solutions substitute supplemental surface water for groundwater pumping near coastal areas, increase basin recharge, and increase the reliability of imported water. Projects include:

- Winter flood-flow storage for dry season release
- Wells and pipelines to move pumping for drinking water away from the coast
- Diversion structures to supply surface water to spreading grounds and irrigation
- Pipelines to convey surface water to coastal areas
- Las Posas Basin Aquifer Storage and Recovery project

Institutional Solutions

Institutional solutions focus on developing and implementing effective groundwater management programs, reducing pumping demands, tracking groundwater levels and water quality, managing groundwater pumping patterns, and destroying abandoned wells to prevent cross-contamination of aquifers. Solutions include:

- Creation of Fox Canyon Groundwater Management Agency (GMA), which represents each major pumping constituency
- Use of irrigation efficiency (agriculture), water conservation, and alternative sources of water (urban) to reduce pumping by 25%
- Manage outside the GMA area through an AB 3030 plan and a court adjudication
- Limit new permits for wells in specific aquifers to avoid seawater intrusion
- Creation of a program to destroy abandoned wells
- Creation of a database of historical groundwater levels and quality information collected since the 1920s
- Development of a regional groundwater flow model and a regional master plan for groundwater projects
- Creation of an irrigation weather station to assist in irrigation efficiency

Implementation of these physical and institutional management tools has resulted in the reversal of seawater intrusion in key coastal monitoring wells. These same tools are being used to mitigate saline intrusion (not seawater) in two inland basins and to reduce seasonal nitrate problems in the recharge area. Work is being expanded to help reduce loading of agricultural pesticides and nutrients. Without close coordination and cooperation of the county's water-related agencies, municipalities, and landowners, it would have been very difficult to implement most of these solutions. Although such coordination takes time, the investment has paid off in solutions that help provide a sustainable water supply for all water users in Ventura County.

Source: United Water Conservation District

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necessarily improved groundwater management. The primary intent of most ordinances is to ensure that proponents of projects are held accountable for potential impacts of the proposed export projects. As studies lead to a better understanding of local water resources, development of pilot export and transfer projects, with appropriate monitoring, may lead to greater certainty in managing groundwater resources. Areas managed under adjudications and ordinances will continue to develop more active management approaches. Population growth and its accompanying increased demand on the resources is a certainty. Most geographic areas in California are not immune to this growth, so strategies for more than just maintaining existing groundwater supply through extraction or export restrictions need to be implemented.

Box I Impediments to Conjunctive Management Programs in California

In 1998 the National Water Research Institute, in cooperation with the Association of Ground Water Agencies and the Metropolitan Water District of Southern California, conducted a workshop to determine the biggest impediments to implementing a cost-effective conjunctive water management program in California.

Since that time, some steps have been taken to overcome those impediments, but several important barriers remain. Workshop participants identified the 10 most significant obstacles:

1) Inability of local and regional water management governance entities to build trust, resolve differences (internally and externally), and share control.
2) Inability to match benefits and funding burdens in ways that are acceptable to all parties, including third parties.
3) Lack of sufficient federal, State, and regional financial incentives to encourage groundwater conjunctive use to meet statewide water needs.
4) Legal constraints that impede conjunctive use, regarding storage rights, basin judgments, area of origin, water rights, and indemnification.
5) Lack of statewide leadership in the planning and development of conjunctive use programs as part of comprehensive water resources plans, which recognize local, regional, and other stakeholders' interests.
6) Inability to address quality difference in "put" versus "take"; standards for injection, export, and reclaimed water; and unforeseeable future groundwater degradation.
7) Risk that water stored cannot be extracted when needed because of infrastructure, water quality or water level, politics, and institutional or contractual provisions.
8) Lack of assurances to prevent third-party impacts and assurances to increase willingness of local citizens to participate.
9) Lack of creativity in developing lasting "win-win" conjunctive use projects, agreements, and programs.
10) Supplemental suppliers and basin managers have different roles and expectations in relation to conjunctive use.

[**Editor's note**: The California Department of Water Resources' Conjunctive Water Management program has taken significant steps to overcome several of these impediments, using a combination of California Bay-Delta Authority, DWR, Proposition 13, and AB 303 funds to promote locally planned and controlled conjunctive use programs.]

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Future Groundwater Management in California

Trying to predict what will happen with groundwater management in California is difficult given that actions by all of the involved groups—landowners, local governments, local, State, and federal agencies, and the courts—will continue to shape groundwater management in the future. However, the increasing population and its demands on California's water supply will accelerate the rate at which groundwater management issues become critical and require resolution. Some general conclusions are:

- Groundwater management will continue to be a local responsibility with increasing emphasis on how actions in one part of a basin impact groundwater resources throughout the basin. Regional cooperation and coordination of groundwater management activities will increase.

- As the State's population continues to grow, the increased reliance on groundwater will keep the topic of groundwater management at the forefront of legislative interest.

- Coordinated management of groundwater and surface water resources, through further development of conjunctive water management programs and projects, will become increasingly important.

- The increased reliance on groundwater in the future will necessitate a more direct link between land use planning, watershed management, floodplain management, and groundwater management plans.

- Current trends indicate that financial incentives in the form of loans and grants are increasing groundwater management planning and implementation at the local level. These successes will only continue at the current pace with increased funding to local agencies.

- Management of groundwater will increasingly include consideration of groundwater quality and groundwater quantity.

- Groundwater will be an important element in the trend toward an integrated water management approach that considers the full range of demand management and supply alternatives.

- Understanding of the relationship of groundwater and surface water and the role of groundwater in the environment will continue to grow.

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Box J Managing Groundwater Quantity and Quality

When people hear the words "groundwater monitoring"' they may think either of measuring groundwater levels or of analyzing for groundwater quality. In reality, monitoring and management of groundwater quantity and groundwater quality are inseparable components of a management plan.

Although the primary focus of the California Department of Water Resources (DWR) is on groundwater quantity and the measures taken by local agencies to manage supply, management must also consider groundwater quality. Natural or anthropogenic contamination and pumping patterns that are not managed to protect groundwater quality may limit the quantity of groundwater that is available for use in a basin.

Several State programs provide useful data as well as regulatory direction on groundwater quality that managers can use in managing their groundwater supply. One program is the Drinking Water Source Assessment and Protection Program prepared by the California Department of Health Services in response to 1996 amendments to the federal Safe Drinking Water Act. The DWSAP requires water purveyors to assess sources of drinking water, develop zones indicating time of travel of groundwater, and identify potentially contaminating activities around supply wells. The goal is to ensure that the quality of drinking water sources is maintained and protected. Other useful water quality data for groundwater managers is collected by the agencies within the California Environmental Protection Agency, including the State Water Resources Control Board, Department of Pesticide Regulation and the Department of Toxic Substances Control, which are discussed in more detail in Chapter 5. Each of these agencies has a specific statutory responsibility to collect groundwater quality information and protect water quality.

Protection of Recharge Areas

Groundwater recharge areas, and the human activities that can render them unusable, are an example of the need to coordinate land use activities to protect both groundwater quality and quantity. Protection of recharge areas, whether natural or man-made, is necessary if the quantity and quality of groundwater in the aquifer are to be maintained. Existing and potential recharge areas must be protected so that they remain functional, that is they continue to provide recharge to the aquifer and they are not contaminated with chemical or microbial constituents. Land-use practices should be implemented so that neither the quantity nor quality of groundwater is reduced. A lack of protection of recharge areas could decrease the availability of usable groundwater and require the substitution of a more expensive water supply.

Many potentially contaminating activities have routinely been practiced in recharge areas, leading to the presence of contaminants in groundwater. In many areas, groundwater obtained from aquifers now requires remediation. Recent studies in some areas show that recharge areas are contaminated, but down-gradient wells are not, indicating that it is only a matter of time before contaminants in wells reach concentrations that require treatment of the groundwater.

In addition to quality impacts, urban development, consisting of pavement and buildings on former agricultural land, lining of flood control channels, and other land use changes have reduced the capacity of recharge areas to replenish groundwater, effectively reducing the safe yield of some basins.

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Box J Managing Groundwater Quantity and Quality (continued)

To ensure that recharge areas continue to replenish high quality groundwater, water managers and land use planners should work together to:

- Identify recharge areas so the public and local zoning agencies are aware of the areas that need protection from paving and from contamination;
- Include recharge areas in zoning categories that eliminate the possibility of contaminants entering the subsurface;
- Standardize guidelines for pre-treatment of the recharge water, including recycled water;
- Build monitoring wells to collect data on changes in groundwater quality that may be caused by recharge; and
- Consider the functions of recharge areas in land use and development decisions.

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Chapter 3
Groundwater Management Planning and Implementation

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The 1990s were a very important decade in the history of groundwater management in California. In 1992, the State Legislature provided an opportunity for more formal groundwater management with the passage of AB 3030 (Water Code § 10750 et seq.). More than 200 agencies have adopted an AB 3030 groundwater management plan. Additionally, 24 of the 27 counties with ordinances related to groundwater management adopted those laws during the 1990s. Plans prepared under AB 3030 certainly brought unprecedented numbers of water agencies into the groundwater management arena, and counties are now heavily involved in groundwater management, primarily through ordinances. However, many plans prepared under AB 3030 have had little or no implementation, and many counties focus primarily on limiting exports rather than on a comprehensive management program. As a result, the California Budget Act of 1999 (Stats. 1999, ch. 50), which authorized this update to Bulletin 118, directed the California Department of Water Resources (DWR) to complete several tasks, including developing criteria for evaluating groundwater management plans and developing a model groundwater management ordinance. This chapter presents the results of these directives. The intent is to provide a framework that will assist local agencies in proactively planning and implementing effective groundwater management programs.

Criteria for Evaluating Groundwater Management Plans—Required and Recommended Components

In 2002, the Legislature passed SB 1938 (Stats 2002, ch 603), which amended Water Code section 10750 et seq to require that groundwater management plans adopted by local agencies include certain components to be eligible for public funds administered by DWR for construction of groundwater projects; the statute applies to funds authorized or appropriated after September 1, 2002. In addition to the required components, DWR worked with representatives from local water agencies to develop a list of additional recommended components that are common to effective groundwater management.

Both the "required" and the "recommended" components are tools that local agencies can use either to institute a groundwater management plan for the first time or to update existing groundwater management plans. These components are discussed below and listed in Appendix C, which can be used as a checklist by local agencies to assess whether their groundwater management plans are addressing these issues.

Required Components of Local Groundwater Management Plans

As of January 1, 2003, amendments to Water Code Section 10750 et seq., resulting from the passage of SB 1938, require new groundwater management plans prepared under section 10750, commonly referred to as AB 3030 plans, to include the first component listed below.

Groundwater management plans prepared under any statutory authority must include components 2 through 7 to be eligible for the award of public funds administered by DWR for the construction of groundwater projects or groundwater quality projects. These requirements apply to funds authorized or appropriated after September 1, 2002. Funds appropriated under Water Code section 10795 et seq. (AB 303 – Local Groundwater Assistance Fund) are specifically excluded.

1) Documentation that a written statement was provided to the public "describing the manner in which interested parties may participate in developing the groundwater management plan" (Water Code, § 10753.4 (b)).

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2) Basin management objectives (BMOs) for the groundwater basin that is subject to the plan (Water Code, § 10753.7 (a)(1)).
3) Components relating to the monitoring and management of groundwater levels, groundwater quality, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping (Water Code, § 10753.7 (a)(1)).
4) A plan by the managing entity to "involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin" (Water Code, § 10753.7 (a)(2)). A local agency includes "any local public agency that provides water service to all or a portion of its service area" (Water Code, § 10752 (g)).
5) Adoption of monitoring protocols (Water Code, § 10753.7 (a)(4)) for the components in Water Code section 10753.7 (a)(1). Monitoring protocols are not defined in the Water Code, but the section is interpreted to mean developing a monitoring program capable of tracking changes in conditions for the purpose of meeting BMOs.
6) A map showing the area of the groundwater basin as defined by DWR Bulletin 118 with the area of the local agency subject to the plan as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a groundwater management plan (Water Code, § 10753.7 (a)(3)).
7) For local agencies not overlying groundwater basins, plans shall be prepared including the above listed components and using geologic and hydrologic principles appropriate to those areas (Water Code, § 10753.7 (a)(5)).

Recommended Components of Groundwater Management Plans

Although the seven components listed above are required only under certain conditions, they should always be considered for inclusion in any groundwater management planning process. In addition to the required components of a groundwater management plan resulting from the passage of SB 1938, it is recommended that the components listed below be included in any groundwater management plan adopted and implemented by a local managing entity. These additional components were developed in accord with the Budget Act of 1999 and with the assistance of stakeholder groups. The components should be considered and developed for specific application within the basin, subbasin, or agency service area covered by the plan. Additional components will likely be needed in specific areas. The level of detail for each component will vary from agency to agency. None of the suggested data reporting in the components should be construed to require disclosure of information that is confidential under State law. Local agencies should consider both the benefits of public dissemination of information and water supply security in developing reporting requirements.

Manage with the Guidance of an Advisory Committee

The managing entity should establish an advisory committee of interested parties that will help guide the development and implementation of the plan. The committee can benefit management in several ways. First, the committee can bring a variety of perspectives to the management team. As the intent of local groundwater management is to maintain and expand local benefits from the availability of the resource, it makes sense that the intended beneficiaries are a part of the management process. Second, the committee is free to focus on the specifics of groundwater management without being distracted by the many operational activities that the managing entity (such as a water district) must complete. Third, some parties could be negatively impacted by certain groundwater management decisions, and these actions and potential adverse impacts should be a part of the decision-making process to help reduce future conflicts. Finally, the advisory committee helps the managing entity gain the confidence of the local constituency by providing the opportunity for interested parties to participate in the management process.

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Many managing entities have already elected to use advisory committees for implementation of their groundwater management plans. The composition of these committees varies widely. Some groups consist entirely of stakeholders, others add local or State government representatives or academic members as impartial third parties, and some have included consultants as technical advisers. Some plans use multiple advisory committees to manage unique subareas. Some plans appoint advisory committees with different objectives, such as one that deals with technical issues and another that deals with policy issues. There is no formula for the composition of an advisory committee because it should ultimately be based on local management needs and should include representation of diverse local interests.

The Tulare Lake Bed Coordinated Management Plan provides an example of the benefit of an advisory committee. The plan includes nine groups of participants, making coordination and communication a complicated issue. To allow for greater communication, an executive committee was established consisting of one voting member from each public agency participating in the plan and one voting member representing a combined group of private landowner plan participants. The committee administers groundwater management activities and programs for the plan (TLBWSD 2002).

Describe the Area to Be Managed under the Plan

The plan should include a description of the physical setting and characteristics of the aquifer system underlying the plan area in the context of the overall basin. The summary should also include a description of historical data, including data related to groundwater levels, groundwater quality, subsidence, and groundwater-surface water interaction; known issues of concern with respect to the above data; and a general discussion of historical and projected water demands and supplies. All of these data are critical to effective groundwater management because they demonstrate the current understanding of the system to be managed and serve as a point of departure for monitoring activities as part of plan implementation.

Create a Link Between Management Objectives and Goals and Actions of the Plan

The major goal of any groundwater management plan is to maintain a reliable supply of groundwater for long-term beneficial uses of groundwater in the area covered by the plan. The plan should clearly describe how each of the adopted management objectives helps attain that goal. Further, the plan should clearly describe how current and planned actions by the managing entity help meet the adopted management objectives. The plan will have a greater chance of success by developing an understanding of the relationship between each action, management objectives, and the goal of the groundwater management plan.

For example, prevention of contamination of groundwater from the land surface is a management objective that clearly supports the goal of groundwater sustainability. Management actions that could help support this objective include (1) educating the public through outreach programs that explain how activities at the surface ultimately impact groundwater, (2) developing wellhead protection programs or re-evaluating existing programs, (3) working with the local responsible agency to ensure that permitted wells are constructed, abandoned, and destroyed according to State well standards, (4) investigating whether local conditions necessitate higher standards than those adopted by the local permitting agency for the construction, abandonment, or destruction of wells, and (5) working with businesses engaged in practices that might impact groundwater to reduce the risks of contamination.

The concept of having a management objective is certainly not new. While many existing plans do not clearly include management objectives nor specifically identify actions to achieve objectives, some plans indirectly include these components. As an example, Eastern Municipal Water District's (EMWD) Groundwater Management Plan states that its goal includes maximizing "the use of groundwater for all beneficial uses in such a way as to lower the cost of water supply and to improve the reliability of the total

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water supply for all users." To achieve this goal, EMWD has listed several issues to be addressed. One is the prevention of long-term depletion of groundwater. This can be defined as a management objective even though it is not labeled as such. Where this management objective is currently unmet in the North San Jacinto watershed portion of the plan area, EMWD has identified specific actions to achieve that objective including the reduction of groundwater extraction coupled with pursuing the construction of a pipeline to act as an alternative source of surface water for the impacted area (EMWD 2002).

Describe the Plan Monitoring Program

The groundwater management plan should include a map indicating the locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence, stream gaging, and other applicable monitoring. The groundwater management plan should summarize the type of monitoring (for example, groundwater level, groundwater quality, subsidence, streamflow, precipitation, evaporation, tidal influence), type of measurements, and the frequency of monitoring for each location. Site specific monitoring information should be included in each groundwater management plan. The plan should include the well depth, screened interval(s) and aquifer zone(s) monitored and the type of well (public, irrigation, domestic, industrial, monitoring). These components will serve as a tool for the local managing entity to assess the adequacy of the existing monitoring network in tracking the progress of plan activities.

The groundwater management plan developed for the Scotts Valley Water District (SVWD) provides a detailed description of the monitoring program in Santa Cruz County (Todd Engineers 1994) Table 6 is SVWD's monitoring table, which serves as an example of the level of detail that is useful in a plan (Todd Engineers 2003a). Figure 9 shows the locations and types of monitoring points for each monitoring site. The monitoring table specifies in detail the data available and the planned monitoring. These serve as useful tools for SVWD to visualize the types and distribution of data available for their groundwater management activities. In addition to the minimum types of monitoring, SVWD summarizes other types of data that are relevant to their groundwater management effort.

Describe Integrated Water Management Planning Efforts

Water law in California treats groundwater and surface water as two separate resources with the result that they have largely been managed separately. Such management does not represent hydrologic reality. Recently, managers of a number of resources are becoming increasingly aware of how their planning activities could impact or be impacted by the groundwater system. Because of this, the local managing entity should describe any current or planned actions to coordinate with other land use, zoning, or water management planning entities.

Integrated management is addressed in existing groundwater management plans in several ways, including conjunctively managing groundwater with surface water supplies, recharging water from municipal sewage treatment plants, and working with local planning agencies to provide comments when a project is proposed that could impact the groundwater system.

Examples of planning efforts that should be integrated with groundwater management may include watershed management, protection of recharge areas, agricultural water management, urban water management, flood management, drinking water source assessment and protection, public water system emergency and disaster response, general plans, urban development, agricultural land preservation, and environmental habitat protection or restoration. Another example that may appear insignificant is transportation infrastructure. However, local impacts on smaller aquifers could be significant when landscaping of medians and interchanges requires groundwater pumping for irrigation or when paved areas are constructed over highly permeable sediments that act as recharge zones for the underlying aquifer.

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Table 6 Scotts Valley Water District's Groundwater Monitoring Plan

Monitoring type	Location	Measurement type	Date started	Frequency/ maintainer	Notes
Precipitation	El Pueblo Yard	15-minute recording	Feb-85	Daily/District, Monthly/City	Other historic gages:(1) Blair site on Granite Ck. Rd. (Jan. 1975 - Dec. 1980)
	WWTP	5-minute recording	1990	Daily/City	(2) Hacienda Dr. (Jul. 1974 - Mar. 1979) (3) El Pueblo Yard bucket gage (Jan. 1981 - Jan. 1985)
Evaporation	El Pueblo Yard	Pan	Jan-86	Daily/District	Evaporation pan raw data not compiled after July 1990
Evapotranspiration	De Laveaga Park, Santa Cruz	Automated active weather station	Sep-90	California Irrigation Management Information System/Monthly	Data available on-line through CIMIS
Streamflow	Carbonera Ck at Scotts Valley @ Cabonera Way Bridge (#111613000)	15-minute recording	Jan-85	USGS/ Daily	Other historic gages: (1) Carbonera Ck @ Santa Cruz (#11161400) 150 feet upstream from mouth (1974-1976 partial data)
	Bean Ck near Scotts Valley @ Hermon Crossing (#11160430)	15-minute recording	Dec-88	USGS/ Daily	(2) Bean Ck near Felton (#11160320) (1973-1978 partial data), low flows at same location (1983-1988)
	Eagle Creek In Henry Cowell Redwoods State Park	Bucket-Fall, Flow Meter-Spring	Mar-01	Semi-annually/ Todd Engineers	(3) Carbonera Creek @ Glen Canyon (1990-1994?)
Well Inventory	T10S/R01E Sections 6-9, 16-20, 30 and T10S/R02E Sections 1,11-14, 23-26, 36	Over 400 wells: location, log, type, capacity, etc. stored in GIS, and Access database	1950s	Logs from DWR maintained by Todd Engineers	
Groundwater Levels	~34 Santa Magarita aquifer and ~14 Lompico formation wells	Depth to water	1968	Quarterly/ District and cooperators	Data from over 75 wells, as early as 1968, bi-monthly 1983-1989
Pumpage	T10S/R01E Sections 6-9, 16-20, 30 and T10S/R02E Sections 1,11-14, 23-26, 36 District wells in production and on standby	Metered	1975	Monthly/ Scotts Valley Water District, Mt. Hermon Association, Hanson Aggregates West, San Lorenzo Valley Water District	Other historic pumpage data: Manana Woods (1988-1996 partial data)

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Table 6 Scotts Valley Water District's Groundwater Monitoring Plan (continued)

Monitoring type	Location	Measurement type	Date started	Frequency/ maintainer	Notes
Groundwater Quality	T10S/R01E Sections 6-9, 16-20, 30 and T10S/R02E Sections 1,11-14,23-26, 36 District wells in production	Title 22 constituents	1963	At least semi-annual/ District and others	Data from over 80 wells, as early as 1963, monitoring frequency similar to groundwater level program
	North Scotts Valley 3 shallow monitoring wells	Metals, nitrogen species, general minerals	Mar-01	Semi-annually/ Todd Engineers	
Surface Water Quality	4 sites on Carbonera and 3 sites on Bean Creek	Grab samples - metals, nitrogen species, general minerals	Mar-01	Semi-annually/ Todd Engineers	
Wastewater Outflows	City of Scotts Valley WWTP @ Lundy Lane	Wastewater outflow volume and effluent quality	1965	Daily/City of Scotts Valley	Plant operational in 1965 (septic systems pre-1965)
Recycled Water Production	Scotts Valley WWTP	Recycled water quantity and quality	2002	At least quarterly/ WWTP	

Source: Todd Engineering 2003a

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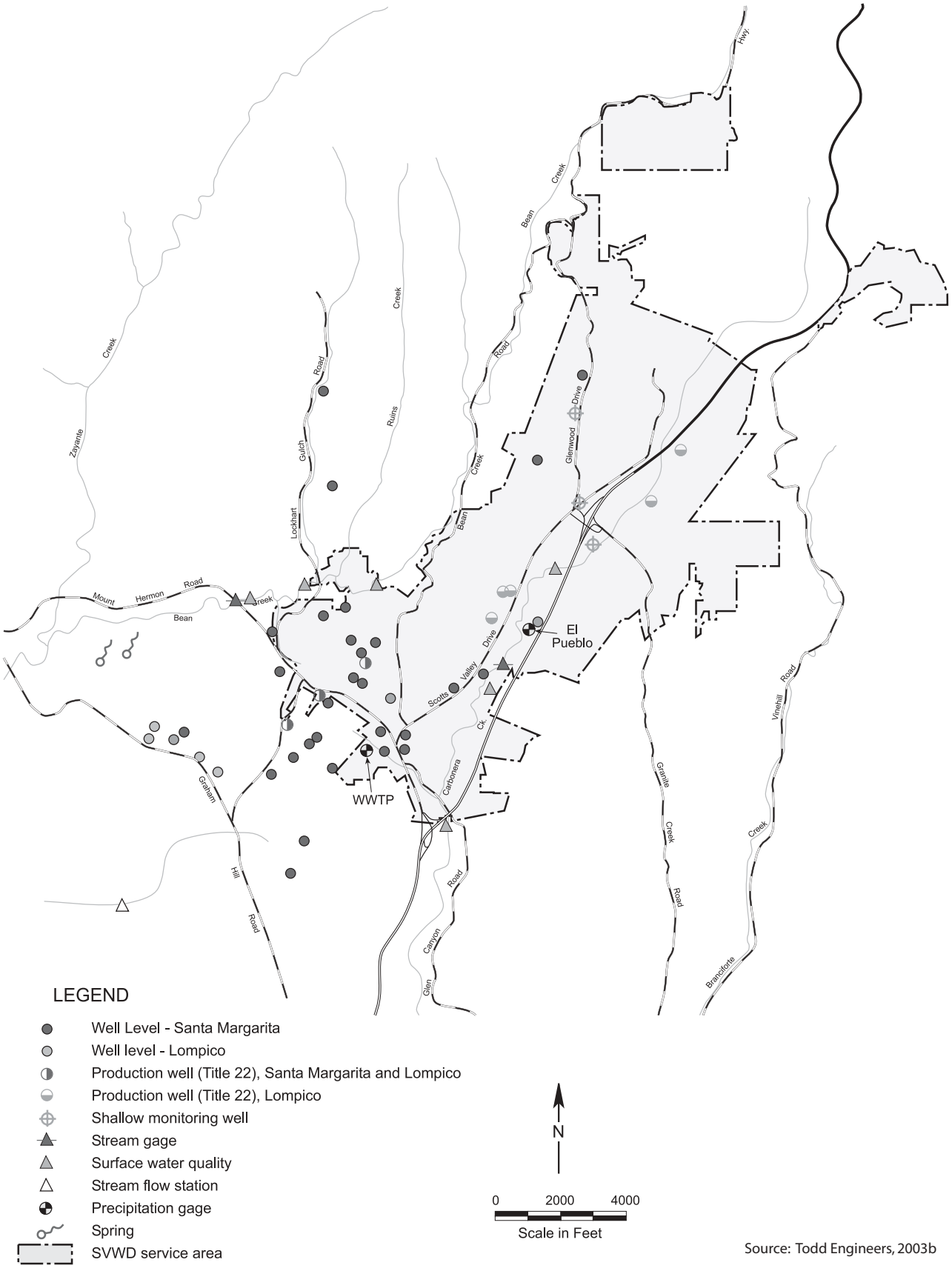

Figure 9 Scotts Valley Water District's Groundwater Management Plan monitoring locations

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Box K What are Management Objectives?

Management objectives are the local managing entity's way of identifying the most important issues in meeting local resource needs; they can be seen as establishing a "value system" for the plan area. There is no fixed set of management objectives for any given plan area. Some of the more commonly recognized management objectives include the monitoring and managing of groundwater levels, groundwater quality, inelastic land subsidence, and changes in streamflow and surface water quality where they impact or are impacted by groundwater pumping. Management objectives may range from being entirely qualitative to strictly quantified.

Each management objective would have a locally determined threshold value associated with it, which can vary greatly. For example, in establishing a management objective for groundwater quality, one area may simply choose to establish an average value of total dissolved solids as the indicator of whether a management objective is met, while another agency may choose to have no constituents exceeding the maximum contaminant level for public drinking water standards. While there is great latitude in establishing management objectives, local managers should remember that the objectives should serve to support the goal of a sustainable supply for the beneficial use of the water in their particular area.

An example of an alternative management objective is Orange County Water District's (OCWD) objective of maintaining available storage space in its management area at 200,000 acre-feet. The objective does not require that groundwater elevations be fixed at any particular location, although managing to this objective would likely have the net benefit of stabilizing water levels. Groundwater storage is a dynamic value, so attempting to meet this management objective is an ongoing challenge. OCWD has implemented many management actions directly aimed at managing the basin to meet this objective.

The Deer Creek and Tule River Authority provides an excellent example of how groundwater management activities can be coordinated with other resources. The authority, in conjunction with the U.S. Bureau of Reclamation, has constructed more than 200 acres of recharge basins as part of its Deer Creek Recharge-Wildlife Enhancement Project. When available, the project takes surplus water during winter months and delivers it to the basins, which serve as winter habitat for migrating waterfowl, creating a significant environmental benefit. Most of the water also recharges into the underlying aquifer, thereby benefiting the local groundwater system.

Report on Implementation of the Plan

The managing entity should produce periodic reports—annually or at other frequencies determined by the local managing entity—summarizing groundwater basin conditions and groundwater management activities. For the period since the previous update, the reports should include:

- A summary of monitoring results, including historical trends,
- A summary of actual management actions,
- A summary, supported by monitoring results, of whether management actions are achieving progress in meeting management objectives,
- A summary of proposed management actions, and
- A summary of any plan component changes, including addition or modification of management objectives.

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Unfortunately, many plans were prepared in the mid-1990s with little or no follow-up documentation of whether the plan is actually being implemented. This makes it difficult to determine what progress has been achieved in managing the groundwater resource. Periodic reports will serve as a tool for the managing entity to organize its many activities to implement the plan, act as a driving force for plan implementation, and help interested parties understand the progress made by local entities in managing their groundwater resource.

Progress reports on SVWD (Todd Engineers 2002) and EMWD (2002) groundwater management plans serve as excellent examples of the value of such an exercise. Both reports effectively portray the results of management actions: progress toward achieving objectives and specific recommendations for future management actions. An example of reporting on the modification of a management objective for water quality can be found in EMWD's 2000 Annual Report (EMWD 2001). A task force of more than 20 water suppliers and wastewater agencies, including EMWD, worked to update the Regional Water Quality Control Board's Region 5 Basin Plan objectives for nitrogen and total dissolved solids in water, effectively changing EMWD's management objectives for those constituents.

Evaluate the Plan Periodically

The managing entity and advisory committee should re-evaluate the entire plan. Periodic evaluation of the entire management plan is essential to define successes and failures under the plan and identify changes that may be needed. Additionally, re-evaluation of the plan should include assessment of changing conditions in the basin that may warrant modification of the plan or management objectives. Adjustment of components in the plan should occur on an ongoing basis if necessary. The re-evaluation of the plan should focus on determining whether the actions under the plan are meeting the management objectives and whether the management objectives are meeting the goal of sustaining the resource.

While there are several examples of existing groundwater management plans that demonstrate ongoing changes to plan activities, there are no known examples of such an approach to entirely re-evaluate an existing plan. This is likely due in part to the occurrence of several consecutive wet years in the mid- and late-1990s. The abundant surface water supplies reduced the need to actively manage groundwater supplies in many cases. More recent dry conditions and the recent passage of SB 1938 will create an excellent opportunity for managing entities to begin a re-evaluation of existing plans.

Model Groundwater Management Ordinance

As discussed in the previous chapter, ordinances are groundwater management mechanisms enacted by local governments through exercise of their police powers to protect the health and safety of their citizens. In Baldwin v. Tehama County (1994), the appellate court declared that State law does not preempt the field of groundwater management.

In the mid- to late-1990s, many counties adopted ordinances that effectively prevented export of groundwater from the county, even though none specifically prohibited export. The intent of each of these ordinances is to sustain groundwater as a viable local resource. To ensure that goal, an export project proponent is required by most of the ordinances to show that the proposed project will not cause depletion of the groundwater, degradation of groundwater quality, or subsidence before a permit to export groundwater can be issued. Although these ordinances do not specifically require threshold limits for each of these potential negative impacts, a project proponent can really only show that these negative effects will not occur if the proponent develops a groundwater management plan.

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Many of these ordinances were developed in response to the plans of some agencies or landowners to export groundwater or develop a groundwater substitution project where surface water is exported and groundwater is substituted for local use. In some cases, short-term export actually took place, leading to a number of claims of negative third party impacts. Residents of some counties became concerned because no one knew how much groundwater was available for local use and how much groundwater was available for export. In short, details of the hydrology of the basin, including surface water and groundwater availability, water quality, and the interaction of surface water and groundwater were not known. This lack of detailed knowledge about the operating potential of their groundwater resources led counties to take what they viewed as protective action, which consisted of requiring a permit before anyone could export groundwater from the county.

From the perspective of DWR, groundwater should be managed in a manner that ensures long-term sustainability of the resource for beneficial uses. Those beneficial uses are to be decided by the local stakeholders within the basin. In some areas, there may be an ample supply of water, so groundwater exports or substitution projects are feasible while local beneficial uses of the water supply are maintained. In other areas, limiting exports may be necessary to maintain local beneficial uses. Such determinations can be made only after the data are collected and evaluated and the results are used to develop management objectives for the basin.

While developing both the criteria for evaluating groundwater management plans and the model groundwater management ordinance, DWR staff has borne two principles in mind. First, the goal of groundwater management, whether accomplished by a plan or by an ordinance, is to sustain and often expand a groundwater resource. Second, groundwater management, whether accomplished by a plan or by an ordinance, requires that local agencies address and resolve the same or similar issues within the boundaries of the agencies. To say it in different words, whether it is a plan or an ordinance, good groundwater management should address the same issues and problems and arrive at the same conclusions and solutions to satisfy the needs of the local area. While some areas may allow or promote exports, others may not.

As stated above, the Legislature required a model ordinance as one of the elements of this update of Bulletin 118. The model ordinance is included as Appendix D and can be used by local governments that have identified a need to adopt a groundwater management ordinance. The model is an example of what a local ordinance might include. Local conditions will require some additions, modifications, or deletions. The variety of political, institutional, legal, technical, and economic opportunities and constraints throughout California guarantees that there will be differences to which the model will have to be adapted. Local governments interested in adopting a groundwater management ordinance are encouraged to consider all components included in the model.

Water Code section 10753.7(b)(1)(A) allows an agency to participate in or consent to be subject to a groundwater management plan, a basin-wide management plan, or other integrated regional water management plan in order to meet the funding eligibility requirements that resulted from passage of SB 1938 (2001). A local government that adopts an ordinance should consider whether or not it will have local agencies that do not have their own groundwater management plan, but consent to be managed under the ordinance. If this situation is anticipated, the ordinance should include the required components described in the Water Code so State funding can be pursued.

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Chapter 4

Recent Actions Related to Groundwater Management

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Chapter 4
Recent Actions Related to Groundwater Management

The past few years have seen significant actions that impact groundwater management in California. Below are several examples of recent actions including legislation, ballot measures, and executive orders that show the State Legislature and the citizens of California clearly recognize the importance of groundwater and its appropriate management in meeting the present and future water supply needs of the State.

Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act of 2000 (Proposition 13)

On March 7, 2000, California voters approved a $1.97-billion general obligation bond known as the Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act (Proposition 13). Of the nearly $2 billion, $230 million was earmarked for groundwater programs. The act authorizes $200 million for grants for feasibility studies, project design, and construction of conjunctive use facilities (Water Code, § 79170 et seq.) and $30 million in loans for local agency acquisition and construction of groundwater recharge facilities and feasibility study grants for projects potentially eligible for the loan program (Water Code, § 79161 et seq.). More than $120 million have been awarded in grants and loans to local agencies in the first two years of implementation of these programs.

California Bay-Delta Record of Decision

The goal of the California Bay-Delta (formerly CALFED) program is to restore ecosystem health and improve water management in the Bay-Delta system. The program has four primary objectives:

- Provide good water quality for all beneficial uses,
- Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species,
- Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system, and
- Reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

The Record of Decision (ROD), released in August 2000, sets forth a 30-year plan to address ecosystem health and water supply reliability problems in the Bay-Delta system. The ROD lays out specific actions and investments over the first seven years to meet program goals. Most important, with respect to groundwater is the California Bay-Delta program's commitment to local groundwater management. The ROD states, "CALFED will work with local governments and affected stakeholders to develop legislation to strengthen AB 3030 and provide technical and financial incentives to encourage more effective basin-wide groundwater management plans…" (CALFED 2000). The ROD encourages basin management that is developed at the subbasin level so that it addresses local needs, but is coordinated at the basin-wide level so that it considers impacts to other users in the basin. The ROD also commits Bay-Delta agencies to "facilitate and fund locally supported, managed, and controlled groundwater and conjunctive use projects with a total of 500,000 acre-feet to 1 million acre-feet (maf) of additional storage capacity by 2007" (CALFED 2000).

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Local Groundwater Management Assistance Act of 2000 (AB 303, Water Code Section 10795 et seq.)

The goal of the Local Groundwater Management Assistance Act is to help local agencies better understand how to manage groundwater resources effectively to ensure the safe production, quality, and proper storage of groundwater in the State. The act created the Local Groundwater Assistance Fund, which must be appropriated annually. In three years, more than $15 million in grants were awarded for 71 projects. Grants went to local agencies for groundwater studies and projects that contribute to basin and subbasin management objectives, including but not limited to groundwater monitoring and groundwater basin management. Grants are available to all geographic areas of the State. This act serves to emphasize that groundwater is recognized as an important local resource and, to the extent that groundwater is properly managed at the local level, serves to benefit all Californians.

Groundwater Quality Monitoring Act of 2001 (AB 599, Water Code Section 10780 et seq.)

Assembly Bill 599, known as the Groundwater Quality Monitoring Act of 2001, set a goal to establish comprehensive groundwater monitoring and increase the availability of information about groundwater quality to the public. The objective of the program is to highlight those basins in which contamination has occurred or is likely to occur and provide information that will allow local managers to develop programs to curtail, treat, or avoid additional contamination. The act required the State Water Resources Control Board (SWRCB), in coordination with an Interagency Task Force (ITF) and a Public Advisory Committee (PAC), to integrate existing monitoring programs and design new program elements, as necessary, to establish a comprehensive statewide groundwater quality monitoring program.

Through the ITF and PAC, the Comprehensive Groundwater Quality Monitoring Program was developed. The program will seek to:

- Accelerate the monitoring and assessment program already established by the SWRCB,
- Implement monitoring and assessment in accordance with a prioritization of basins/subbasins,
- Increase coordination and data sharing among groundwater agencies, and
- Maintain groundwater data in a single repository to provide useful access by the public while maintaining appropriate security measures.

The Comprehensive Groundwater Quality Monitoring Program is expected to provide the following key benefits:

- A common base communications medium for agencies to utilize and supply groundwater quality data at multiple levels,
- A mechanism to unite local, regional and statewide groundwater programs in a common effort,
- Better understanding of local, regional and statewide water quality issues and concerns that in turn can provide agencies at all levels with better information to deal with the concerns of consumers and consumer advocate groups,
- Trend and long-term forecasting information for groundwater agencies, which is essential for groundwater management plan preparation and implementation, and
- The motivation for small- and medium-sized agencies to begin or improve their own groundwater monitoring and management programs.

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Water Supply Planning

Three bills enacted by the Legislature to improve water supply planning processes at the local level became effective January 1, 2002. In general, the new laws are intended to improve the assessment of water supplies during the local planning process before land use projects that depend on water are approved. The new laws require the verification of sufficient water supplies as a condition for approving developments, and they compel urban water suppliers to provide more information on the reliability of groundwater if used as a supply.

SB 221 (Bus. and Prof. Code, § 11010 as amended; Gov. Code, § 65867.5 as amended; Gov. Code, §§ 66455.3 and 66473.7) prohibits approval of subdivisions consisting of more than 500 dwelling units unless there is verification of sufficient water supplies for the project from the applicable water supplier(s). This requirement also applies to increases of 10 percent or more of service connections for public water systems with less than 500 service connections. The law defines criteria for determining "sufficient water supply," such as using normal, single-dry, and multiple-dry year hydrology and identifying the amount of water that the supplier can reasonably rely on to meet existing and future planned uses. Rights to extract additional groundwater must be substantiated if used for the project.

SB 610 (Water Code, §§ 10631, 10656, 10910, 10911, 10912, and 10915 as amended; Pub. Resources Code, § 21151.9 as amended) and AB 901 (Water Code, §§ 10610.2 and 10631 as amended; Water Code § 10634) make changes to the Urban Water Management Planning Act to require additional information in Urban Water Management Plans (UWMP) if groundwater is identified as a source available to the supplier. Required information includes a copy of any groundwater management plan adopted by the supplier, proof that the developer or agency has rights to the groundwater, a copy of the adjudication order or decree for adjudicated basins, and if not adjudicated, whether the basin has been identified as being overdrafted or projected to be overdrafted in the most current DWR publication on the basin. If the basin is in overdraft, the UWMP must include current efforts to eliminate any long-term overdraft. A key provision in SB 610 requires that any project subject to the California Environmental Quality Act supplied with water from a public water system must provide a water supply assessment, except as specified in the law. AB 901 requires the plan to include information relating to the quality of existing sources of water available to an urban water supplier over given periods and include the manner in which water quality affects water management strategies and supply reliability.

Emergency Assistance to the Klamath Basin

On May 4, 2001, the Governor proclaimed a State of Emergency in the Klamath Basin in Siskiyou and Modoc counties. The proclamation included disaster assistance of up to $5 million under authority of the State Natural Disaster Assistance Act. This assistance went directly into constructing wells to extract groundwater for use on cover crops to avoid loss of critical topsoil. The Governor's proclamation also included $1 million for a study of the Klamath River Basin to determine the long-term water supply in the California portion of the basin.

Governor's Drought Panel

The Governor's Advisory Drought Planning Panel was formed in 2000 to develop a contingency plan to address the impacts of critical water shortages in California. The panel formed with the recognition that critical water shortages may severely impact the health, welfare, and economy of California. Panel recommendations included securing funding for the Local Groundwater Management Assistance Act (described above), continued support of critical groundwater monitoring in basins with inadequate data, and the formation of a technical assistance and education program for "rural homeowners and small domestic water systems relying on self-supplied groundwater" (GADPP 2000).

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Sacramento Valley Water Management Agreement

On May 22, 1995, SWRCB adopted the "Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary" (the 1995 WQCP). Following this action, SWRCB initiated a water rights hearing process with the intent of allocating responsibility for meeting the standards of the 1995 WQCP among water right holders in areas tributary to the Delta. The water rights hearing was conducted in phases with all phases being resolved with the exception of Phase 8, which involved water rights holders in the Sacramento Valley.

Proceeding with Phase 8 may have involved litigation and judicial review for years. That extended process could have resulted in adverse impacts to the environment and undermined progress on other statewide water management initiatives. To avoid the consequences of delay, the Sacramento Valley Water Users, DWR, the U.S. Bureau of Reclamation (USBR), and export water users developed the Sacramento Valley Water Management Agreement. The agreement became effective April 20, 2001. At that time, SWRCB issued an order staying the Phase 8 hearing for 18 months. The parties negotiated a short-term settlement agreement that obligated DWR and USBR to continue to fully meet the Bay-Delta water quality standards while providing for the development of conjunctive use and system improvement projects by participating upstream water rights holders that would make water available to help meet water quality standards while improving the reliability of local water supplies. SWRCB has subsequently dismissed the Phase 8 proceedings, and work is being undertaken on both short-term and long-term activities included in the Sacramento Valley Water Management Agreement.

Groundwater Management Water Code Amendments

In September 2002, SB 1938 (Water Code, § 10753.4 and § 10795.4 as amended; Water Code, § 10753.7, § 10753.8 and § 10753.9 as amended and renumbered; Water Code, § 10753.1 and § 10753.7 as added) was signed into law. The act amends existing law related to groundwater management by local agencies. The law requires any public agency seeking State funds administered through DWR for the construction of groundwater projects or groundwater quality projects to prepare and implement a groundwater management plan with certain specified components. Prior to this, there were no required plan components. New requirements include establishing basin management objectives, preparing a plan to involve other local agencies in a cooperative planning effort, and adopting monitoring protocols that promote efficient and effective groundwater management. The requirements apply to agencies that have already adopted groundwater management plans as well as agencies that do not overlie groundwater basins identified in Bulletin 118 and its updates when these agencies apply for state funds. The requirements do not apply to funds administered through the AB 303-Local Groundwater Management Assistance Act (Water Code, § 10795 et seq.) or to funds authorized or appropriated prior to September 1, 2002. Further discussion of the requirements is included in Chapter 3 and Appendix C.

Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50)

California voters approved the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50; Water Code, § 79500 et seq.) in the November 2002 elections. The initiative provides for more than $3.4 billion of funding, subject to appropriation by the Legislature, for a number of land protection and water management activities.

Several chapters of Proposition 50 allocate funds for specified water supply and water quality projects, including:

- Chapter 3 Water Security. Provides $50 million to protect State, local, and regional drinking water systems from terrorist attack or deliberate acts of destruction or degradation.

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- Chapter 4 Safe Drinking Water. Provides $435 million for grants and loans for infrastructure improvements to meet safe drinking water standards.
- Chapter 5 Clean Water and Water Quality. Provides $390 million for a number of water quality and environmental improvements.
- Chapter 6 Contaminant and Salt Removal Technologies. Provides $100 million for desalination of ocean or brackish waters as well as treatment and removal of contaminants.
- Chapter 7 California Bay-Delta program. Provides $825 million for continuing implementation of all elements of the program.
- Chapter 8 Integrated Regional Water Management. Provides $500 million for many categories of water management projects that will protect communities from drought, protect and improve water quality, and reduce dependence on imported water supplies.
- Chapter 9 Colorado River. Provides $70 million for canal-lining projects necessary to reduce water use and to meet commitments related to California's allocation of water from the Colorado River.

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Chapter 5

The Roles of State and Federal Agencies in California Groundwater Management

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Chapter 5
The Roles of State and Federal Agencies in California Groundwater Management

Even though groundwater management is a local responsibility and mostly voluntary, several State and federal agencies have key roles in California groundwater management. Some of these roles may not be immediately recognized, but because they work toward the goal of maintaining a reliable groundwater supply, they are closely related to groundwater management. Some of the programs available through the California Department of Water Resources (DWR) and other agencies that assist local agencies in managing groundwater resources are described below.

Local Groundwater Management Assistance from DWR

DWR's role in groundwater management begins with the fundamental understanding that groundwater management is locally driven and management programs should respond to local needs and concerns. DWR recognizes that when groundwater is effectively managed at the local level, benefits are realized at a statewide level.

DWR has historically maintained many programs that directly benefit local groundwater management efforts including:

- Providing assistance to local agencies to assess basin hydrogeologic characteristics,
- Assisting local agencies to identify opportunities to develop additional groundwater supply,
- Monitoring groundwater levels and quality,
- Providing watermaster services for court-adjudicated basins,
- Providing standards for well construction and destruction,
- Managing the State's extensive collection of well completion reports, and
- Reviewing proposals and distributing grant funds and low-interest loans for conjunctive use projects, as well as local groundwater management and monitoring programs.

Conjunctive Water Management Program

DWR's Conjunctive Water Management Program consists of a number of integrated efforts to assist local agencies in improving groundwater management and increasing water supply reliability.

One goal of the Integrated Storage Investigations (ISI) Program, an element of the Bay-Delta program, is to increase water supply reliability statewide through the planned, coordinated management and use of groundwater and surface water resources. The effort emphasizes forming working partnerships with local agencies and stakeholders to share technical data and costs for planning and developing locally controlled and managed conjunctive water management projects.

Toward that end, the Conjunctive Water Management Program has:

- Developed a vision in which DWR would assist local agencies throughout the State so that these agencies can effectively manage groundwater resources,
- Adopted a set of working principles to ensure local planning; local control, operation, and management of conjunctive use projects; voluntary implementation of projects; and local benefits from the proposed projects,
- Executed to date memoranda of understanding with 37 local agency partners and provided technical and financial assistance to study groundwater basins and assess opportunities for conjunctive water management,

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- Provided technical assistance in the form of groundwater monitoring, groundwater modeling, and local water management planning, as well as a review of numerous regional and statewide planning efforts on a variety of water issues, and
- Provided facilitation assistance to promote broad stakeholder involvement in regional water management planning processes.

DWR staff review proposals and distribute grants pursuant to the Local Groundwater Management Assistance Act of 2000 (AB 303). To date, DWR has awarded more than $15 million to local agencies to fund 71 projects dealing with groundwater investigation, monitoring, or management.

With funds provided under Proposition 13, DWR has awarded more than $170 million in loans and grants for groundwater recharge and storage studies and projects to local agencies throughout the State. Applicant estimates of the water supply reliability increases that will be realized from these projects exceeds 150 thousand acre-feet annually. Recipients of loans and grants must provide progress reports to allow an evaluation of the successes of the various programs. Figure 10 shows the distribution of loan and grant awardees throughout the State.

Both grant programs have active outreach efforts to inform and to assist agencies in preparation of applications. Selection of projects for funding relies in part on input from advisory committees composed of stakeholders from throughout the State.

Box L Providing Data:
The Internet Makes Groundwater Elevation Data Readily Accessible to the Public

In 1996, the California Department of Water Resources (DWR) began providing Internet access to groundwater level data and hydrographs for wells in groundwater basins throughout California. The website provides historical data for more than 35,000 wells monitored by DWR and its many cooperators and has proven very popular, with more than 60,000 visits to date. Options include a form or map interface to locate wells with water level data and the ability to download long-term water levels for specific wells or seasonal measurements for specific areas to create groundwater contour maps. The accessibility of this data makes it a significant resource for local agencies in making sound groundwater management decisions. The address of the site is http://wdl.water.ca.gov/.





Wells can be located with a map interface. By clicking on a well, a hydrograph with the latest data available is automatically generated.

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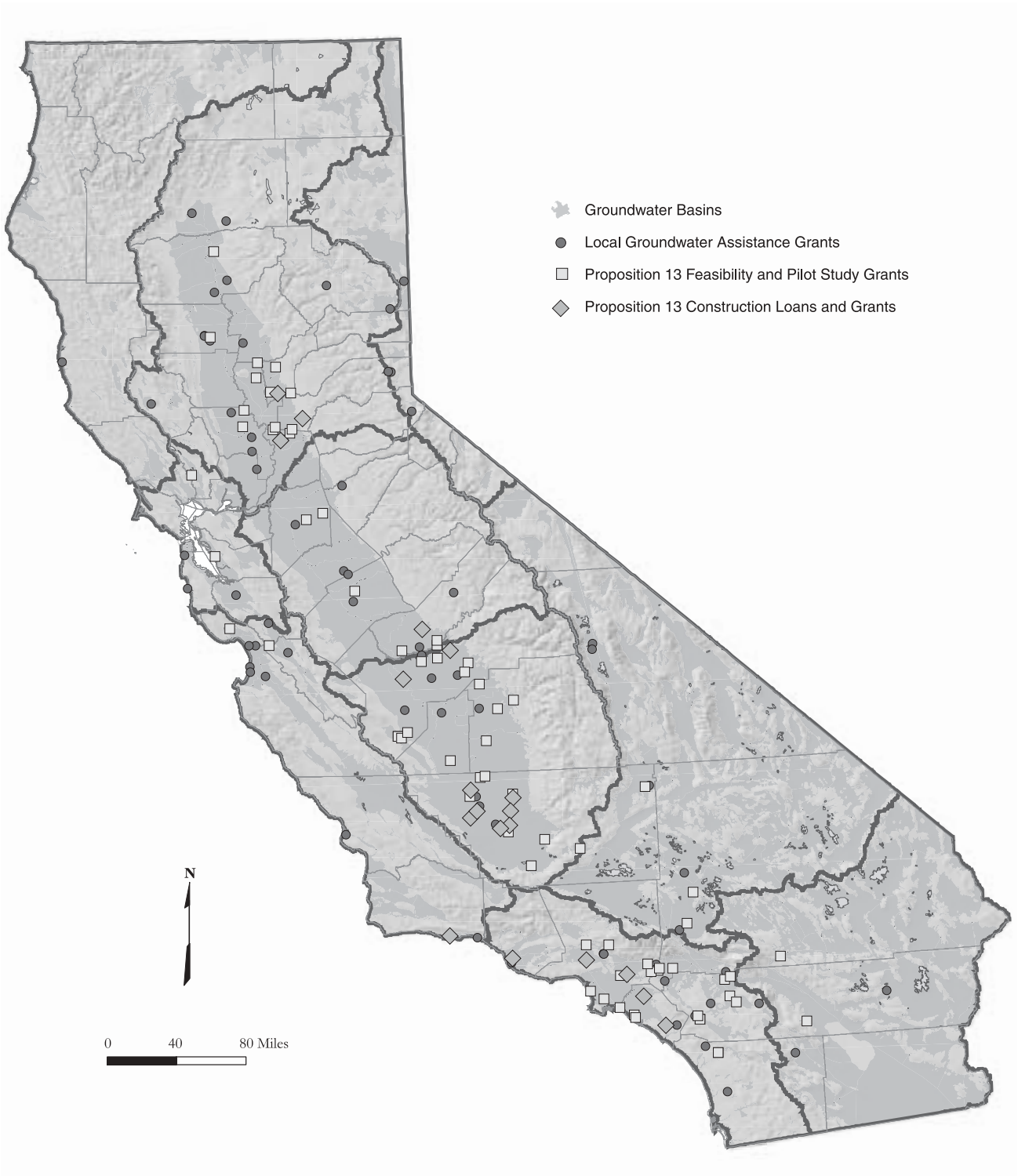

Figure 10 Broad distribution of grant and loan awardees for 2001 through 2003

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Assistance from Other State and Federal Agencies

Many other State and federal agencies provide groundwater management assistance to local agencies. Some of those roles are described below. For more information on the roles of various agencies in protecting the groundwater resource, see the California Department of Health Services' Drinking Water Source Assessment and Protection Program Document (DHS 2000), California Groundwater Management (Bachman and others 1997), or the individual agency websites.

State Water Resources Control Board and Regional Water Quality Control Boards

http://www.swrcb.ca.gov The mission of the State Water Resources Control Board (SWRCB) is to ensure the highest reasonable quality of waters of the State, while allocating those waters to achieve the optimum balance of beneficial uses. In turn, the nine Regional Water Quality Control Boards (RWQCB) develop and enforce water quality objectives and implement plans to protect the beneficial uses of the State's waters, recognizing differences in climate, topography, geology, and hydrology.

SWRCB has many responsibilities regarding the protection of the groundwater resource. One of the more notable is the Groundwater Ambient Monitoring and Assessment (GAMA) Program. GAMA is a recently enacted program that will provide a comprehensive assessment of water quality in water wells throughout the state. GAMA has two main components: the California Aquifer Susceptibility (CAS) Assessment and the Voluntary Domestic Well Assessment Project.

The CAS combines age dating of water and sampling for low-level volatile organic compounds (VOCs), such as methyl tertiary-butyl ether (MTBE), to assess the relative susceptibility of all of approximately 16,000 public supply wells throughout the State. Age dating provides a general assessment of how quickly groundwater is moving through the system, while the sampling of low-level VOCs allows greater reaction time for potential remediation strategies before contaminants reach action levels. Sampling is being conducted by staff from the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory. The CAS Assessment was developed cooperatively with DHS and DWR.

The Voluntary Domestic Well Assessment Project will provide a previously unavailable sampling of water quality in domestic wells, which will assist in assessing the relative susceptibility of California's groundwater. Because water quality in individual domestic wells is unregulated, the program is voluntary and will focus, as resources permit, on specific areas of the state. Constituents to be analyzed include nitrate, total and fecal coliform bacteria, MTBE, and minerals. Additional constituents will be added in areas with known water quality problems.

Other SWRCB/RWQCB activities related to groundwater protection include developing basin plans that identify existing and potential beneficial uses of marine water, groundwater, and surface waters; regulating the discharge of waste that may affect water quality in California; monitoring of landfills and hazardous waste facilities; establishing standards for the construction and monitoring of underground storage tanks; establishing management plans for control of nonpoint source pollutants; and issuing cleanup and abatement orders that require corrective actions by the responsible party for a surface water or groundwater pollution problem or nuisance.

The Groundwater Quality Monitoring Act of 2001 (AB599, Water Code, § 10780 et seq.) required the SWRCB to develop a comprehensive monitoring program in a report to the Legislature. See Chapter 4 for details.

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California Department of Health Services

http://www.dhs.ca.gov/ps/ddwem The DHS Drinking Water Program, part of the Division of Drinking Water and Environmental Management, is responsible for DHS implementation of the federal Safe Drinking Water Act, as well as California statutes and regulations related to drinking water. As part of this responsibility, DHS inspects and provides regulatory oversight of approximately 8,500 public water systems (and approximately 16,000 drinking water wells) to assure delivery of safe drinking water to all California consumers.

Public water system operators are required to regularly monitor their drinking water sources for microbiological, chemical and radiological contaminants to show that drinking water supplies meet regulatory requirements (called primary maximum contaminant levels–MCLs). Among these contaminants are approximately 80 specific inorganic and organic chemical contaminants and six radiological contaminants that reflect the natural environment as well as human activities.

Public water system operators also monitor their water for a number of other contaminants and characteristics that deal with the aesthetic properties of drinking water (known as secondary MCLs). They are also required by regulation to analyze for certain unregulated contaminants (to allow DHS to collect information on emerging contaminants, for example), and to report findings of other contaminants that may be detected during routine monitoring. The DHS water quality monitoring database contains the results of analyses since 1984. These data, collected for purposes of regulatory compliance with drinking water laws, also provide an extensive body of information on the quality of groundwater throughout the State.

California Department of Pesticide Regulation

http://www.cdpr.ca.gov/dprprograms.htm The California Department of Pesticide Regulation (DPR) protects human health and the environment by regulating pesticide sales and use and by promoting reduced-risk pest management. DPR plays a significant role in monitoring for the presence of pesticides and in preventing further contamination of the groundwater resource.

DPR conducts six types of groundwater monitoring:

1) Monitoring for pesticides on a DPR-determined Ground Water Protection List, which lists pesticides with the potential to pollute groundwater;
2) Four-section survey monitoring to verify a reported detection and to help determine if a detected pesticide resulted from legal agricultural use;
3) Areal extent monitoring to identify the extent of contaminated wells;
4) Adjacent section monitoring to identify additional areas sensitive to pesticide movement to groundwater;
5) Monitoring to repeatedly sample a network of wells to determine whether pesticide residues are declining; and
6) Special project monitoring.

When pesticides are found in groundwater, they are normally regulated in one-square mile areas identified in regulation as sensitive to groundwater pollution. These pesticides are subject to permitting by the county agricultural commissioner and to use restrictions specified in regulation. DPR maintains an extensive database of pesticide sampling in groundwater and reports a summary of annual sampling and detections to the State Legislature.

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California Department of Toxic Substances Control

http://www.dtsc.ca.gov The California Department of Toxic Substances Control (DTSC) has two programs related to groundwater resources protection: the Hazardous Waste Management Program and the Site Mitigation Program. These programs are authorized under Division 20 of the California Health and Safety Code, and implementing regulations are codified in Title 22 of the California Code of Regulations.

A critical element of both programs is maintaining environmental quality and economic vitality through the protection of groundwater resources. This is accomplished through hazardous waste facility permitting and design; oversight of hazardous waste handling, removal, and disposal; oversight of remediation of hazardous substances releases; funding of emergency removal actions involving hazardous substances, including the cleanup of illegal drug labs; cleanup of abandoned hazardous waste sites; oversight of the closure of military bases; and pollution prevention.

If groundwater is threatened or impacted by a hazardous substance release, DTSC provides technical oversight for the characterization and remediation of soil and groundwater contamination. DTSC and the nine RWQCBs coordinate regulatory oversight of groundwater remediation. To ensure site-specific groundwater quality objectives are met, DTSC consults with RWQCB staff and appropriate groundwater basin plans.

Box M Improving Coordination of Groundwater Information

California's groundwater resources are addressed by an array of different State and federal agencies. Each agency approaches groundwater from a unique perspective, based on its individual statutory mandate. As a result, each agency collects different types of groundwater data and information. To facilitate the effective and efficient exchange of groundwater resource information, the State Water Resources Control Board (SWRCB) is coordinating the Groundwater Resources Information Sharing Team (GRIST), which is composed of representatives from various groundwater agencies. Agencies currently participating in GRIST are:

- State Water Resources Control Board
- Department of Health Services
- Department of Water Resources
- Department of Pesticide Regulation
- Lawrence Livermore National Laboratory
- U.S. Geological Survey

One of the tasks of the GRIST is to identify data relevant to California groundwater resources. A listing of the data, along with the appropriate agency contacts and Internet links, will be maintained by SWRCB on the Groundwater Resources Information Database. In addition, to facilitate effective information sharing and communication among stakeholders, groundwater data will be made available on the SWRCB GeoTracker system. GeoTracker is a geographic information system that provides Internet access to environmental data. The centralization of environmental data through GeoTracker will enable more in-depth geospatial and statistical analyses of groundwater data in the future. For more information about GeoTracker, visit the GeoTracker Internet site at http://geotracker.arsenautlegg.com.

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California Bay-Delta Authority

http://calwater.ca.gov The California Bay-Delta program was initiated in 1994 to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Sacramento-San Joaquin Bay-Delta System. The partnership currently consists of more than 20 State and federal agencies. An important element of the program is to increase storage by developing an additional 500,000 acre-feet to 1.0 million acre-feet of groundwater storage capacity by the year 2007 (CALFED 2000).

Effective January 1, 2003, a newly formed State agency assumed responsibility for overseeing implementation of the Bay-Delta program. The California Bay-Delta Authority provides a permanent governance structure for the collaborative state-federal effort. The authority was established by enactment of Senate Bill 1653 in 2002. The legislation calls for the authority to sunset on January 1, 2006, unless federal legislation has been enacted authorizing the participation of appropriate federal agencies in the authority.

U.S. Environmental Protection Agency

http://www.epa.gov/safewater The U.S. Environmental Protection Agency (EPA) Office of Ground Water and Drinking Water, together with states, tribes, and many partners, protects public health by ensuring safe drinking water and protecting groundwater. The EPA's role in California groundwater is primarily related to protection of the resource and comes in the form of administering several federal programs in close coordination with State agencies such as SWRCB, DHS, and DTSC.

U.S. Geological Survey

http://ca.water.usgs.gov USGS has published results of many studies of California groundwater basins. USGS maintains an extensive groundwater level and groundwater quality monitoring network and has compiled this data in a database. The California District is working on cooperative programs with local, State, and other federal agencies. The most notable programs include three regional studies of the San Joaquin-Tulare Basin, the Sacramento River Basin, and the Santa Ana River basin under the National Water Quality Assessment Program. Results were published for the San Joaquin-Tulare Basin in 1995 and the Sacramento River Basin in 2000. The Santa Ana River basin study is in progress.

U.S. Bureau of Reclamation

http://www.usbr.gov The U.S. Bureau of Reclamation (USBR) operates the Central Valley Project (CVP), an extensive network of dams, canals, and related facilities that delivers about 7 maf during normal years for agricultural, urban, and wildlife use. USBR's role with respect to groundwater is generally limited to monitoring for impacts to the groundwater systems adjacent to its CVP facilities. Through the cooperative efforts of USBR, DWR, irrigation districts, farmers, and other local entities, groundwater level data have been collected continuously since project conception in the 1930s and 1940s.

In addition to CVP monitoring, USBR monitors groundwater levels to identify potential impacts as a result of two other projects in California. That monitoring includes the Santa Ynez basin as part of the Cachuma Project on the central coast, and the Putah Creek Cone as part of the Solano Project in the southwest Sacramento Valley. Both monitoring efforts are required as part of permitting for the projects.

USBR is planning to implement a groundwater information system to collect and distribute to the public the large volume of historical groundwater level data associated with its projects.

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Chapter 6
Basic Groundwater Concepts

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Chapter 6
Basic Groundwater Concepts

This chapter presents general concepts relating to the origin, occurrence, movement, quantity, and quality of groundwater. The concepts will be useful in providing the nontechnical reader with a basic understanding of groundwater. For more experienced readers, many topics are discussed specifically as they apply to California or as the terms are used in this report. A glossary of terms is included at the end of this report. For additional reading on basic groundwater concepts see *Basic Ground-Water Hydrology* (Heath 1983).

Origin of Groundwater

Groundwater is a component of the hydrologic cycle (Figure 11), which describes locations where water may occur and the processes by which it moves or is transformed to a different phase. In simple terms, water or one of its forms—water vapor and ice—can be found at the earth's surface, in the atmosphere, or beneath the earth's surface. The hydrologic cycle is a continuum, with no beginning or end; however, it is often thought of as beginning in the oceans. Water evaporates from a surface water source such as an ocean, lake, or through transpiration from plants. The water vapor may move over the land and condense to form clouds, allowing the water to return to the earth's surface as precipitation (rain or snow). Some of the snow will end up in polar ice caps or in glaciers. Most of the rain and snowmelt will either become overland flow in channels or will infiltrate into the subsurface. Some of the infiltrated water will be transpired by plants and returned to the atmosphere, while some will cling to particles surrounding the pore spaces in the subsurface, remaining in the vadose (unsaturated) zone. The rest of the infiltrated water will move gradually under the influence of gravity into the saturated zone of the subsurface, becoming groundwater. From here, groundwater will flow toward points of discharge such as rivers, lakes, or the ocean to begin the cycle anew. This flow from recharge areas to discharge areas describes the groundwater portion of the hydrologic cycle.

The importance of groundwater in the hydrologic cycle is illustrated by considering the distribution of the world's water supply. More than 97 percent of all earth's water occurs as saline water in the oceans (Fetter 1988). Of the world's fresh water, almost 75 percent is in polar ice caps and glaciers, which leaves a very small amount of fresh water readily available for use. Groundwater accounts for nearly all of the remaining fresh water (Alley and others 1999). All of the fresh water stored in the world's rivers and lakes accounts for less than 1 percent of the world's fresh water.

Occurrence of Groundwater

Groundwater is the water occurring beneath the earth's surface that completely fills (saturates) the void space of rocks or sediment. Given that all rock has some open space (voids), groundwater can be found underlying nearly any location in the State. Several key properties help determine whether the subsurface environment will provide a significant, usable groundwater resource. Most of California's groundwater occurs in material deposited by streams, called alluvium. Alluvium consists of coarse deposits, such as sand and gravel, and finer-grained deposits such as clay and silt. The coarse and fine materials are usually coalesced in thin lenses and beds in an alluvial environment. In this environment, coarse materials such as sand and gravel deposits usually provide the best source of water and are termed aquifers; whereas, the finer-grained clay and silt deposits are relatively poor sources of water and are referred to as aquitards. California's groundwater basins usually include one or a series of alluvial aquifers with intermingled aquitards. Less frequently, groundwater basins include aquifers composed of unconsolidated marine sediments that have been flushed by fresh water. The marine-deposited aquifers are included in the discussion of alluvial aquifers in this bulletin.

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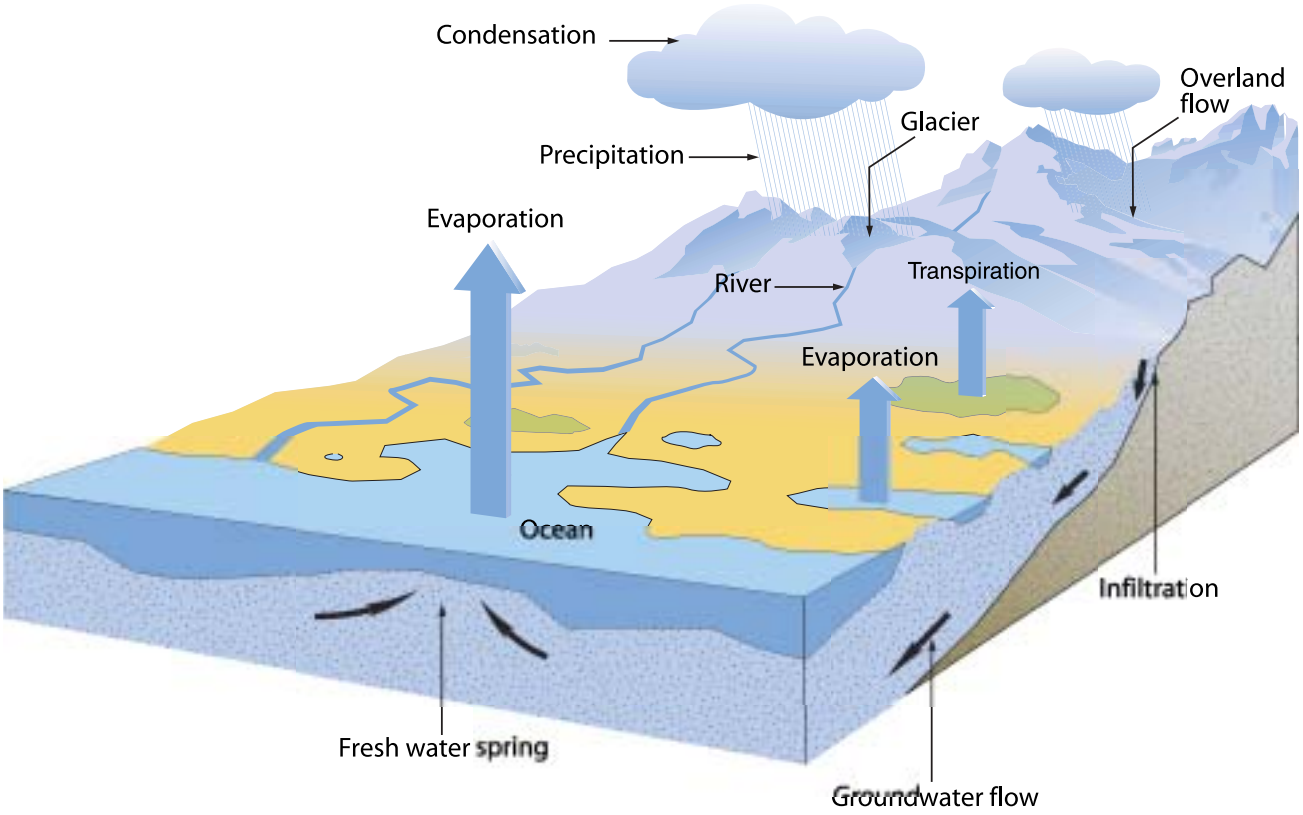

Figure 11 The Hydrologic Cycle

Although alluvial aquifers are most common in California, other groundwater development occurs in fractured crystalline rocks, fractured volcanics, and limestones. For this report, these nonalluvial areas that provide groundwater are referred to as "groundwater source areas," while the alluvial aquifers are called groundwater basins. Each of these concepts is discussed more fully below.

Groundwater and Surface Water Interconnection

Groundwater and surface water bodies are connected physically in the hydrologic cycle. For example, at some locations or at certain times of the year, water will infiltrate the bed of a stream to recharge groundwater. At other times or places, groundwater may discharge, contributing to the base flow of a stream. Changes in either the surface water or groundwater system will affect the other, so effective management requires consideration of both resources. Although this physical interconnection is well understood in general terms, details of the physical and chemical relationships are the topic of considerable research.

These details are the subject of significant recent investigations into the hyporheic zone, the zone of sand and gravel that forms the channel of a stream. As surface water flows downstream it may enter the gravels in the

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Box N One Resource, Two Systems of Law

In California, two distinct legal regimes govern the appropriation of surface water and subterranean streams, and percolating groundwater. The California Water Code requires that water users taking water for beneficial use from surface watercourses and "subterranean streams flowing through known and definite channels" obtain water right permits or licenses from the State Water Resources Control Board (SWRCB) (Water Code § 1200 et seq.). Groundwater classified as percolating groundwater is not subject to the Water Code provisions concerning the appropriation of water, and a water user can take percolating groundwater without having a State-issued water right permit or license. Current Water Code section 1200 is derived from a provision in the Water Commission Act of 1913, which became effective on December 19, 1914.

The SWRCB developed a test to identify groundwater that is in a subterranean stream flowing through a known and definite channel and is therefore subject to the SWRCB's permitting authority. The physical conditions that must be present in a subterranean stream flowing in a known and definite channel are: (1) a subsurface channel must be present; (2) the channel must have relatively impermeable bed and banks; (3) the course of the channel must be known or capable of being determined by reasonable inference; and (4) groundwater must be flowing in the channel. Whether groundwater is subject to the SWRCB's permitting authority under this test is a factual determination. Water that does not fit this test is "percolating groundwater" and is not subject to the SWRCB's permitting authority.

The SWRCB has issued decisions that find that groundwater under the following streams constitutes a "subterranean stream flowing through known and definite channels" and is therefore subject to the SWRCB's permitting authority (Murphey 2003 pers com):

Los Angeles River in Los Angeles County
Sheep Creek in San Bernardino County
Mission Basin of the San Luis Rey River in San Diego County
Bonsall Basin of the San Luis Rey River in San Diego County
Pala Basin of the San Luis Rey River in San Diego County
Carmel River in Monterey County
Garrapata Creek in Monterey County
Big Sur River in Monterey County
Russian River
Chorro Creek in San Luis Obispo County
Morro Creek in San Luis Obispo County
North Fork Gualala River in Mendocino County

Contact the SWRCB, Division of Water Rights for specific stream reaches and other details of these decisions.

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hyporheic zone, mix with groundwater, and re-enter the surface water in the stream channel. The effects of this interchange between surface water and groundwater can change the dissolved oxygen content, temperature, and mineral concentrations of the water. These changes may have a significant effect on aquatic and riparian biota.

Significantly, the physical and chemical interconnection of groundwater and surface water is not well represented in California's water rights system (see Box N "One Resource, Two Systems of Law").

Physical Properties That Affect Groundwater

The degree to which a body of rock or sediments will function as a groundwater resource depends on many properties, some of which are discussed here. Two of the more important physical properties to consider are porosity and hydraulic conductivity. Transmissivity is another important concept to understand when considering an aquifer's overall ability to yield significant groundwater. Throughout the discussion of these properties, keep in mind that sediment size in alluvial environments can change significantly over short distances, with a corresponding change in physical properties. Thus, while these properties are often presented as average values for a large area, one might encounter different conditions on a more localized level. Determination of these properties for a given aquifer may be based on lithologic or geophysical observations, laboratory testing, or aquifer tests with varying degrees of accuracy.

Porosity

The ratio of voids in a rock or sediment to the total volume of material is referred to as porosity and is a measure of the amount of groundwater that may be stored in the material. Figure 12 gives several examples of the types of porosity encountered in sediments and rocks. Porosity is usually expressed as a percentage and can be classified as either primary or secondary. Primary porosity refers to the voids present when the sediment or rock was initially formed. Secondary porosity refers to voids formed through fracturing or weathering of a rock or sediment after it was formed. In sediments, porosity is a function of the uniformity of grain size (sorting) and shape. Finer-grained sediments tend to have a higher porosity than coarser sediments because the finer-grained sediments generally have greater uniformity of size and because of the tabular shape and surface chemistry properties of clay particles. In crystalline rocks, porosity becomes greater with a higher degree of fracturing or weathering. As alluvial sediments become consolidated, primary porosity generally decreases due to compaction and cementation, and secondary porosity may increase as the consolidated rock is subjected to stresses that cause fracturing.

Porosity does not tell the entire story about the availability of groundwater in the subsurface. The pore spaces must also interconnect and be large enough so that water can move through the ground to be extracted from a well or discharged to a water body. The term "effective porosity" refers to the degree of interconnectedness of pore spaces. For coarse sediments, such as the sand and gravel encountered in California's alluvial groundwater basins, the effective porosity is often nearly equal to the overall porosity. In finer sediments, effective porosity may be low due to water that is tightly held in small pores. Effective porosity is generally very low in crystalline rocks that are not highly fractured or weathered.

While porosity measures the total amount of water that may be contained in void spaces, there are two related properties that are important to consider: specific yield and specific retention. Specific yield is the fractional amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of the groundwater that could actually be available for extraction. The portion of groundwater that is retained either as a film on grains or in small pore spaces is called specific retention. Specific yield and specific retention of the aquifer material together equal porosity. Specific retention increases with decreasing

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grain size. Table 7 shows that clays, while having among the highest porosities, make poor sources of groundwater because they yield very little water. Sand and gravel, having much lower porosity than clay, make excellent sources of groundwater because of the high specific yield, which allows the groundwater to flow to wells. Rocks such as limestone and basalt yield significant quantities of groundwater if they are well-weathered and highly fractured.

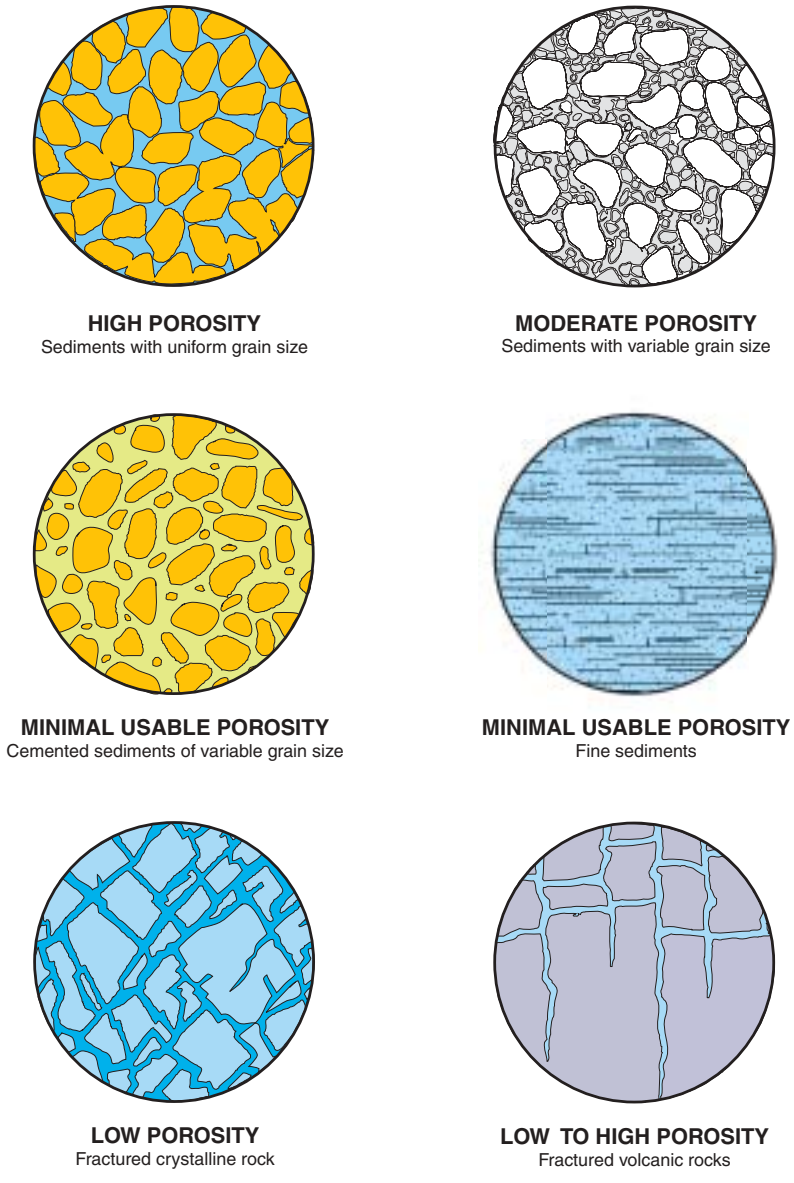

Figure 12 Examples of porosity in sediments and rocks

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Table 7 Porosity (in percent) of soil and rock types

Material	Porosity	Specific yield	Specific retention
Clay	50	2	48
Sand	25	22	2
Gravel	20	19	1
Limestone	20	18	2
Sandstone (semiconsolidated)	11	6	5
Granite	0.1	0.09	0.01
Basalt (young)	11	8	3

Modified from Heath (1983)

Hydraulic Conductivity

Another major property related to understanding water movement in the subsurface is hydraulic conductivity. Hydraulic conductivity is a measure of a rock or sediment's ability to transmit water and is often used interchangeably with the term permeability. The size, shape, and interconnectedness of pore spaces affect hydraulic conductivity (Driscoll 1986).

Hydraulic conductivity is usually expressed in units of length/time: feet/day, meters/day, or gallons/day/square-foot. Hydraulic conductivity values in rocks range over many orders of magnitude from a low permeability unfractured crystalline rock at about 10^{-8} feet/day to a highly permeable well-sorted gravel at greater than 10^{4} feet/day (Heath 1983). Clays have low permeability, ranging from about 10^{-3} to 10^{-7} feet/day (Heath 1983). Figure 13 shows hydraulic conductivity ranges of selected rocks and sediments.

Transmissivity

Transmissivity is a measure of the aquifer's ability to transmit groundwater through its entire saturated thickness and relates closely to the potential yield of wells. Transmissivity is defined as the product of the hydraulic conductivity and the saturated thickness of the aquifer. It is an important property to understand because a given area could have a high value of hydraulic conductivity but a small saturated thickness, resulting in limited overall yield of groundwater.

Aquifer

An aquifer is a body of rock or sediment that yields significant amounts of groundwater to wells or springs. In many definitions, the word "significant" is replaced by "economic." Of course, either term is a matter of perspective, which has led to disagreement about what constitutes an aquifer. As discussed previously, coarse-grained sediments such as sands and gravels deposited in alluvial or marine environments tend to function as the primary aquifers in California. These alluvial aquifers are the focus of this report. Other aquifers, such as those found in volcanics, igneous intrusive rocks, and carbonate rocks are described briefly in the section Groundwater Source Areas.

Aquitard

An aquitard is a body of rock or sediment that is typically capable of storing groundwater but does not yield it in significant or economic quantities. Fine-grained sediments with low hydraulic conductivity, such as clays and silts, often function as aquitards. Aquitards are often referred to as confining layers because they retard the vertical movement of groundwater and under the right hydrogeologic conditions confine groundwater that is under pressure. Aquitards are capable of transmitting enough water to allow some flow between adjacent aquifers, and depending on the magnitude of this transfer of water, may be referred to as leaky aquitards.

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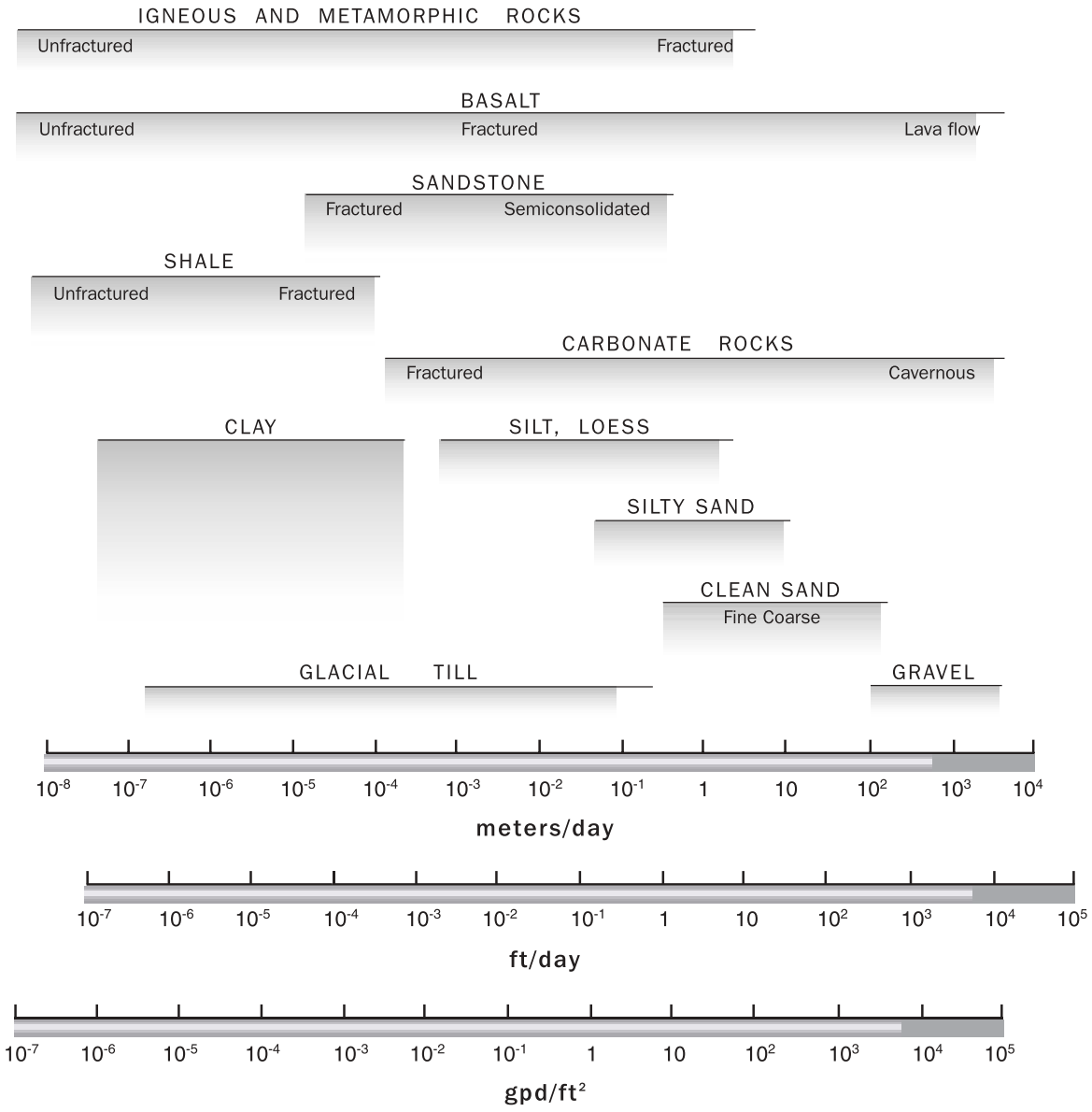

Figure 13 Hydraulic conductivity ranges of selected rocks and sediments

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Unconfined and Confined Aquifers

In most depositional environments, coarser-grained deposits are interbedded with finer-grained deposits creating a series of aquifers and aquitards. When a saturated aquifer is bounded on top by an aquitard (also known as a confining layer), the aquifer is called a confined aquifer (Figure 14). Under these conditions, the water is under pressure so that it will rise above the top of the aquifer if the aquitard is penetrated by a well. The elevation to which the water rises is known as the potentiometric surface. Where an aquifer is not bounded on top by an aquitard, the aquifer is said to be unconfined. In an unconfined aquifer, the pressure on the top surface of the groundwater is equal to that of the atmosphere. This surface is known as the water table, so unconfined aquifers are often referred to as water table aquifers. The arrangement of aquifers and aquitards in the subsurface is referred to as hydrostratigraphy.

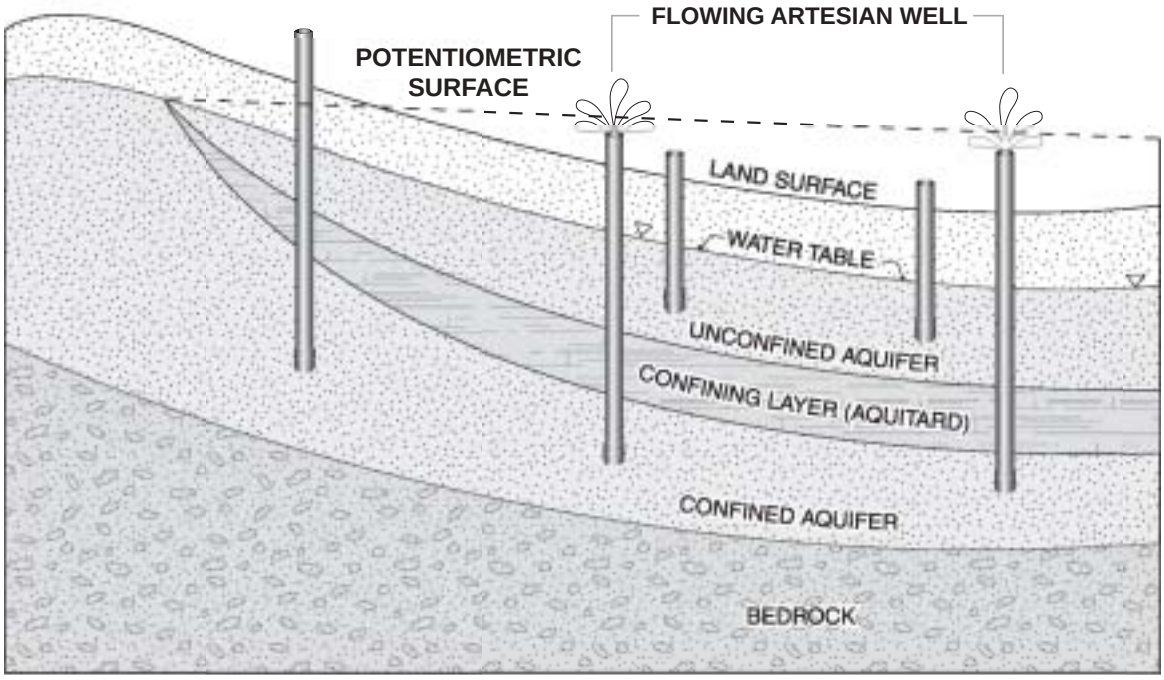

Figure 14 Interbedded aquifers with confined and unconfined conditions

With the notable exception of the Corcoran Clay of the Tulare Formation in the San Joaquin Valley and the aquitard in West Coast Basin in Los Angeles County, there are no clearly recognizable regional aquitards in California alluvial basins. Instead, due to the complexity of alluvial environments, it is the cumulative effect of multiple thin lenses of fine-grained sediments that causes increasing confinement of groundwater with increasing depth, creating what is often referred to as a semiconfined aquifer.

In some confined aquifers groundwater appears to defy gravity, but that is not the case. When a well penetrates a confined aquifer with a potentiometric surface that is higher than land surface, water will flow naturally to the surface. This is known as artesian flow, and results from pressure within the aquifer. The pressure results when the recharge area for the aquifer is at a higher elevation than the point at which discharge is occurring (Figure 14). The confining layer prevents the groundwater from returning to the surface until the confining layer is penetrated by a well. Artesian flow will discontinue as pressure in the aquifer is reduced and the potentiometric surface drops below the land surface elevation.

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Groundwater Basin

A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom. Lateral boundaries are features that significantly impede groundwater flow, such as rock or sediments with very low permeability or a geologic structure such as a fault. Bottom boundaries would include rock or sediments of very low permeability if no aquifers occur below those sediments within the basin. In some cases, such as in the San Joaquin and Sacramento Valleys, the base of fresh water is considered the bottom of the groundwater basin. Table 8 is a generalized list of basin types and the features that define the basin boundaries.

Table 8 Types and boundary characteristics of groundwater basins

Characteristics of groundwater basins	
Groundwater basin	An aquifer or an aquifer system that is bounded laterally and at depth by one or more of the following features that affect groundwater flow: • Rocks or sediments of lower permeability • A geologic structure, such as a fault • Hydrologic features, such as a stream, lake, ocean, or groundwater divide
Types of basins and their boundaries	
Single simple basin	Basin surrounded on all sides by less permeable rock. Higher permeability near the periphery. Clays near the center. Unconfined around the periphery. Confined near the center. May have artesian flow near the center.
Basin open at one or more places to other basins	Many desert basins. Merged alluvial fans. Topographic ridges on fans. Includes some fault-bounded basins.
Basin open to Pacific Ocean	260 basins along the coast. Water-bearing materials extend offshore. May be in contact with sea water. Vulnerable to seawater intrusion.
Single complex basin	Basin underlain or surrounded by older water-bearing materials and water-bearing volcanics. Quantification is difficult because of unknown contacts between different rock types within the basin.
Groundwater in areas of volcanic rocks	Basin concept is less applicable in volcanic rocks. Volcanic rocks are highly variable in permeability.
Groundwater in weathered crystalline rocks (fractured hard rock)—not considered a basin	Small quantities of groundwater. Low yielding wells. Most wells are completed in the crystalline rock and rely on fractures to obtain groundwater.
Political boundaries or management area boundaries	Usually not related to hydrogeologic boundaries. Formed for convenience, usually to manage surface water storage and delivery.

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Although only the upper surface of a groundwater basin can be shown on a map, the basin is three-dimensional and includes all subsurface fresh water-bearing material. These boundaries often do not extend straight down, but are dependent on the spatial distribution of geologic materials in the subsurface. In fact, in a few cases near California's coastal areas, aquifers in the subsurface are known to extend beyond the mapped surface of the basin and may actually be exposed under the ocean. Under natural conditions, fresh water flows from these aquifers into the ocean. If groundwater levels are lowered, sea water may flow into the aquifer. This has occurred in Los Angeles, Orange, Ventura, Santa Cruz and Monterey Counties, and some areas around San Francisco Bay. Depiction of a groundwater basin in three dimensions requires extensive subsurface investigation and data evaluation to delineate the basin geometry. Figure 15 is a cross-section showing how a coastal basin might appear in the subsurface.

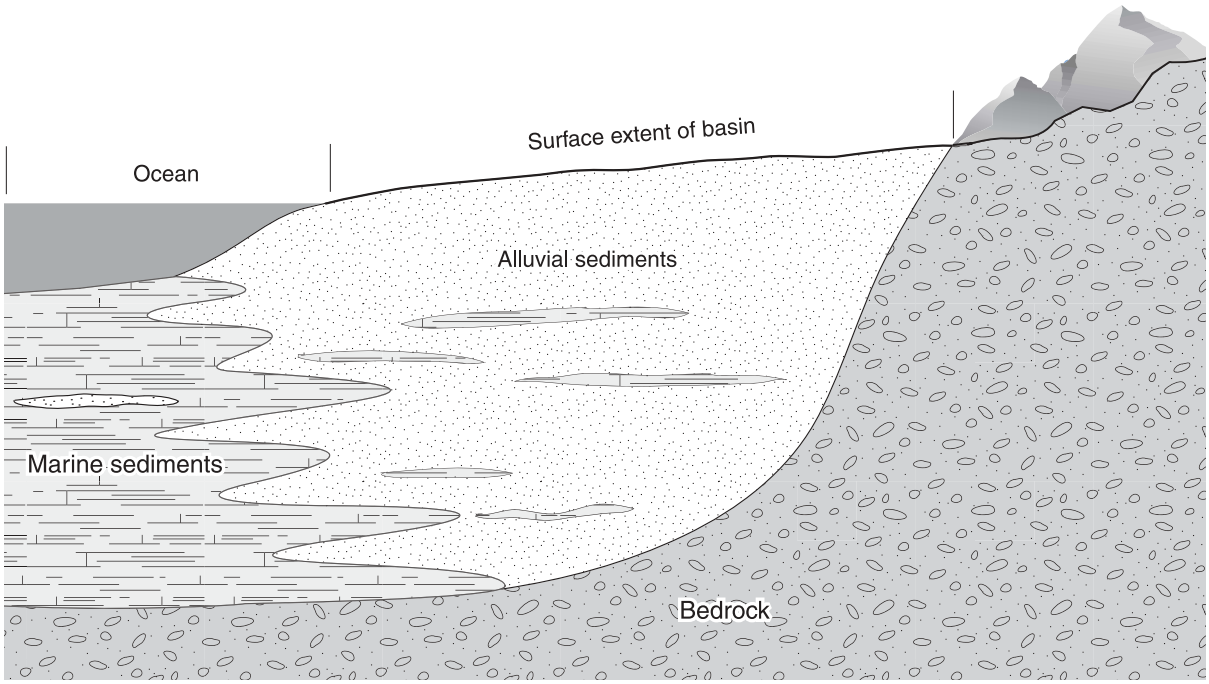

Figure 15 Groundwater basin near the coast with the aquifer extending beyond the surface basin boundary

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated. In many other basins where much less is known and understood about the basin, boundaries will probably change as a better understanding of the basin is developed. A procedure for collecting information from all the stakeholders should be developed for use statewide so that agreement on basin boundaries can be achieved.

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Groundwater Subbasin

A subbasin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries (see Table 8). These subbasins are created for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins. As the definition implies, the designation of a subbasin boundary is flexible and could change in the future. The limiting rule for a subbasin is that it should not cross over a groundwater basin boundary.

An example of a hydrologic subbasin boundary would be a river or stream that creates a groundwater divide. While hydrologic boundaries may limit groundwater flow in the shallow subsurface, data indicate significant groundwater flow may occur across the boundary at greater depths. In addition, the location of the boundary may change over time if pumping or recharge patterns change. Institutional subbasin boundaries could be based on a political boundary, such as a county line or a water agency service area, or a legally mandated boundary, such as a court adjudicated basin.

Groundwater Source Areas

Groundwater in California is also found outside of alluvial groundwater basins. Igneous extrusive (volcanic), igneous intrusive, metamorphic, and sedimentary rocks are all potential sources of groundwater. These rocks often supply enough water for domestic use, but in some cases can also yield substantial quantities. In this report, the term groundwater source area is used for rocks that are significant in terms of being a local groundwater source, but do not fit the category of basin or subbasin. The term is not intended to imply that groundwater actually originates in these rocks, but that it is withdrawn from rocks underlying a generally definable area. Because of the increased difficulty in defining and understanding the hydrogeologic properties of these rocks, the limited data available for the areas in which these rocks occur, and the relatively small, though rapidly growing, segment of the population served by these water supplies, they are discussed separately from groundwater basins.

Volcanics

Groundwater in volcanics can occur in fractures that result from cooling or changes in stress in the crust of the Earth, lava tubes, tree molds, weathering surfaces, and porous tuff beds. Additionally, the volcanics could overlie other deposits from an alluvial environment. Flow in the fractures may approach the same velocities as that of surface water, but there is often very limited storage potential for groundwater. The tuff beds can act similarly to alluvial aquifers.

Some of the most productive volcanic rocks in the State include the Modoc Plateau volcanics in the northeast and the Napa-Sonoma volcanics northeast of San Francisco Bay (Figure 16). Wells in Modoc Plateau volcanics are commonly reported to yield between 100 and 1,000 gallons per minute, with some yields of 4,000 gpm (Planert and Williams 1995). Bulletin 118-75 assigned identification numbers to these volcanic rocks throughout the State (for example, Modoc Plateau Recent Volcanic Areas, 1-23). The numbers led some to interpret them as being groundwater basins. In this update, the numbers corresponding to the volcanics are retired to eliminate this confusion.

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Figure 16 Significant volcanic groundwater source areas

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Igneous Intrusive, Metamorphic, and Sedimentary Rocks

Groundwater in igneous intrusive, metamorphic, and consolidated sedimentary rocks occurs in fractures resulting from tectonism and expansion of the rock as overburden pressures are relieved. Groundwater is extracted from fractured rock in many of the mountainous areas of the State, such as the Sierra Nevada, the Peninsular Range, and the Coast Ranges. Rocks in these areas often yield only enough supply for individual domestic wells, stock water wells, or small community water systems. Availability of groundwater in such formations can vary widely, even over a distance of a few yards. Areas of groundwater production from consolidated rocks were not defined in previous versions of Bulletin 118 and are not included in this update.

As population grows in areas underlain by these rocks, such as the foothills of the Sierra Nevada and southern California mountains, many new wells are being built in fractured rock. However, groundwater data are often insufficient to accurately estimate the long term reliability of groundwater supplies in these areas. Additional investigation, data evaluation, and management will be needed to ensure future sustainable supplies. The Legislature recognized both the complexity of these areas and the need for management in SB 1938 (2002), which amended the Water Code to require groundwater management plans with specific components be adopted for agencies to be eligible for certain funding administered by DWR for construction of groundwater projects. Water Code section 10753.7(a)(5) states:

> Local agencies that are located in areas outside the groundwater basins delineated on the latest edition of the department's groundwater basin and subbasin map shall prepare groundwater management plans incorporating the components in this subdivision, and shall use geologic and hydrologic principles appropriate to those areas.

In carbonate sedimentary rocks such as limestone, groundwater occurs in fractures and cavities formed as a result of dissolution of the rock. Flow in the largest fractures may approach the velocities of surface water, but where these rocks occur in California there is limited storage potential for groundwater. Carbonate rocks occur mostly in Inyo County near the Nevada border (USGS 1995), in the Sierra Nevada foothills, and in some parts of the Sacramento River drainage north of Redding. The carbonates near the Nevada state border in Inyo County are part of a regional aquifer that extends northeastward into Nevada. Springs in Nevada and in the Death Valley region in California are dependent on groundwater flow in this regional aquifer. In other parts of the country, such as Florida, carbonate rocks constitute significant sources of groundwater.

Movement of Groundwater

The movement of groundwater in the subsurface is quite complex, but in simple terms it can be described as being driven by potential energy. At any point in the saturated subsurface, groundwater has a hydraulic head value that describes its potential energy, which is the combination of its elevation and pressure. In an unconfined aquifer, the water table elevation represents the hydraulic head, while in a confined aquifer the potentiometric surface represents the hydraulic head (Figure 14). Water moves in response to the difference in hydraulic head from the point of highest energy toward the lowest. On a regional scale, this results in flow of groundwater from recharge areas to discharge areas. In California, pumping depressions around extraction wells often create the discharge points to which groundwater flows. Groundwater may naturally exit the subsurface by flowing into a stream, lake, or ocean, by flowing to the surface as a spring or seep, or by being transpired by plants.

The rate at which groundwater flows is dependent on the hydraulic conductivity and the rate of change of hydraulic head over some distance. In the mid-19th century, Henry Darcy found through his experiments on sand filters that the amount of flow through a porous medium is directly proportional to the difference

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between hydraulic head values and inversely proportional to the horizontal distance between them (Fetter 1988). His conclusions extend to flow through aquifer materials. The difference between hydraulic heads divided by the distance between them is referred to as the hydraulic gradient. When combined with the hydraulic conductivity of the porous medium and the cross-sectional area through which the groundwater flows, Darcy's law states:

$$Q = KA(dh/dl) \quad \text{(volume/time)}$$

Where:

Q = flow discharging through a porous medium
K = hydraulic conductivity (length/time)
A = cross-sectional area (length^2)
dh = change in hydraulic head between two points (length)
dl = distance between two points (length)

This version of Darcy's law provides a volumetric flow rate. To calculate the average linear velocity at which the water flows, the result is divided by the effective porosity. The rate of movement of groundwater is very slow, usually less than 1,000 feet per year because of the great amount of friction resulting from movement through the spaces between grains of sand and gravel.

Quantity of Groundwater

Because groundwater is a precious resource, the questions of how much there is and how more can be made available are important. There are many terms and concepts associated with the quantity of groundwater available in a basin, and some controversy surrounding their definition. Some of these include groundwater storage capacity, usable storage capacity, groundwater budget, change in storage, overdraft, and safe yield. This section discusses some of the more common terms used to represent groundwater quantity in California.

Groundwater Storage Capacity

The groundwater storage capacity of an individual basin or within the entire State is one of the questions most frequently asked by private citizens, water resource planners, and politicians alike. Total storage capacity seems easy to understand. It can be seen as how much physical space is available for storing groundwater. The computation of groundwater storage capacity is quite simple if data are available: capacity is determined by multiplying the total volume of a basin by the average specific yield. The total storage capacity is constant and is dependent on the geometry and hydrogeologic characteristics of the aquifer(s) (Figure 17).

Estimates of total groundwater storage capacity in California are staggering. Previous estimates of total storage range from 850 million acre-feet (maf) to 1.3 billion acre-feet (DWR 1975, DWR 1994). However, due to incomplete information about many of the groundwater basins, there has never been an accurately quantified calculation of total storage capacity statewide. Even if such a calculation were possible, the utility of such a number is questionable because total storage capacity might lead to overly optimistic estimates of how much additional groundwater development can contribute to meeting future demands.

Total groundwater storage capacity is misleading because it only takes into account one aspect of the physical character of the basin. Many other factors limit the ultimate development potential of a groundwater basin. These limiting factors may be physical, chemical, economic, environmental, legal, and institutional (Table 9). Some of these factors, such as the economic and institutional ones, can change with time. However, there may remain significant physical and chemical constraints that will limit groundwater development.

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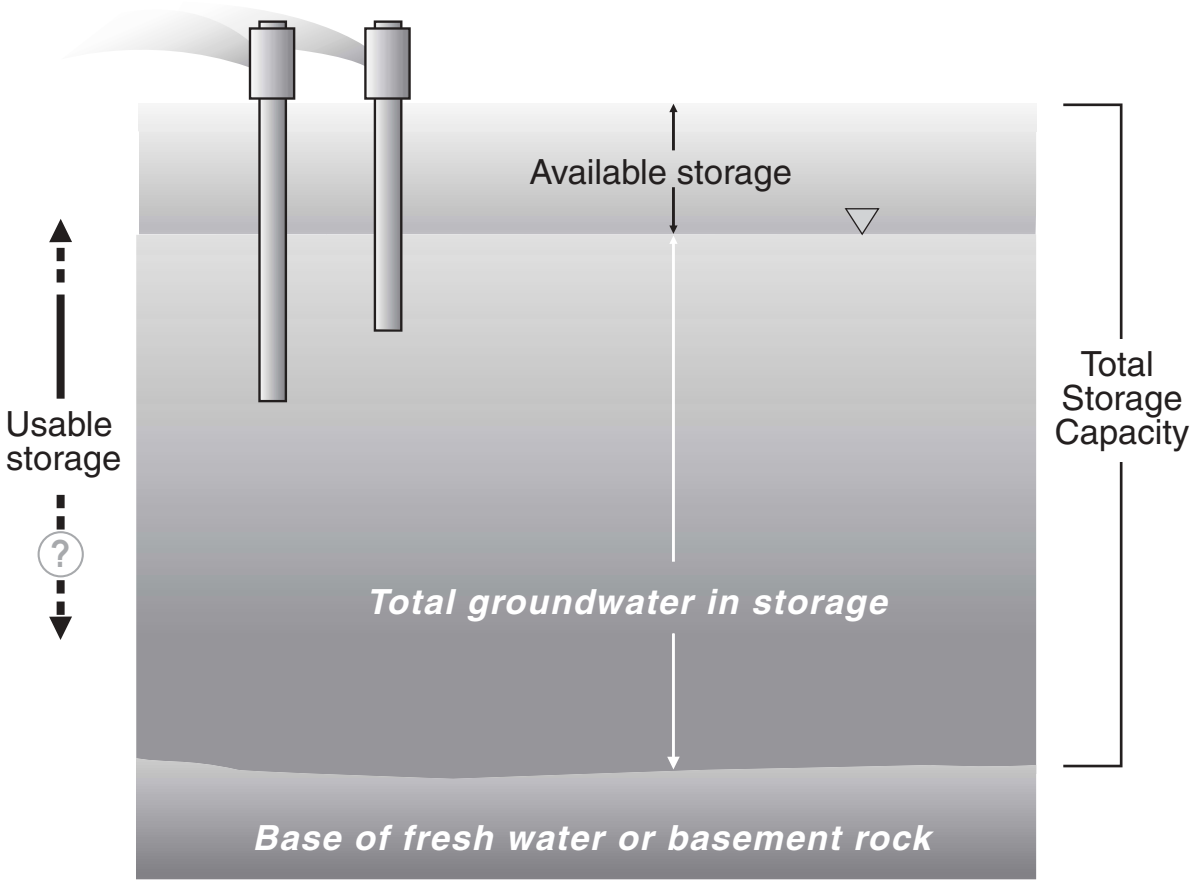

Figure 17 Schematic of total, usable, and available groundwater storage capacity

Table 9 Examples of factors that limit development of a groundwater basin

Limiting factor	Examples
Physical	Basin recharge area not adequate to sustain development; pumping too concentrated in a portion of basin; well yields too low for intended use.
Quality	Water quality not suitable for intended use; increased potential for seawater intrusion in coastal areas; upwelling of poorer quality water in deeper parts of basin.
Economic	Excessive costs associated with increased pump lifts and deepening of wells; cost of treating water if it does meet requirements for intended use.
Environmental	Need to maintain groundwater levels for wetlands, stream base flow, or other habitat.
Institutional	Local groundwater management plans or ordinances restricting use; basin adjudication; impacts on surface water rights of others.

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Usable Groundwater Storage Capacity

Usable storage capacity is defined as the amount of groundwater of suitable quality that can be economically withdrawn from storage. It is typically computed as the product of the volume of the basin to some basin-specific depth that is considered economically available and the average specific yield of the basin (see Figure 17).

As more groundwater is extracted, groundwater levels may fall below some existing wells, which may then require replacement or deepening. This may be a consideration in management of the basin and will depend on the cost of replacement, the cost of pumping the water from deeper zones, and whether managers are willing to pay that cost. Other impacts that may increase the cost include subsidence and groundwater quality degradation. The usable storage may change because of changes in economic conditions.

Estimates of usable storage represent only the total volume of groundwater assumed to be usable in storage, not what would be available for sustained use on an annual basis. Previous estimates of usable groundwater storage capacity range from 143 to 450 maf (DWR 1975, DWR 1994). Unfortunately, the term "usable storage" is often used to indicate the amount of water that can be used from a basin as a source of long-term annual supply. However, the many limitations associated with total groundwater storage capacity discussed above may also apply to usable storage.

Available Groundwater Storage Capacity

Available storage capacity is defined as the volume of a basin that is unsaturated and capable of storing additional groundwater. It is typically computed as the product of the empty volume of the basin and the average specific yield of the unsaturated part of the basin (see Figure 17). The available storage capacity does not include the uppermost portion of the unsaturated zone in which saturation could cause problems such as crop root damage or increased liquefaction potential. The available storage will vary depending on the amount of groundwater taken out of storage and the recharge. The total groundwater in storage will change inversely as the available storage changes.

Available storage has often been used as a number to represent the potential for additional yield from a particular basin. Unfortunately, many of the limitations that exist in developing existing supply discussed above also limit taking advantage of available storage. Although limitations exist, looking only at available groundwater storage capacity may underestimate the potential for groundwater development. Opportunities to use groundwater already in storage and create additional storage space would be overlooked by this approach.

Groundwater Budget

A groundwater budget is an analysis of a groundwater basin's inflows and outflows to determine the change in groundwater storage. Alternatively, if the change in storage is known, the value of one of the inflows or outflows could be determined. The basic equation can be expressed as:

INFLOWS – OUTFLOWS = CHANGE IN STORAGE

Typical inflows include:

- natural recharge from precipitation;
- seepage from surface water channels;
- intentional recharge via ponds, ditches, and injection wells;
- net recharge of applied water for agricultural and other irrigation uses;
- unintentional recharge from leaky conveyance pipelines; and
- subsurface inflows from outside basin boundaries.

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Outflows include:

- groundwater extraction by wells;
- groundwater discharge to surface water bodies and springs;
- evapotranspiration; and
- subsurface outflow across basin or subbasin boundaries.

Groundwater budgets can be useful tools to understand a basin, but detailed budgets are not available for most groundwater basins in California. A detailed knowledge of each budget component is necessary to obtain a good approximation of the change in storage. Absence or inaccuracy of one or more parameters can lead to an analysis that varies widely from a positive to a negative change in storage or vice versa. Since much of the data needed requires subsurface exploration and monitoring over a series of years, the collection of detailed field data is time-consuming and expensive. A management plan should develop a monitoring program as soon as possible.

Change in Groundwater Storage

As stated above, a groundwater budget is one potential way of estimating the change in storage in a basin, although it is limited by the accuracy and availability of data. There is a simpler way—by determining the average change in groundwater elevation over the basin, multiplied by the area overlying the basin and the average specific yield (or storativity in the case of a confined aquifer). The time interval over which the groundwater elevation change is determined is study specific, but annual spring-to-spring changes are commonly used. A change in storage calculation does not attempt to determine the volume of water in storage at any time interval, but rather the change from a previous period or baseline condition.

A change in storage calculation is a relatively quick way to represent trends in a basin over time. If change in storage is negligible over a representative period, the basin is in equilibrium under current use. Changes in storage calculations are more often available for a groundwater basin than groundwater budgets because water level measurements are available in many basins. Specific yield and storativity are readily estimated based on knowledge of the hydrogeologic setting and geologic materials or through aquifer pumping tests. Although simple, change in storage calculations have potential sources of error, so it is important to treat change in storage as just one of many tools in determining conditions in a groundwater basin. Well data sets must be carefully evaluated before use in these calculations. Mixing of wells constructed in confined and unconfined portions of the basin and measurement of different well sets over time can result in significant errors.

Although the change in storage calculation is a relatively quick and inexpensive method of observing changes in the groundwater system, the full groundwater budget is preferable. A detailed budget describes an understanding of the physical processes affecting storage in the basin, which the simple change in storage calculation does not. For example, the budget takes into account the relationship between the surface water and the groundwater system. If additional groundwater extraction induced additional infiltration of surface water, the calculated change in storage could be minimal. However, if the surface water is used as a source of supply downstream, the impact of reduced flows could be significant.

Overdraft

Groundwater overdraft is defined as the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions (DWR 1998). Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts.

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Despite its common usage, the term overdraft has been the subject of debate for many years. Groundwater management is a local responsibility, therefore, the decision whether a basin is in a condition of overdraft is the responsibility of the local groundwater or water management agency. In some cases, local agencies may choose to deliberately extract groundwater in excess of recharge in a basin (known as "groundwater mining") as part of an overall management strategy. An independent analysis of water levels in such a basin might conclude that the basin is in overdraft. In other cases, where basin management is less active or nonexistent, declining groundwater levels are not considered a problem until levels drop below the depth of many wells in the basin. As a result, overdraft may not be reported for many years after the condition began.

Water quality changes and subsidence may also indicate that a basin has been overdrafted. For example, when groundwater levels decline in coastal aquifers, seawater fills the pore spaces in the aquifer that are vacated by the groundwater, indicating that the basin is being overdrafted. Overdraft has historically led to as much as 30 feet of land subsidence in one area of the State and lesser amounts in other areas.

The word "overdraft" has been used to designate two unrelated types of water shortages. The first is "historical overdraft" similar to the type illustrated in Figure 18, which shows that ground water levels began to decline in the mid 1950s and then leveled off in the mid 1980s, indicating less groundwater extraction or more recharge. The second type of shortage is "projected overdraft" as used in the *California Water Plan Update* (DWR 1998). In reality, this is an estimate of future water shortages based on an assumed management program within the basin, including projected supply and projected demand. If water management practices change in those basins in which a water shortage is projected, the amount of projected shortage will change.

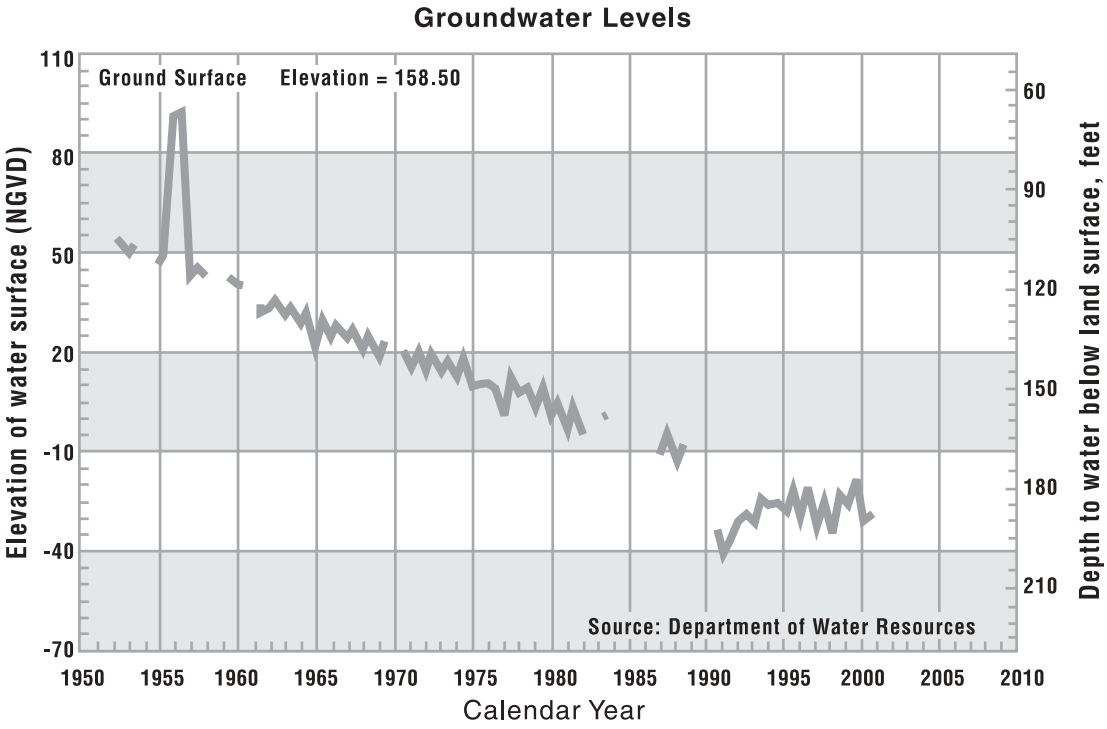

Figure 18 Hydrograph indicating overdraft

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In some basins or subbasins, groundwater levels declined steadily over a number of years as agricultural or urban use of groundwater increased. In response, managing agencies developed surface water import projects to provide expanded water supplies to alleviate the declining groundwater levels. Increasing groundwater levels, or refilling of the aquifer, demonstrate the effectiveness of this approach in long-term water supply planning. In some areas of the State, the past overdraft is now being used to advantage. When the groundwater storage capacity that is created through historical overdraft is used in coordination with surface water supplies in a conjunctive management program, local and regional water supplies can be augmented.

In 1978, DWR was directed by the legislature to develop a definition of critical overdraft and to identify basins that were in a condition of critical overdraft (Water Code § 12924). The process that was followed and the basins that were deemed to be in a condition of critical overdraft are discussed in Box O, "Critical Conditions of Overdraft." This update to Bulletin 118 did not include similar direction from the legislature, nor funding to undertake evaluation of the State's groundwater basins to determine whether they are in a state of overdraft.

Box O Critical Conditions of Overdraft

In 1978, DWR was directed by the legislature to develop a definition of critical overdraft and to identify those basins in a critical condition of overdraft (Water Code §12924). DWR held public workshops around the state to obtain public and water managers' input on what the definition should include, and which basins were critically overdrafted. Bulletin 118-80, *Ground Water Basins in California* was published in 1980 with the results of that local input. The definition of critical overdraft is:

> *A basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts.*

No time is specified in the definition. Definition of the time frame is the responsibility of the local water managers, as is the definition of significant adverse impacts, which would be related to the local agency's management objectives.

Eleven basins were identified as being in a critical condition of overdraft. They are:

- Pajaro Basin
- Ventura Central Basin
- Chowchilla Basin
- Kings Basin
- Tulare Lake Basin
- Kern County Basin
- Cuyama Valley Basin
- Eastern San Joaquin County Basin
- Madera Basin
- Kaweah Basin
- Tule Basin

The task was not identified by the Legislature, nor was the funding for this update (2003) sufficient to consult with local water managers and fully re-evaluate the conditions of the 11 critically overdrafted basins. Funding and duration were not sufficient to evaluate additional basins with respect to conditions of critical overdraft.

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If a basin lacks existing information, the cost of a thorough evaluation of overdraft conditions in a single basin could exceed $1 million. In this update of Bulletin 118, DWR has included groundwater budget information for each basin description, where available. In most cases, however, sufficient quantitative information is not available, so conditions of overdraft or critical overdraft were not reported.

While this bulletin does not specifically identify overdrafted basins (other than the 11 basins from Bulletin 118-80), the negative effects of overdraft are occurring or may occur in the future in many basins throughout the State. Declining water levels, diminishing water quality, and subsidence threaten the availability of groundwater to meet current and future demands. A thorough understanding of overdraft can help local groundwater managers minimize the impacts and take advantage of the opportunity created by available groundwater storage capacity. Local groundwater managers and DWR should seek funding and work cooperatively to evaluate the groundwater basins of the State with respect to overdraft and its potential impacts. Beginning with the most heavily used basins and relying to the extent possible on available data collected by DWR and through local groundwater management programs, current or projected conditions of critical overdraft should be identified. If local agencies take the lead in collecting and analyzing data to fully understand groundwater basin conditions, DWR can use the information to update the designations of critically overdrafted basins. This can be a cost effective approach since much of the data needed to update the overdraft designations are the same data that agencies need to effectively manage groundwater.

Safe Yield

Safe yield is defined as the amount of groundwater that can be continuously withdrawn from a basin without adverse impact. Safe yield is commonly expressed in terms of acre-feet per year. Depending on how it is applied, safe yield may be an annual average value or may be calculated based on changed conditions each year. Although safe yield may be indicated by stable groundwater levels measured over a period of years, a detailed groundwater budget is needed to accurately estimate safe yield. Safe yield has commonly been determined in groundwater basin adjudications.

Proper application of the safe yield concept requires that the value be modified through time to reflect changing practices within the basin. One of the common misconceptions is that safe yield is a static number. That is, once it has been calculated, the amount of water can be extracted annually from the basin without any adverse impacts. An example of a situation in which this assumption could be problematic is when land use changes. In some areas, where urban development has replaced agriculture, surface pavement, storm drains, and sewers have increased runoff and dramatically reduced recharge into the basin. If extraction continued at the predetermined safe yield of the basin, water level decline and other negative impacts could occur.

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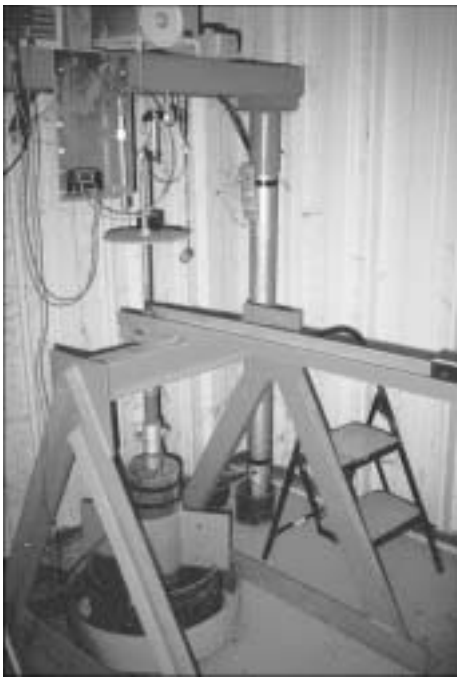

Figure 19 Photograph of extensometer

An extensometer is a well with a concrete bench mark at the bottom. A pipe extends from the concrete to the land surface. If compaction of the finer sediments occurs, leading to land surface subsidence, the pipe in the well will appear to rise out of the well casing. When this movement is recorded, the data show how much the land surface has subsided.

Subsidence

When groundwater is extracted from some aquifers in sufficient quantity, compaction of the fine-grained sediments can cause subsidence of the land surface. As the groundwater level is lowered, water pressure decreases and more of the weight of the overlying sediments is supported by the sediment grains within the aquifer. If these sediments have not previously been surcharged with an equivalent load, the overlying load will compact them. Compaction decreases the porosity of the sediments and decreases the overall volume of the finer grain sediments, leading to subsidence at the land surface. While the finer sediments within the aquifer system are compacted, the usable storage capacity of the aquifer is not greatly decreased.

Data from extensometers (Figure 19) show that as groundwater levels decline in an aquifer, the land surface falls slightly. As groundwater levels rise, the land surface also rises to its original position. This component of subsidence is called elastic subsidence because it recovers. Inelastic subsidence, the second component of subsidence, is what occurs when groundwater levels decline to the point that the finer sediments are compacted. This compaction is not recoverable.

Conjunctive Management

Conjunctive management in its broadest definition is the coordinated and combined use of surface water and groundwater to increase the overall water supply of a region and improve the reliability of that supply. Conjunctive management may be implemented to meet other objectives as well, including reducing groundwater overdraft and land subsidence, protecting water quality, and improving environmental conditions. Although surface water and groundwater are sometimes considered to be separate resources, they are connected in the hydrologic cycle. By using or storing additional surface water when it is plentiful, and relying more heavily on groundwater during dry periods, conjunctive management can change the timing and location of water so it can be used more efficiently.

Although a specific project or program may be extremely complex, there are several components common to conjunctive management projects. The first is to recharge surplus surface water when it is available to increase groundwater in storage. Recharge may occur through surface spreading, by injection wells, or by reducing groundwater use by substituting surface water. The surplus surface water used for recharge may be local runoff, imported water, stored surface water, or recycled water. The second component is to reduce surface water use in dry years or dry seasons by switching to groundwater. This use of the stored groundwater may take place through direct extraction and use, pumping back to a conveyance facility, or through exchange of another water supply. A final component that should be included is an ongoing monitoring program to evaluate operations and allow water managers to respond to changes in groundwater, surface water, or environmental conditions that could violate management objectives or impact other water users.

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Quality of Groundwater

All water contains dissolved constituents. Even rainwater, often described as being naturally pure, contains measurable dissolved minerals and gases. As it moves through the hydrologic cycle, water dissolves and incorporates many constituents. These include naturally occurring and man-made constituents.

Most natural minerals are harmless up to certain levels. In some cases, higher mineral content is preferable to consumers for taste. For example, minerals are added to many bottled drinking waters after going through a filtration process. At some level, however, most naturally occurring constituents, along with those introduced by human activities, are considered contaminants. The point at which a given constituent is considered a contaminant varies depending on the intended use of the groundwater and the toxicity level of the constituents.

Beneficial Uses

For this report, water quality is a measure of the suitability of water for its intended use, with respect to dissolved solids and gases and suspended material. An assessment of water quality should include the investigation of the presence and concentration of any individual constituent that may limit the water's suitability for an intended use.

The SWRCB has identified 23 categories of water uses, referred to as beneficial uses. The beneficial use categories and a brief description of each are presented in Appendix E. The actual criteria that are used to evaluate water quality for each of the beneficial uses are determined by the nine Regional Water Quality Control Boards, resulting in a range of criteria for some of the uses. These criteria are published in each of the Regional Boards' Water Quality Control Plans (Basin Plans)[1].

A summary of water quality for all of the beneficial uses of groundwater is beyond the scope of this report. Instead, water quality criteria for two of the most common uses—municipal supply (referred to as public drinking water supply in this report) and agricultural supply—are described below.

Public Drinking Water Supply

Standards for maximum contaminant levels (MCLs) of constituents in drinking water are required under the federal Safe Drinking Water Act of 1974 and its updates. There are primary and secondary standards. Primary standards are developed to protect public health and are legally enforceable. Secondary standards are generally for the protection of aesthetic qualities such as taste, odor, and appearance, and cosmetic qualities, such as skin or tooth discoloration, and are generally non-enforceable guidelines. However, in California secondary standards are legally enforceable for all new drinking water systems and new sources developed by existing public water suppliers (DWR 1997). Under these primary and secondary standards, the U.S. Environmental Protection Agency regulates more than 90 contaminants, and the California Department of Health Services regulates about 100. Federal and State primary MCLs are listed in Appendix F.

Agricultural Supply

An assessment of the suitability of groundwater as a source of agricultural supply is much less straightforward than that for public water supply. An evaluation of water supply suitability for use in agriculture is difficult because the impact of an individual constituent can vary depending on many factors, including soil chemical and physical properties, crop type, drainage, and irrigation method. Elevated levels of constituents usually do not result in an area being taken entirely out of production, but may lower crop yields. Management decisions will determine appropriate land use and irrigation methods.

[1] Digital versions of these plans are available online at http://www.swrcb.ca.gov/plnspols/index.html

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There are no regulatory standards for water applied on agriculture. Criteria for crop water have been provided as guidelines. Many constituents have the potential to negatively impact agriculture, including more than a dozen trace elements (Ayers and Westcot 1985). Two constituents that are commonly considered with respect to agricultural water quality are salinity—expressed as total dissolved solids (TDS)—and boron concentrations.

Increasing salinity in irrigation water inhibits plant growth by reducing a plant's ability to absorb water through its roots (Pratt and Suarez 1996). While the impact will depend on crop type and soil conditions, it is useful to look at the TDS of the applied water as a general assessment tool. A range of values for TDS with their estimated suitability for agricultural uses is presented in Table 10. These ranges are modified from criteria developed for use in the San Joaquin Valley by the San Joaquin Valley Drainage Program. However, they are similar to values presented in Ayers and Westcot (1985).

Table 10 Range of TDS values with estimated suitability for agricultural uses

Range of TDS (mg/L)	Suitability
<500	Generally no restrictions on use
500 – 1,250	Generally slight restrictions on use
1,250 – 2,500	Generally moderate restrictions on use
>2,500	Generally severe restrictions on use

Modified from SJVDP (1990)
TDS = total dissolved solids

High levels of boron can present toxicity problems in plants by damaging leaves. The boron is absorbed through the root system and transported to the leaves. Boron then accumulates during plant transpiration, resulting in leaf burn (Ayers and Westcot 1985). Boron toxicity is highly dependent on a crop's sensitivity to the constituent. A range of values of dissolved boron in irrigation water, with their estimated suitability on various crops is presented in Table 11. These ranges are modified from Ayers and Westcot (1985).

Table 11 Range of boron concentrations with estimated suitability on various crops

Range of dissolved boron (mg/L)	Suitability
<0.5	Suitable on all but most highly boron sensitive crops
0.5 – 1.0	Suitable on most boron sensitive crops
1.0 – 2.0	Suitable on most moderately boron sensitive crops
>2.0	Suitable for only moderately to highly boron tolerant crops

Source: Modified from Ayers and Westcot 1985

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Contaminant Groups

Because there are so many potential individual constituents to evaluate, researchers have often summarized contaminants into groups depending on the purpose of the study. Recognizing that there are exceptions to any classification scheme, this update considered groups according to their common sources of contamination—those naturally occurring and those caused by human activities (anthropogenic). Each of these sources includes more than one contaminant group. A listing of the contaminant groups and the individual constituents belonging to those groups, summarized in this report, is included in Appendix F.

Naturally Occurring Sources

In this report, naturally occurring sources include three primary groups: (1) inorganic constituents with primary MCLs, (2) inorganic constituents with secondary MCLs, and (3) radiological constituents. Inorganics primarily include naturally occurring minerals such as arsenic or mercury, although human activities may certainly contribute to observed concentrations. Radiological constituents include primarily naturally occurring constituents such as radon, gross alpha, and uranium. Although radioactivity is not considered a significant contaminant statewide, it can be locally important, particularly in communities in the Sierra Nevada.

Anthropogenic Sources

Anthropogenic contaminants include pesticides, volatile organic compounds (VOCs), and nitrates. Pesticides and VOCs are often grouped together into an organic contaminant group. However, separating the two gives a general idea of which contaminants are primarily from agricultural activities (pesticides) and which are primarily from industrial activities (VOCs). One notable exception to the groupings is dibromochloropropane (DBCP). Even though this compound is a VOC, DBCP is a soil fumigant and is included with pesticides. Nitrates are a surprising anthropogenic class to some observers. Nitrogen is certainly a naturally occurring inorganic constituent. However, because most nitrates are associated with agriculture (see Box P, "Focused on Nitrates: Detailed Study of a Contaminant") and nitrates are among California's leading contaminants, it is appropriate to consider them separately from inorganics.

Box P Focused on Nitrates: Detailed Study of a Contaminant

Because water has so many potential uses, the study of water quality means different things to different people. Thomas Harter, a professor at the University of California at Davis, has chosen to focus on nitrates as one of his research interests. Harter's monitoring network consists of 79 wells on 5 dairies in the San Joaquin Valley.

A common result of dairy activities is the release of nitrogen into the surroundings, which changes to nitrate in groundwater. Nitrates are notorious for their role in interfering with oxygen transport in babies, a condition commonly referred to as "blue baby syndrome." Nitrates are also of interest because more public supply wells have been closed due to nitrate contamination than from any other contaminant (Bachman and others 1997).

Harter's study has focused on two primary activities. The first is a meticulous examination of nitrogen at the surface and nitrates in the uppermost 25 feet of the subsurface. This monitoring has been ongoing since 1993, and has shown that a significant amount of nitrate can reach shallow groundwater. The second focus of the study has been to change management practices to reduce the amount of nitrogen available to reach groundwater, along with continued monitoring. This has occurred since 1998. Results of the study are better management practices that significantly reduce the amount of nitrogen available to groundwater. This will help minimize the potential adverse impacts to groundwater quality from nitrates.

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Chapter 7

Inventory of California's Groundwater Information

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Chapter 7
Inventory of California's Groundwater Information

The groundwater information in this chapter summarizes the available information on statewide and regional groundwater issues. For more detailed information on specific groundwater basins see the supplement to this report that is available on the California Department of Water Resources (DWR) website, http://www.waterplan.water.ca.gov/groundwater/118index.htm. See Appendix A for information on accessing individual basin descriptions and the map delineating California's groundwater basins.

Statewide Groundwater Information

There is a large amount of data available for many of the State's most heavily developed groundwater basins. Conversely, there is relatively little data available on groundwater in the undeveloped areas. The information in this report is generally limited to a compilation of the information readily available to DWR staff and may not include the most up-to-date data generated by studies that have been completed recently by water management agencies. For this reason, the collection of additional, more recent data on groundwater basins should be continued and integrated into the basin descriptions. Statewide summaries are included below.

Groundwater Basins

There are currently 431 groundwater basins delineated, underlying about 40 percent of the surface area of the State. Of those, 24 basins are subdivided into a total of 108 subbasins, giving a total of 515 distinct groundwater systems described in this report (Figure 20). Basin delineation methods are described in Appendix G. Additionally, many of the subbasin boundaries were developed or modified with public input, but little physical data. These boundaries should not be considered as precisely defining a groundwater basin boundary; the determination of whether any particular area lies within a groundwater basin boundary should be determined only after detailed local study.

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated.

Groundwater Budgets

Rather than simply providing all groundwater budget data collected during this update, the budget information was classified into one of three categories indicating the relative level of detail of information available. These categories, types A, B, and C, are discussed in Box R, "Explanation of Groundwater Data Tables." A type A budget indicates that much of the information needed to characterize the groundwater budget for the basin or subbasin was available. DWR staff did not verify these type A budgets, so DWR cannot address the accuracy of the data provided by them. Type B indicates that enough data are available to estimate the groundwater extraction to meet local water use needs. This is useful in understanding the reliance of a particular area on groundwater. Type C indicates a low level of knowledge of any of the budget components for the area.

Figure 21 depicts where these type A, B, and C budgets occur. In general, there is a greater level of understanding (type A or B) in the more heavily developed areas in terms of groundwater use. These include the Central Valley and South Coast. The lowest level of knowledge of groundwater budget data is in the southeast desert area. A discussion of groundwater use in each region is included below.

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Box Q How Does the Information in This Report Relate to the Recently Enacted Laws Senate Bill 221 and Senate Bill 610 (2002)?

Recently enacted legislation requires developers of certain new housing projects to demonstrate an available water supply for that development. If a part of that proposed water supply is groundwater, urban water suppliers must provide additional information on the availability of an adequate supply of groundwater to meet the projected demand and show that they have the legal right to extract that amount of groundwater. SB 610 (2002) amended the Water Code to require, among other things, the following information (Section 10631(b)(2)):

> *For basins that have not been adjudicated, information as to whether the department has identified the basin or basins as overdrafted or has projected that the basin will become overdrafted if present management conditions continue, in the most current official departmental bulletin that characterizes the condition of the groundwater basin, and a detailed description of the efforts being undertaken by the urban water supplier to eliminate the long-term overdraft condition.*

The hydrogeologic information contained in the basin descriptions that supplement this update of Bulletin 118 includes only the information that was available in California Department of Water Resources (DWR) files through reference searches and through limited contact with local agencies. Local agencies may have conducted more recent studies that have generated additional information about water budgets and aquifer characteristics. Unless the agency notified DWR, or provided a copy of the recent reports to DWR staff, that recent information has not been included in the basin descriptions. Therefore, although SB 610 refers to groundwater basins identified as overdrafted in Bulletin 118, it would be prudent for local water suppliers to evaluate the potential for overdraft of any basin included as a part of a water supply assessment.

Persons interested in collecting groundwater information in accordance with the Water Code as amended by SB 221 and SB 610 may start with the information in Bulletin 118, but should follow up by consulting the references listed for each basin and contacting local water agencies to obtain any new information that is available. Otherwise, evaluation of available groundwater resources as mandated by SB 221 and SB 610 may not be using the most complete and recent information about water budgets and aquifer characteristics.

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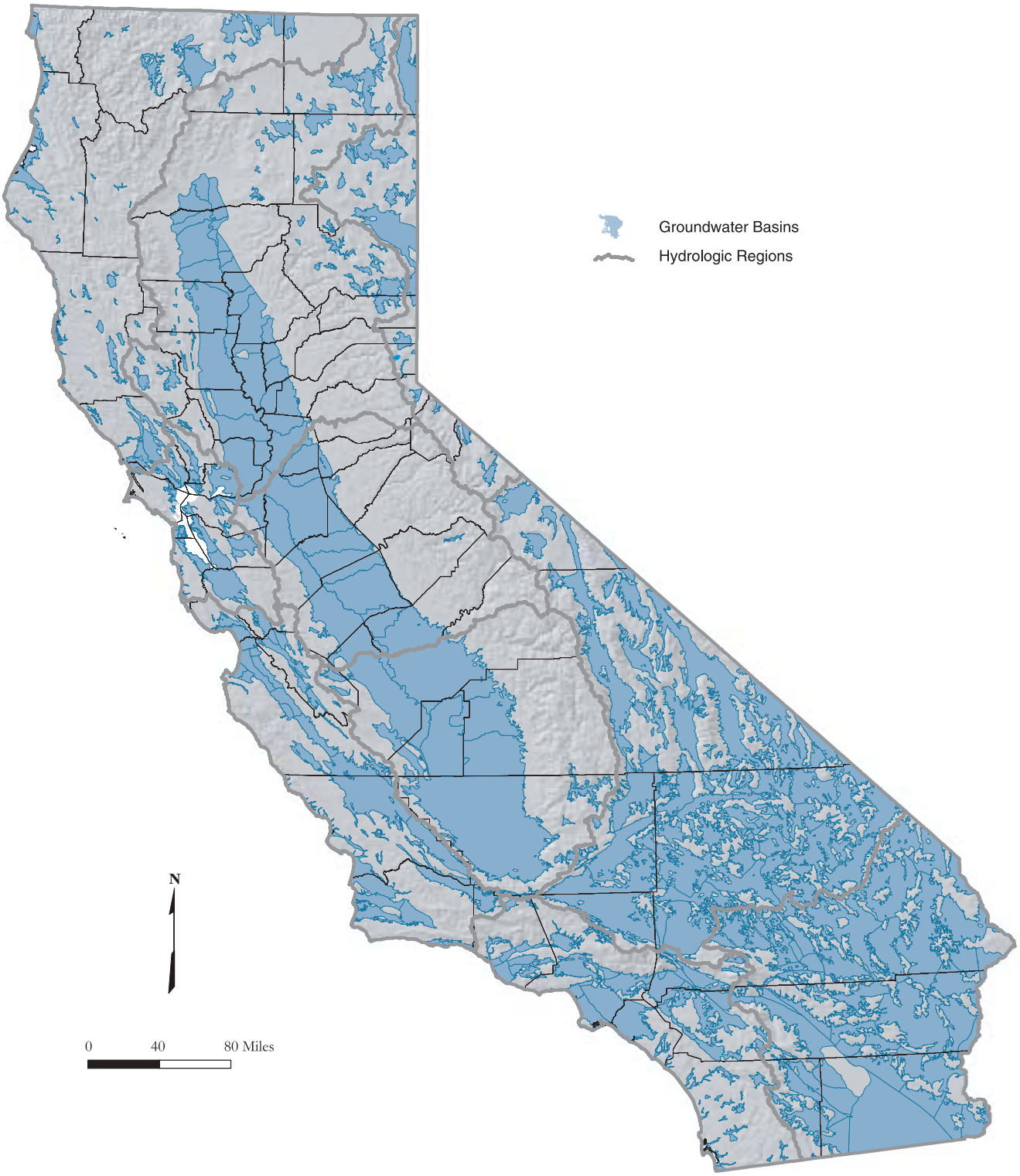

Figure 20 Groundwater basins and subbasins

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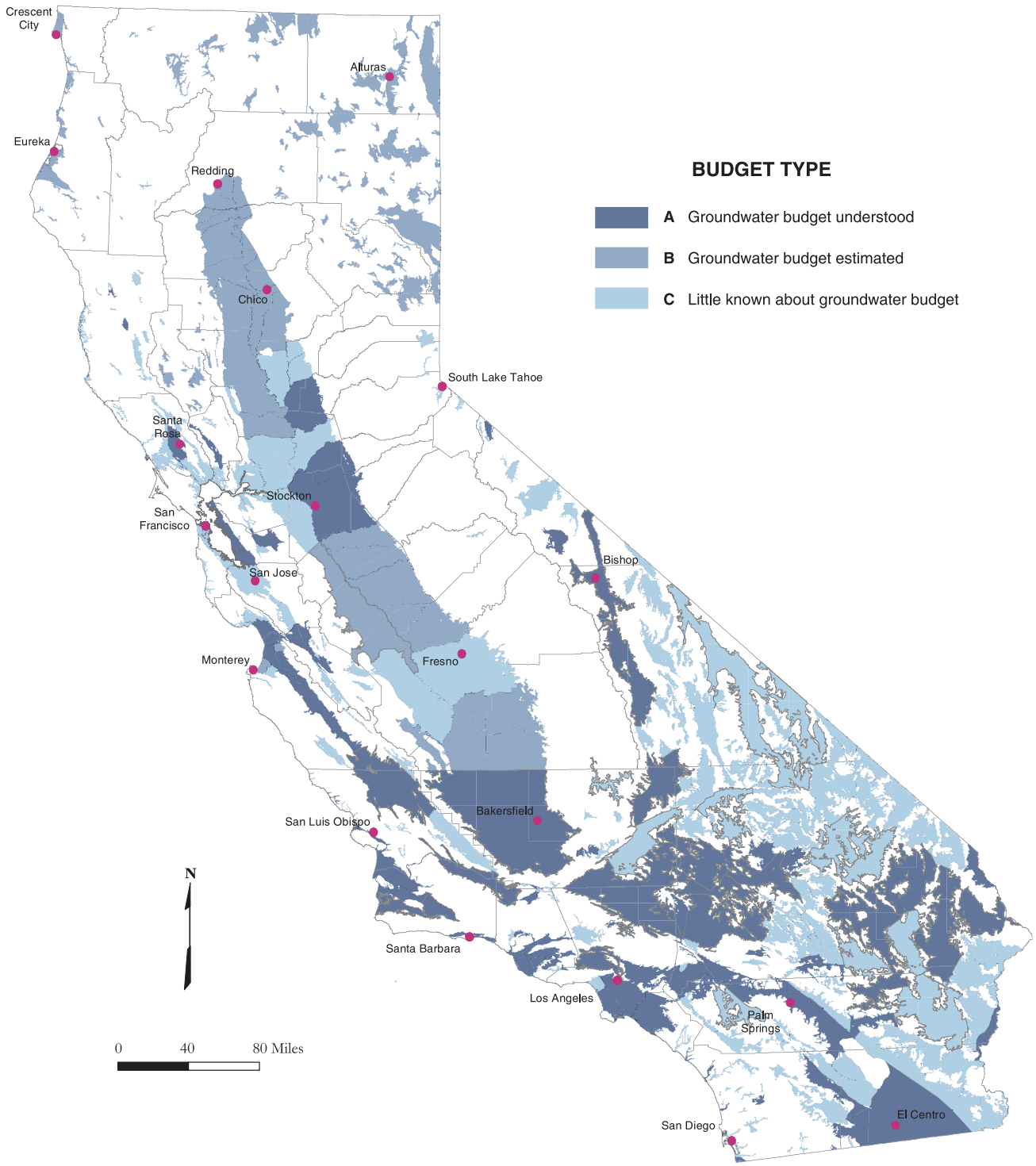

Figure 21 Basin and subbasin groundwater budget types

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Box R Explanation of Groundwater Data Tables

A groundwater data table for each hydrologic region is included at the end of each hydrologic region section in Chapter 7. The tables include the following information:

Basin/Subbasin Number. The basin numbering format is x-xxx.xx. The first number in the sequence assigns the basin to one of the nine Regional Water Quality Control Board boundaries. The second number is the groundwater basin number. Any number following the decimal identifies that the groundwater basin has been further divided into subbasins. Reevaluation of available hydrogeologic information resulted in the deletion of some basins and subbasins identified in Bulletins 118-75 and 118-80. Because of this, there are some gaps in the sequence of basin numbers in this report. The methods used for developing the current groundwater basin maps are discussed in Appendix H. The names and numbers of the basins deleted, along with any comments related to their elimination are included in the appropriate region in Chapter 7. Previously unidentified groundwater basins or subbasins that were delineated during this update are assigned new identification numbers that sequentially follow the last number used in Bulletin 118-80 for groundwater basins or subbasins.

Basin or Subbasin Name. Basin names are based on published and unpublished reports, topographic maps, and local terminology. Names of more recently delineated basins or subbasins are based on the principal geographic feature, which in most cases corresponds to the name of a valley. In the case of a subbasin, its formal name should include the name of the basin (for example, Sacramento Valley Groundwater Basin, North American Subbasin). However, both locally and informally, the term subbasin is used interchangeably with basin (for example, North American Basin).

Area. The area for each basin or subbasin is presented in acres rounded to three significant figures (for example, 147,148 acres was rounded to 147,000 acres). The area describes only the upper surface or map view of a basin. The basin underlies the area and may extend beyond the surface expression (discussed in Chapter 6).

Groundwater Budget Type. The type of groundwater budget information available was classified as Type A, B, or C based on the following criteria:

Type A – indicates one of the following: (1) a groundwater budget exists for the basin or enough components from separate studies could be combined to give a general indication of the basin's groundwater budget, (2) a groundwater model exists for the basin that can be used to calculate a groundwater budget, or (3) actual groundwater extraction data exist for the basin.

Type B – indicates that a use-based estimate of groundwater extraction is calculated for the basin. The use-based estimate is determined by calculating the overall use from California Department of Water Resources land use and urban water use surveys. Known surface water supplies are then subtracted from the total demand leaving the rest of the use to be met by groundwater extraction.

Type C – indicates that there are not enough data to provide either an estimate of the basin's groundwater budget or groundwater extraction from the basin.

Well Yields. Maximum and average well yields in gallons per minute (gpm) are reported for municipal supply and agricultural wells where available. Most of the values reported are from initial tests reported during construction of the well, which may not be an accurate indication of the long-term production capacity of the wells.

Box R continued on next page

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Box R Explanation of Groundwater Data Tables (continued)

Types of Monitoring. This includes monitoring of both groundwater levels and quality. "Levels" indicate the number of wells actively monitored without consideration of frequency. Most wells are monitored semi-annually, but many are monitored monthly. "Quality" indicates the number of wells monitored for various constituents; these could range from a grab sample taken for a field specific conductance measurement to a full analysis of organic and inorganic constituents. "Title 22" indicates the number of public water system wells that are actively sampled and monitored under the direction of California Department of Health Services (DHS) Title 22 Program.

Total Dissolved Solids. This category includes range and average values of total dissolved solids (TDS). This data primarily represents data from published reports. In some cases, a range of average TDS values is presented.

Active Monitoring

The summary of active monitoring includes wells that are monitored for groundwater elevation or groundwater quality within the delineated groundwater basins as of 1999. Groundwater elevation data collected by DWR and cooperators are available online at http://wdl.water.ca.gov. Most of the water quality data are for public supply wells and were provided by the California Department of Health Services (DHS). Other groundwater level and water quality monitoring activities were reported by local agencies during this update. The summary indicates that there are nearly 14,000 wells monitored for groundwater levels, 10,700[1] wells monitored under DHS water quality monitoring program, and 4,700 wells monitored for miscellaneous water quality by other agencies.

[1] These numbers include the wells in basins and subbasins only; throughout the entire state, DHS has responsibility for more than 16,000 public supply wells.

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Box S What Happens When an MCL Exceedance Occurs?

All suppliers of domestic water to the public are subject to regulations adopted by the U.S. Environmental Protection Agency under the Safe Drinking Water Act (42 U.S.C. 300f et seq.) as well as by the California Department of Health Services under the California Safe Drinking Water Plan Act (Health and Safety Code §§ 116270-116750).

These regulations include primary drinking water standards that establish maximum contaminant levels (MCLs) for inorganic and organic chemicals and radioactivity. MCLs are based on health protection, technical feasibility, and economic factors.

California requires public water systems to sample their drinking water sources, analyze for regulated contaminants, and determine compliance with the MCLs on a regular basis. Sampling frequency depends on the contaminant, type of water source, and previous sampling results; frequency can range from monthly to once every nine years, or none at all if sampling is waived because the source is not vulnerable to the contaminant.

Primary MCLs are enforceable standards. In California, compliance is usually determined at the wellhead or the surface water intake. To meet water quality standards and comply with regulations, a water system with a contaminant exceeding an MCL must notify the public and remove the source from service or initiate a process and schedule to install treatment for removing the contaminant.

Notification requirements reflect the severity of the associated health risks; immediate health concerns prompt immediate notice to consumers. Violations that do not pose a significant health concern may use a less immediate notification process. In addition to consumer notification, a water system is required by statute to notify the local governing body (for example, city council or county board of supervisors) whenever a drinking water well exceeds an MCL, even if the well is taken out of service.

Detections of regulated contaminants (and certain unregulated contaminants) must also be reported to consumers in the water system's annual Consumer Confidence Report.

Groundwater Quality

The summary of water quality relied heavily on data from the DHS Title 22 water quality monitoring program. The assessment consisted of querying the DHS database for active wells that have constituents exceeding the maximum contaminant level (MCL) for drinking water. Summaries of this assessment for each of the State's hydrologic regions (HRs) are discussed in this chapter.

DHS data are the most comprehensive statewide water quality data set available, but this data set should not be used as a sole indicator of the groundwater quality in California. Data from these wells are not necessarily representative of any given basin; it only represents the quality of groundwater where a public water supply is extracted.

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The Natural Resources Defense Council (NRDC 2001) issued a report that concludes California's groundwater resources face a serious long-term threat from contamination. Despite heavy reliance on groundwater, no comprehensive statewide assessments of groundwater quality were available. In response to the NRDC report, the State Water Resources Control Board (SWRCB) is planning a comprehensive assessment of the State's groundwater quality. This program is discussed in Chapter 4, in the section titled "Groundwater Quality Monitoring Act of 2001 (AB 599)."

Regional Groundwater Use

The importance of groundwater as a resource varies regionally throughout the State. For planning purposes, DWR divides California into 10 hydrologic regions (HRs), which correspond to the State's major drainage areas. HR boundaries are shown in Figure 22. A review of average water year supplies from the California Water Plan (DWR 1998) shows the importance of groundwater as a local supply for agricultural and municipal use throughout the State and in each of California's 10 HRs (Table 12 and Figure 23).

Table 12 Annual agricultural and municipal water demands met by groundwater

Hydrologic region	Total Demand Volume (TAF)	Demand met by Groundwater (TAF)	Demand met by Groundwater (%)
North Coast	1063	263	25
San Francisco Bay	1353	68	5
Central Coast	1263	1045	83
South Coast	5124	1177	23
Sacramento River	8720	2672	31
San Joaquin River	7361	2195	30
Tulare Lake	10556	4340	41
North Lahontan	568	157	28
South Lahontan	480	239	50
Colorado River	4467	337	8

Source: DWR 1998

With more than 80 percent of demand met by groundwater, the Central Coast HR is heavily reliant on groundwater to meet its local needs. The Tulare Lake and South Lahontan HRs meet more than 40 percent of their local demand from groundwater. The South Coast, North Coast, North Lahontan, San Joaquin River, and Sacramento River HRs take between 20 and 40 percent of their supply from groundwater. Groundwater is a relatively minor source of supply in the San Francisco Bay and Colorado River HRs.

Of all the groundwater extracted annually in the state, an estimated 35 percent is produced from the Tulare Lake HR. More than 70 percent of groundwater extraction occurs in the Central Valley (Tulare Lake, San Joaquin River, and Sacramento River HRs combined). Nearly 20 percent is extracted in the highly urbanized South Coast and Central Coast HRs, while less than 10 percent is extracted in the remaining five HRs combined.

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Figure 22 California's 10 hydrologic regions

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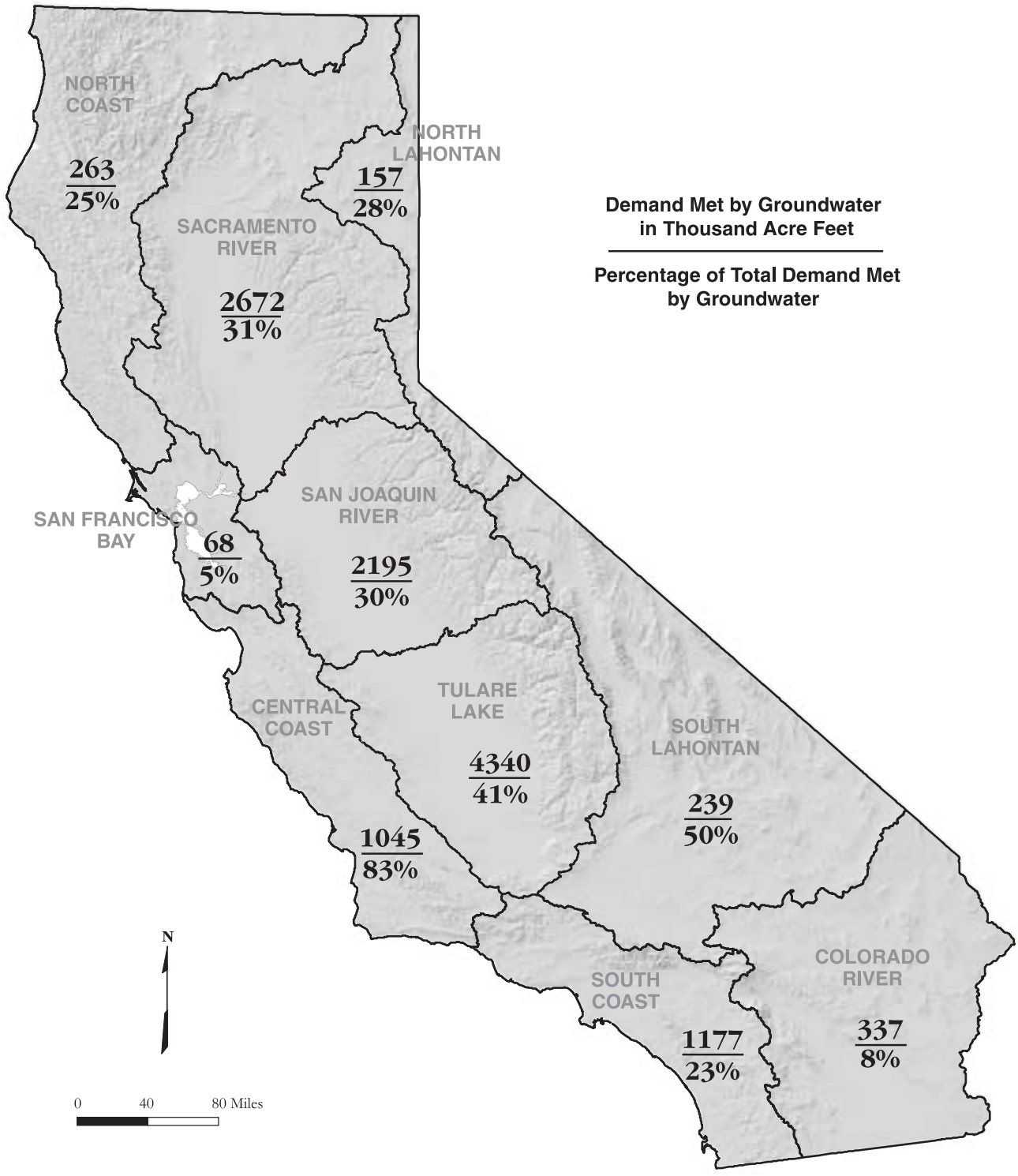

Figure 23 Agricultural and urban demand supplied by groundwater in each hydrologic region

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The remainder of this chapter provides a summary of each of the 10 HRs. A basin location map for each HR is followed by a brief discussion of groundwater occurrence and groundwater conditions. A summary tabulation of groundwater information for each groundwater basin within the HR is provided. Greater detail for the data presented in these tables, including a bibliography, is provided in the individual basin/subbasin descriptions in the supplemental report (see Appendix A). Because the groundwater basin numbers are based on the boundaries of the State's nine Regional Water Quality Control Boards (RWQCB), Figure 24 shows the relationship between the Regional Board boundaries and DWR's HR boundaries.

The groundwater basin tabulations give an overview of available data. Where a basin is divided into subbasins, only the information for the subbasins is provided. The data for each subbasin generally come from different sources, so it is inappropriate to sum the data into a larger basin summary. An explanation of each of the data items presented in the summary table is provided in Box R.

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Figure 24 Regional Water Quality Control Board regions and Department of Water Resources hydrologic regions

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North Coast Hydrologic Region

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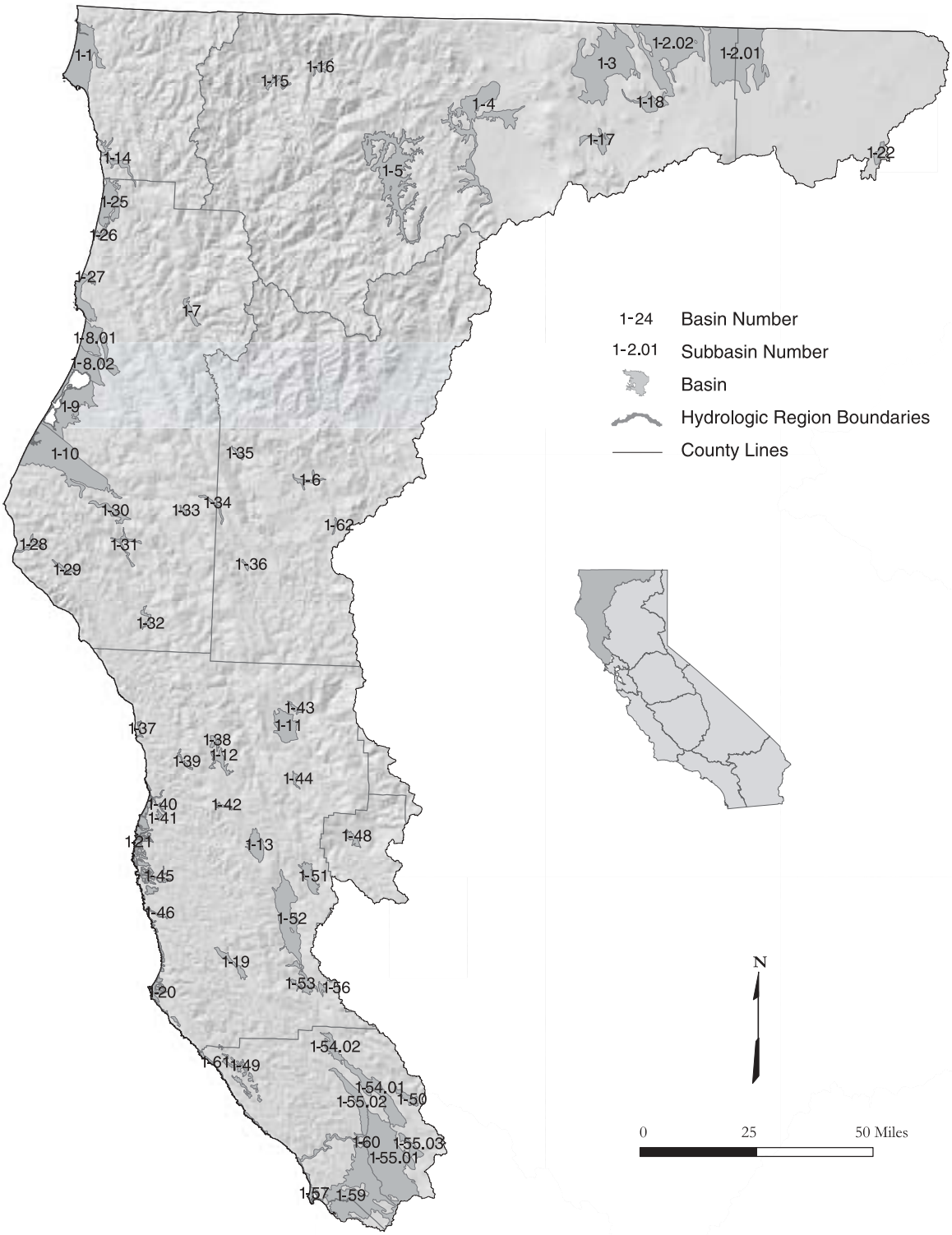

Figure 25 North Coast Hydrologic Region

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Basins and Subbasins of the North Coast Hydrologic Region

Basin/subbasin	Basin name
1-1	Smith River Plain
1-2	Klamath River Valley
1-2.01	Tule Lake
1-2.02	Lower Klamath
1-3	Butte Valley
1-4	Shasta Valley
1-5	Scott River Valley
1-6	Hayfork Valley
1-7	Hoopa Valley
1-8	Mad River Valley
1-8.01	Mad River Lowland
1-8.02	Dows Prairie School Area
1-9	Eureka Plain
1-10	Eel River Valley
1-11	Covelo Round Valley
1-12	Laytonville Valley
1-13	Little Lake Valley
1-14	Lower Klamath River Valley
1-15	Happy Camp Town Area
1-16	Seiad Valley
1-17	Bray Town Area
1-18	Red Rock Valley
1-19	Anderson Valley
1-20	Garcia River Valley
1-21	Fort Bragg Terrace Area
1-22	Fairchild Swamp Valley
1-25	Prairie Creek Area
1-26	Redwood Creek Area
1-27	Big Lagoon Area
1-28	Mattole River Valley
1-29	Honeydew Town Area
1-30	Pepperwood Town Area
1-31	Weott Town Area
1-32	Garberville Town Area
1-33	Larabee Valley
1-34	Dinsmores Town Area
1-35	Hyampom Valley
1-36	Hettenshaw Valley
1-37	Cottoneva Creek Valley
1-38	Lower Laytonville Valley
1-39	Branscomb Town Area
1-40	Ten Mile River Valley
1-41	Little Valley
1-42	Sherwood Valley
1-43	Williams Valley
1-44	Eden Valley
1-45	Big River Valley
1-46	Navarro River Valley
1-48	Gravelley Valley
1-49	Annapolis Ohlson Ranch Formation Highlands
1-50	Knights Valley
1-51	Potter Valley
1-52	Ukiah Valley
1-53	Sanel Valley
1-54	Alexander Valley
1-54.01	Alexander Area
1-54.02	Cloverdale Area
1-55	Santa Rosa Valley
1-55.01	Santa Rosa Plain
1-55.02	Healdsburg Area
1-55.03	Rincon Valley
1-56	McDowell Valley
1-57	Bodega Bay Area
1-59	Wilson Grove Formation Highlands
1-60	Lower Russian River Valley
1-61	Fort Ross Terrace Deposits
1-62	Wilson Point Area

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Description of the Region

The North Coast HR covers approximately 12.46 million acres (19,470 square miles) and includes all or portions of Modoc, Siskiyou, Del Norte, Trinity, Humboldt, Mendocino, Lake, and Sonoma counties (Figure 25). Small areas of Shasta, Tehama, Glenn, Colusa, and Marin counties are also within the region. Extending from the Oregon border south to Tomales Bay, the region includes portions of four geomorphic provinces. The northern Coast Range forms the portion of the region extending from the southern boundary north to the Mad River drainage and the fault contact with the metamorphic rocks of the Klamath Mountains, which continue north into Oregon. East of the Klamath terrane along the State border are the volcanic terranes of the Cascades and the Modoc Plateau. In the coastal mountains, most of the basins are along the narrow coastal strip between the Pacific Ocean and the rugged Coast Range and Klamath Mountains and along inland river valleys; alluviated basin areas are very sparse in the steep Klamath Mountains. In the volcanic terrane to the east, most of the basins are in block faulted valleys that once held Pleistocene-age lakes. The North Coast HR corresponds to the boundary of RWQCB 1. Significant geographic features include basin areas such as the Klamath River Basin, the Eureka/Arcata area, Hoopa Valley, Anderson Valley, and the Santa Rosa Plain. Other significant features include Mount Shasta, forming the southern border of Shasta Valley, and the rugged north coastal shoreline. The 1995 population of the entire region was about 606,000, with most being centered along the Pacific Coast and in the inland valleys north of the San Francisco Bay Area.

The northern mountainous portion of the region is rural and sparsely populated, primarily because of the rugged terrain. Most of the area is heavily forested. Some irrigated agriculture occurs in the narrow river valleys, but most occurs in the broader valleys on the Modoc Plateau where pasture, grain and alfalfa predominate. In the southern portion of the region, closer to urban centers, crops like wine grapes, nursery stock, orchards, and truck crops are common.

A majority of the surface water in the North Coast HR goes to environmental uses because of the "wild and scenic" designation of most of the region's rivers. Average annual precipitation ranges from 100 inches in the Smith River drainage to 29 inches in the Santa Rosa area and about 10 inches in the Klamath drainage; as a result, drought is likely to affect the Klamath Basin more than other portions of the region. Communities that are not served by the area's surface water projects also tend to experience shortages. Surface water development in the region includes the U.S. Bureau of Reclamation (USBR) Klamath Project, Humboldt Bay Municipal Water District's Ruth Lake, and U.S. Army Corps of Engineer's Russian River Project. An important factor concerning water demand in the Klamath Project area is water allocation for endangered fish species in the upper and lower basin. Surface water deliveries for agriculture in 2001, a severe drought year, were only about 20 percent of normal.

Groundwater Development

Groundwater development in the North Coast HR occurs along the coast, near the mouths of some of the region's major rivers, on the adjacent narrow marine terraces, or in the inland river valleys and basins. Reliability of these supplies varies significantly from area to area. There are 63 groundwater basins/subbasins delineated in the region, two of which are shared with Oregon. These basins underlie approximately 1.022 million acres (1,600 square miles).

Along the coast, most groundwater is developed from shallow wells installed in the sand and gravel beds of several of the region's rivers. Under California law, the water produced in these areas is considered surface water underflow. Water from Ranney collectors installed in the Klamath River, Rowdy Creek, the Smith

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River, and the Mad River supply the towns of Klamath, Smith River and Crescent City in Del Norte County and most of the Humboldt Bay area in Humboldt County. Except on the Mad River, which has continuous supply via releases from Ruth Reservoir, these supplies are dependent on adequate precipitation and flows throughout the season. In drought years when streamflows are low, seawater intrusion can occur causing brackish or saline water to enter these systems. This has been a problem in the town of Klamath, which in 1995 had to obtain community water from a private well source. Toward the southern portion of the region, along the Mendocino coast, the Town of Mendocino typifies the problems related to groundwater development in the shallow marine terrace aquifers. Groundwater supply is limited by the aquifer storage capacity, and surveys done in the Town of Mendocino in the mid-1980s indicate that about 10 percent of wells go dry every year and up to 40 percent go dry during drought years.

Groundwater development in the inland coastal valleys north of the divide between the Russian and Eel Rivers is generally of limited extent. Most problems stemming from reliance on groundwater in these areas is a lack of alluvial aquifer storage capacity. Many groundwater wells rely on hydrologic connection to the rivers and streams of the valleys. The City of Rio Dell has experienced water supply problems in community wells and, as a result, recently developed plans to install a Ranney collector near the Eel River. South of the divide, in the Russian River drainage, a significant amount of groundwater development has occurred on the Santa Rosa Plain and surrounding areas. The groundwater supplies augment surface supplies from the Russian River Project.

In the north-central part of the North Coast HR, the major groundwater basins include the Klamath River Valley, Shasta Valley, Scott River Valley, and Butte Valley. The Klamath River Valley is shared with Oregon. Of these groundwater basins, Butte Valley has the most stable water supply conditions. The historical annual agricultural surface water supply has been about 20,000 acre-feet. As farming in the valley expanded from the early 1950s to the early 1990s, bringing nearly all the arable land in the valley into production, groundwater was developed to farm the additional acres. It has been estimated that current, fully developed demands are only about 80 percent of the available groundwater supply. By contrast, water supply issues in the other three basins are contingent upon pending management decisions regarding restoration of fish populations in the Klamath River and the Upper Klamath Basin system. The Endangered Species Act (ESA) fishery issues include lake level requirements for two sucker fish species and in-stream flow requirements for coho salmon and steelhead trout. Since about 1905, the Klamath Project has provided surface water to the agricultural community, which in turn has provided water to the wildlife refuges. Since the early 1990s, it has been recognized that surface water in the Klamath Project is over-allocated, but very little groundwater development had occurred. In 2001, which was a severe drought year, USBR delivered a total of about 75,000 acre-feet of water to agriculture in California, about 20 percent of normal. In the Klamath River Groundwater Basin this translated to a drought disaster, both for agriculture and the wildlife refuges. In addition, there were significant impacts for both coho salmon and sucker fisheries in the Klamath River watershed. As a result of the reduced surface water deliveries, significant groundwater development occurred, and groundwater extraction increased from an estimated 6,000 acre-feet in 1997 to roughly 60,000 acre-feet in 2001. Because of the complexity of the basin's water issues, a long-term Klamath Project Operation plan has not yet been finalized. Since 1995, USBR has issued an annual operation plan based on estimates of available supply. The Scott River Valley and Shasta Valley rely to a significant extent on surface water diversions. In most years, surface water supplies the majority of demand, and groundwater extraction supplements supply as needed depending on wet or dry conditions. Discussions are under way to develop strategies to conjunctively use surface water and groundwater to meet environmental, agricultural, and other demands.

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Groundwater Quality

Groundwater quality characteristics and specific local impairments vary with regional setting within the North Coast HR. In general, seawater intrusion and nitrates in shallow aquifers are problems in the coastal groundwater basins; high total dissolved solids (TDS) content and general alkalinity are problems in the lake sediments of the Modoc Plateau basins; and iron, boron, and manganese can be problems in the inland basins of Mendocino and Sonoma counties.

Water Quality in Public Supply Wells

From 1994 through 2000, 584 public supply water wells were sampled in 32 of the 63 basins and subbasins in the North Coast HR. Analyzed samples indicate that 553 wells, or 95%, met the state primary Maximum Contaminant Levels (MCL) for drinking water. Thirty-one wells, or 5%, sampled have constituents that exceed one or more MCL. Figure 26 shows the percentage of each contaminant group that exceeded MCLs in the 31 wells.

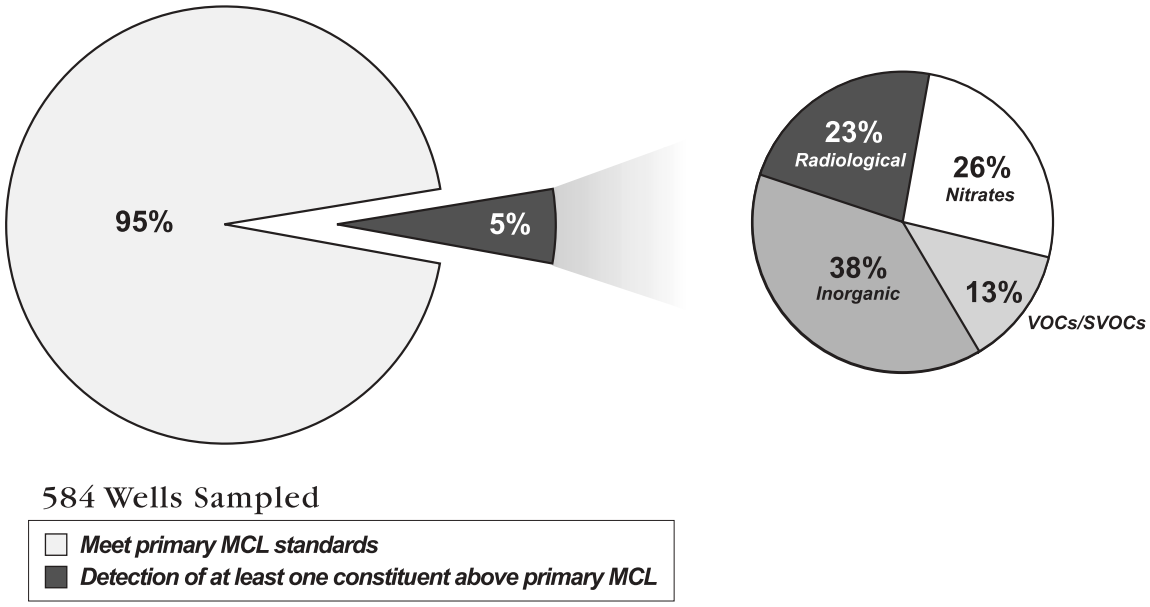

Figure 26 MCL exceedances in public supply wells in the North Coast Hydrologic Region

Table 13 lists the three most frequently occurring individual contaminants in each of the five contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

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Table 13 Most frequently occurring contaminants by contaminant group in the North Coast Hydrologic Region

Contaminant group wellsInorganics – Primary exceedance	Contaminant - # of wells Aluminum – 4	Contaminant - # of wells Arsenic – 4	Contaminant - # of 4 tied at 1
Inorganics – Secondary	Manganese – 150	Iron – 108	Copper – 2
Radiological	Radium 228 – 3	Combined RA226 + RA228 – 3	Radium 226 – 1
Nitrates	Nitrate(as NO_3) – 7	Nitrite(as N) – 1	
VOCs/SVOCs	TCE – 2	3 tied at 1 exceedance	

TCE = Trichloroethylene
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

Changes from Bulletin 118-80

Since Bulletin 118-80 was published, RWQCB 2 boundary has been modified. This resulted in several basins being reassigned to RWQCB 1. These are listed in Table 14, along with other modifications to North Coast HR.

Table 14 Modifications since Bulletin 118-80 of groundwater basins in North Coast Hydrologic Region

Basin name	New number	Old number
McDowell Valley	1-56	2-12
Knights Valley	1-50	2-13
Potter Valley	1-51	2-14
Ukiah Valley	1-52	2-15
Sanel Valley	1-53	2-16
Alexander Valley	1-54	2-17
Santa Rosa Valley	1-55	2-18
Lower Russian River Valley	1-60	2-20
Bodega Bay Area	1-57	2-21
Modoc Plateau Recent Volcanic Area	deleted	1-23
Modoc Plateau Pleistocene Volcanic Area	deleted	1-24
Gualala River Valley	deleted	1-47
Wilson Grove Formation Highlands	1-59	2-25
Fort Ross Terrace Deposits	1-61	
Wilson Point Area	1-62	

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Fort Ross Terrace Deposits (1-61) and Wilson Point Area (1-62) have been defined since B118-80 and are included in this update. Mad River Valley Groundwater Basin (1-8) has been subdivided into two subbasins. Sebastopol Merced Formation (2-25) merged into Basin 1-59 and was renamed Wilson Grove Formation Highlands.

There are a couple of deletions of groundwater basins from Bulletin 118-80. The Modoc Plateau Recent Volcanic Area (1-23) and the Modoc Plateau Pleistocene Volcanic Area (1-24) are volcanic aquifers and were not assigned basin numbers in this bulletin. These are considered to be groundwater source areas as discussed in Chapter 6. Gualala River Valley (1-47) was deleted because the State Water Resources Control Board determined the water being extracted in this area as surface water within a subterranean stream.

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Table 15 North Coast Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
1-1	SMITH RIVER PLAIN	40,450	B	500	50	7	10	33	164	32 - 496
1-2	KLAMATH RIVER VALLEY									
1-2.01	UPPER KLAMATH LAKE BASIN - Tule Lake	85,930	B	3,380	1,208	40	8	5	721	140 - 2,200
1-2.02	UPPER KLAMATH LAKE BASIN - Lower Klamath	73,330	B	2,600	1,550	4	-	-	-	-
1-3	BUTTE VALLEY	79,700	B	5,000	2,358	28	13	9	310	55 - 1,110
1-4	SHASTA VALLEY	52,640	B	1,200	273	9	15	24	-	-
1-5	SCOTT RIVER VALLEY	63,900	B	3,000	794	6	10	5	258	47 - 1,510
1-6	HAYFORK VALLEY	3,300	B	200	-	-	5	-	-	-
1-7	HOOPA VALLEY	3,900	B	300	-	-	4	-	125	95 - 159
1-8	MAD RIVER VALLEY									
1-8.01	MAD RIVER VALLEY LOWLAND	25,600	B	120	72	4	9	2	184	55 - 280
1-8.02	DOWS PRAIRIE SCHOOL AREA	14,000	B	-	-	-	3	-	-	-
1-9	EUREKA PLAIN	37,400	B	1,200	-	4	4	6	177	97 - 460
1-10	EEL RIVER VALLEY	73,700	B	1,200	-	8	11	29	237	110 - 340
1-11	COVELO ROUND VALLEY	16,400	C	850	193	9	5	29	239	116 - 381
1-12	LAYTONVILLE VALLEY	5,020	A	700	7	4	3	-	149	53 - 251
1-13	LITTLE LAKE VALLEY	10,000	A	1,000	45	7	7	-	340	97 - 1,710
1-14	LOWER KLAMATH RIVER VALLEY	7,030	B	-	-	-	-	-	-	43 - 150
1-15	HAPPY CAMP TOWN AREA	2,770	B	-	-	-	-	17	-	-
1-16	SEIAD VALLEY	2,250	B	-	-	-	2	2	-	-
1-17	BRAY TOWN AREA	8,030	B	-	-	-	-	-	-	-
1-18	RED ROCK VALLEY	9,000	B	-	-	-	-	-	-	-
1-19	ANDERSON VALLEY	4,970	C	300	30	7	5	7	-	80 - 400
1-20	GARCIA RIVER VALLEY	2,240	C	-	-	-	-	-	-	-
1-21	FORT BRAGG TERRACE AREA	24,100	C	75	14	-	-	51	185	26 - 650
1-22	FAIRCHILD SWAMP VALLEY	3,300	B	-	-	-	-	-	-	-
1-25	PRAIRIE CREEK AREA	20,000	B	-	-	-	-	1	106	-
1-26	REDWOOD CREEK AREA	2,000	B	-	-	1	0	4	-	102 - 332
1-27	BIG LAGOON AREA	13,400	B	-	-	1	0	31	174	-
1-28	MATTOLE RIVER VALLEY	3,150	B	-	-	-	-	2	-	-
1-29	HONEYDEW TOWN AREA	2,370	B	-	-	-	-	1	-	-
1-30	PEPPERWOOD TOWN AREA	6,290	B	-	-	-	-	1	-	-
1-31	WEOTT TOWN AREA	3,650	B	-	-	-	-	2	-	-
1-32	GARBERVILLE TOWN AREA	2,100	B	-	-	-	-	5	-	-
1-33	LARABEE VALLEY	970	B	-	-	-	-	-	-	-
1-34	DINSMORES TOWN AREA	2,300	B	-	-	-	-	3	-	-
1-35	HYAMPOM VALLEY	1,350	B	-	-	-	-	1	-	-
1-36	HETTENSHAW VALLEY	850	B	-	-	-	-	-	-	-
1-37	COTTONEVA CREEK VALLEY	760	C	-	-	-	-	-	118	118
1-38	LOWER LAYTONVILLE VALLEY	2,150	C	-	-	-	-	-	-	-
1-39	BRANSCOMB TOWN AREA	1,320	C	-	-	-	-	-	130	80 - 179
1-40	TEN MILE RIVER VALLEY	1,490	C	-	-	-	-	-	-	-
1-41	LITTLE VALLEY	810	C	-	-	-	-	-	-	-

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Table 15 North Coast Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
1-42	SHERWOOD VALLEY	1,150	C	-	-	-	-	-	-	-
1-43	WILLIAMS VALLEY	1,640	C	-	-	-	-	-	-	-
1-44	EDEN VALLEY	1,380	C	-	-	-	-	-	140	140
1-45	BIG RIVER VALLEY	1,690	C	-	-	-	-	2	-	-
1-46	NAVARRO RIVER VALLEY	770	C	-	-	-	-	-	-	-
1-48	GRAVELLEY VALLEY	3,000	C	-	-	-	-	3	-	-
1-49	ANAPOLIS OHLSON RANCH FOR. HIGHLANDS	8,650	C	36	-	-	0	1	260	260
1-50	KNIGHTS VALLEY	4,090	C	-	-	-	-	-	-	-
1-51	POTTER VALLEY	8,240	C	100	-	2	0	1	-	140 - 395
1-52	UKIAH VALLEY									
1-53	SANEL VALLEY	5,570	C	1,250	-	5	8	6	-	174 - 306
1-54	ALEXANDER VALLEY									
1-54.01	ALEXANDER AREA									
1-54.02	CLOVERDALE AREA	6,500	C	-	500	3	-	13	-	130 - 304
1-55	SANTA ROSA VALLEY									
1-55.01	SANTA ROSA PLAIN	80,000	A	1,500	-	43	-	155	-	-
1-55.02	HEALDSBURG AREA	15,400	C	500	-	8	-	28	-	90 - 500
1-55.03	RINCON VALLEY	5,600	C	-	-	2	-	12	-	-
1-56	McDOWELL VALLEY	1,500	C	1,200	-	-	-	-	145	143 - 146
1-57	BODEGA BAY AREA	2,680	A	150	-	-	-	6	-	-
1-59	WILSON GROVE FORMATION HIGHLANDS	81,500	C	-	-	14	-	68	-	-
1-60	LOWER RUSSIAN RIVER VALLEY	6,600	C	500 +	-	1	-	32	-	120 - 210
1-61	FORT ROSS TERRACE DEPOSITS	8,490	C	75	27	-	-	13	320	230 - 380
1-62	WILSON POINT AREA	700	B	-	-	-	-	-	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS = total dissolved solids

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San Francisco Bay Hydrologic Region

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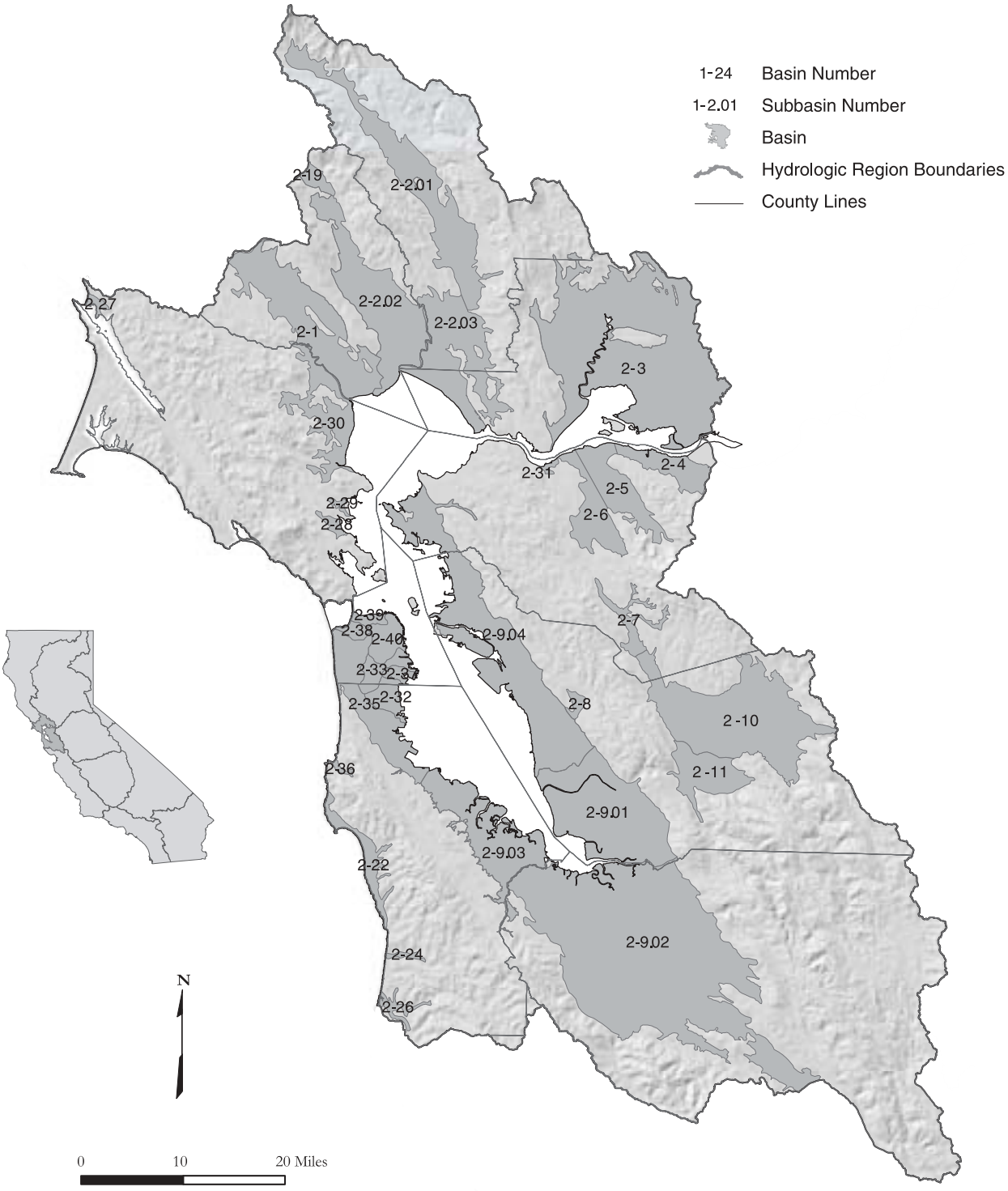

Figure 27 San Francisco Bay Hydrologic Region

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Basins and Subbasins of the San Francisco Bay Hydrologic Region

Basin/subbasin	Basin name
2-1	Petaluma Valley
2-2	Napa-Sonoma Valley
2-2.01	Napa Valley
2-2.02	Sonoma Valley
2-2.03	Napa-Sonoma Lowlands
2-3	Suisun-Fairfield Valley
2-4	Pittsburg Plain
2-5	Clayton Valley
2-6	Ygnacio Valley
2-7	San Ramon Valley
2-8	Castro Valley
2-9	Santa Clara Valley
2-9.01	Niles Cone
2-9.02	Santa Clara
2-9.03	San Mateo Plain
2-9.04	East Bay Plain
2-10	Livermore Valley
2-11	Sunol Valley
2-19	Kenwood Valley
2-22	Half Moon Bay Terrace
2-24	San Gregorio Valley
2-26	Pescadero Valley
2-27	Sand Point Area
2-28	Ross Valley
2-29	San Rafael Valley
2-30	Novato Valley
2-31	Arroyo Del Hambre Valley
2-32	Visitacion Valley
2-33	Islais Valley
2-35	Merced Valley
2-36	San Pedro Valley
2-37	South San Francisco
2-38	Lobos
2-39	Marina
2-40	Downtown San Francisco

Description of the Region

The San Francisco Bay HR covers approximately 2.88 million acres (4,500 square miles) and includes all of San Francisco and portions of Marin, Sonoma, Napa, Solano, San Mateo, Santa Clara, Contra Costa, and Alameda counties (Figure 27). The region corresponds to the boundary of RWQCB 2. Significant geographic features include the Santa Clara, Napa, Sonoma, Petaluma, Suisun-Fairfield, and Livermore valleys; the Marin and San Francisco peninsulas; San Francisco, Suisun, and San Pablo bays; and the Santa Cruz Mountains, Diablo Range, Bolinas Ridge, and Vaca Mountains of the Coast Range. While being the smallest in size of the 10 HRs, the region has the second largest population in the State at about 5.8 million in 1995 (DWR 1998). Major population centers include the cities of San Francisco, San Jose and Oakland.

Groundwater Development

The region has 28 identified groundwater basins. Two of those, the Napa-Sonoma Valley and Santa Clara Valley groundwater basins, are further divided into three and four subbasins, respectively. The groundwater basins underlie approximately 896,000 acres (1,400 square miles) or about 30 percent of the entire HR.

Despite the tremendous urban development in the region, groundwater use accounts for only about 5 percent (68,000 acre-feet) of the region's estimated average water supply for agricultural and urban uses, and accounts for less than one percent of statewide groundwater uses.

In general, the freshwater-bearing aquifers are relatively thin in the smaller basins and moderately thick in the more heavily utilized basins. The more heavily utilized basins in this region include the Santa Clara Valley, Napa-Sonoma Valley, and Petaluma Valley groundwater basins. In these basins, the municipal and irrigation wells have average depths ranging from about 200 to 500 feet. Well yields in these basins range from less than 50 gallons per minute (gpm) to approximately 3,000 gpm. In the smaller basins, most municipal and irrigation wells have average well depths in the 100- to 200-foot range. Well yields in the smaller and less utilized basins are typically less than 500 gpm.

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Land subsidence has been a significant problem in the Santa Clara Valley Groundwater Basin in the past. An extensive annual monitoring program has been set up within the basin to evaluate changes in an effort to maintain land subsidence at less than 0.01 feet per year (SCVWD 2001). Additionally, groundwater recharge projects have been implemented in the Santa Clara Valley to ensure that groundwater will continue to be a viable water supply in the future.

Groundwater Quality

In general, groundwater quality throughout most of the region is suitable for most urban and agricultural uses with only local impairments. The primary constituents of concern are high TDS, nitrate, boron, and organic compounds.

The areas of high TDS (and chloride) concentrations are typically found in the region's groundwater basins that are situated close to the San Francisco Bay, such as the northern Santa Clara, southern Sonoma, Petaluma, and Napa valleys. Elevated levels of nitrate have been detected in a large percentage of private wells tested within the Coyote Subbasin and Llagas Subbasin of the Gilroy-Hollister Valley Groundwater Basin (in the Central Coast HR) located to the south of the Santa Clara Valley (SCVWD 2001). The shallow aquifer zone within the Petaluma Valley also shows persistent nitrate contamination. Groundwater with high TDS, iron, and boron levels is present in the Calistoga area of Napa Valley, and elevated boron levels in other parts of Napa Valley make the water unfit for agricultural uses. Releases of fuel hydrocarbons from leaking underground storage tanks and spills/leaks of organic solvents at industrial sites have caused minor to significant groundwater impacts in many basins throughout the region. Methyl tertiary-butyl ether (MTBE) and chlorinated solvent releases to soil and groundwater continue to be problematic. Environmental oversight for many of these sites is performed either by local city and county enforcement agencies, the RWQCB, the Department of Toxic Substances Control, and/or the U.S. Environmental Protection Agency.

Water Quality in Public Supply Wells

From 1994 through 2000, 485 public supply water wells were sampled in 18 of the 33 basins and subbasins in the San Francisco Bay HR. Analyzed samples indicate that 410 wells, or 85 percent, met the state primary MCLs for drinking water standards. Seventy-five wells, or 15 percent, have constituents that exceed one or more MCL. Figure 28 shows the percentages of each contaminant group that exceeded MCLs in the 75 wells.

Table 16 lists the three most frequently occurring contaminants in each contaminant group and the number of wells in the HR that exceeded the MCL for those contaminants.

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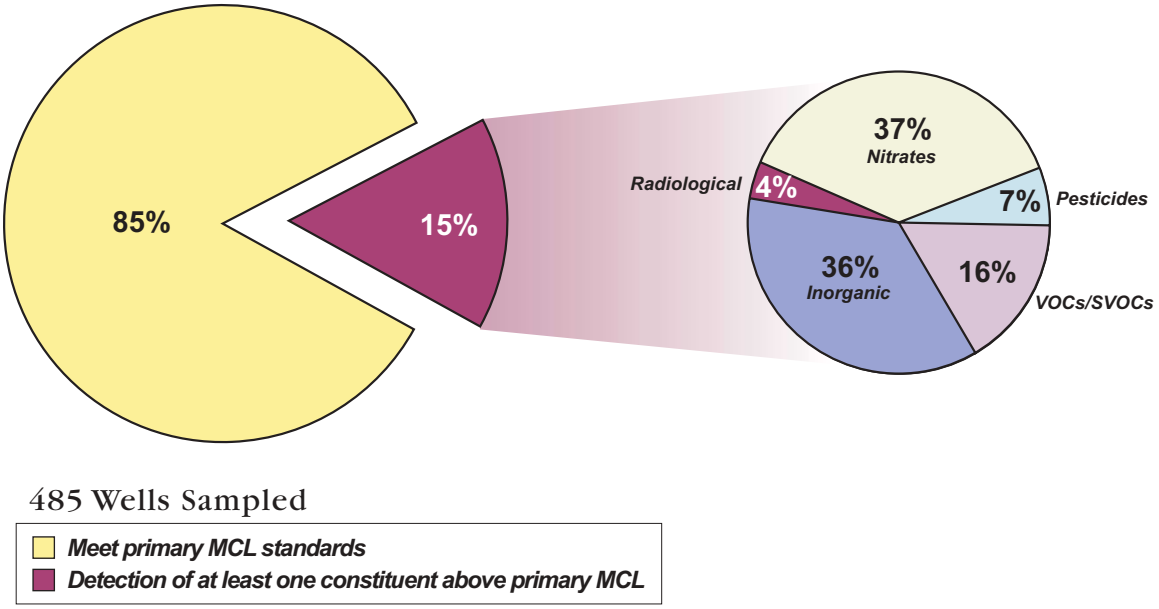

Figure 28 MCL exceedances in public supply wells in the San Francisco Bay Hydrologic Region

Table 16 Most frequently occurring contaminants by contaminant group in the San Francisco Bay Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics	Iron – 57	Manganese – 57	Fluoride – 7
Radiological	Gross Alpha – 2	Radium 226 – 1	
Nitrates	Nitrate (as NO_3) – 27	Nitrate + Nitrite – 3	Nitrite (as N) – 1
Pesticides	Di(2-Ethylhexyl)phthalate – 4	Heptachlor – 1	
VOCs/SVOCs	PCE – 4	Dichloromethane – 3	TCE– 2 Vinyl Chloride – 2

TCE = Trichloroethylene
PCE = Tetrachloroethylene
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Coumpound

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Changes from Bulletin 118-80

Since Bulletin 118-80 was published, RWQCB 2 boundary has been modified. This resulted in several basins being reassigned to RWQCB 1. These are listed in Table 17.

Table 17 Modifications since Bulletin 118-80 of groundwater basins in San Francisco Bay Hydrologic Region

Basin name	New number	Old number
McDowell Valley	1-56	2-12
Knights Valley	1-50	2-13
Potter Valley	1-51	2-14
Ukiah Valley	1-52	2-15
Sanel Valley	1-53	2-16
Alexander Valley	1-54	2-17
Santa Rosa Valley	1-55	2-18
Lower Russian River Valley	1-60	2-20
Bodega Bay Area	1-57	2-21

No additional basins were assigned to the San Francisco Bay HR in this revision. However, the Santa Clara Valley Groundwater Basin (2-9) has been subdivided into four subbasins instead of two, and the Napa-Sonoma Valley Groundwater Basin is now three subbasins instead of two.

There are several deletions of groundwater basins from Bulletin 118-80. The San Francisco Sand Dune Area (2-34) was deleted when the San Francisco groundwater basins were redefined in a USGS report in the early 1990s. The Napa-Sonoma Volcanic Highlands (2-23) is a volcanic aquifer and was not assigned a basin number in this bulletin. This is considered to be a groundwater source area as discussed in Chapter 6. Bulletin 118-80 identified seven groundwater basins that were stated to differ from 118-75: Sonoma County Basin, Napa County Basin, Santa Clara County Basin, San Mateo Basin, Alameda Bay Plain Basin, Niles Cone Basin, and Livermore Basin. They were created primarily by combining several smaller basins and subbasins within individual counties. This report does not consider these seven as basins. There is no change in numbering because the basins were never assigned a basin number.

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Table 18 San Francisco Bay Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Active Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
2-1	PETALUMA VALLEY	46,100	C	100	-	16	7	24	347	58-650
2-2	NAPA-SONOMA VALLEY									
2-2.01	NAPA VALLEY	45,900	A	3,000	223	19	10	23	272	150-370
2-2.02	SONOMA VALLEY	44,700	C	1,140	516	18	9	35	321	100-550
2-2.03	NAPA-SONOMA LOWLANDS	40,500	C	300	98	0	6	9	185	50-300
2-3	SUISUN-FAIRFIELD VALLEY	133,600	C	500	200	21	17	35	410	160-740
2-4	PITTSBURG PLAIN	11,600	C	-	-	-	-	9	-	-
2-5	CLAYTON VALLEY	17,800	C	-	-	-	-	48	-	-
2-6	YGNACIO VALLEY	15,500	C	-	-	-	-	-	-	-
2-7	SAN RAMON VALLEY	7,060	C	-	-	-	-	-	-	-
2-8	CASTRO VALLEY	1,820	C	-	-	-	-	-	-	-
2-9	SANTA CLARA VALLEY									
2-9.01	NILES CONE	57,900	A	3,000	2,000	350	120	20	-	-
2-9.02	SANTA CLARA	190,000	C	-	-	-	10	234	408	200-931
2-9.03	SAN MATEO PLAIN	48,100	C	-	-	-	2	14	407	300-480
2-9.04	EAST BAY PLAIN	77,400	A	1,000	UNK	29	16	7	638	364-1,420
2-10	LIVERMORE VALLEY	69,500	A	-	-	-	-	36	-	-
2-11	SUNOL VALLEY	16,600	C	-	-	-	-	2	-	-
2-19	KENWOOD VALLEY	3,170	C	-	-	-	-	13	-	-
2-22	HALF MOON BAY TERRACE	9,150	C	-	-	5	-	9	-	-
2-24	SAN GREGORIO VALLEY	1,070	C	-	-	-	-	-	-	-
2-26	PESCADERO VALLEY	2,900	C	-	-	3	-	4	-	-
2-27	SAND POINT AREA	1,400	C	-	-	-	-	6	-	-
2-28	ROSS VALLEY	1,770	C	-	-	-	-	-	-	-
2-29	SAN RAFAEL VALLEY	880	C	-	-	-	-	-	-	-
2-30	NOVATO VALLEY	20,500	C	-	-	-	-	1	-	-
2-31	ARROYO DEL HAMBRE VALLEY	790	C	-	-	-	-	-	-	-
2-32	VISITACION VALLEY	880	C	-	-	-	-	-	-	-
2-33	ISLAIS VALLEY	1,550	C	-	-	-	-	-	-	-
2-35	MERCED VALLEY	10,400	C	-	-	-	-	10	-	-
2-36	SAN PEDRO VALLEY	880	C	-	-	-	-	-	-	-
2-37	SOUTH SAN FRANCISCO	2,170	C	-	-	-	-	-	-	-
2-38	LOBOS	2,400	A	-	-	-	-	-	-	-
2-39	MARINA	220	A	-	-	-	-	-	-	-
2-40	DOWNTOWN SAN FRANCISCO	7,600	C	-	-	-	-	-	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS - total dissolved solids

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Central Coast Hydrologic Region

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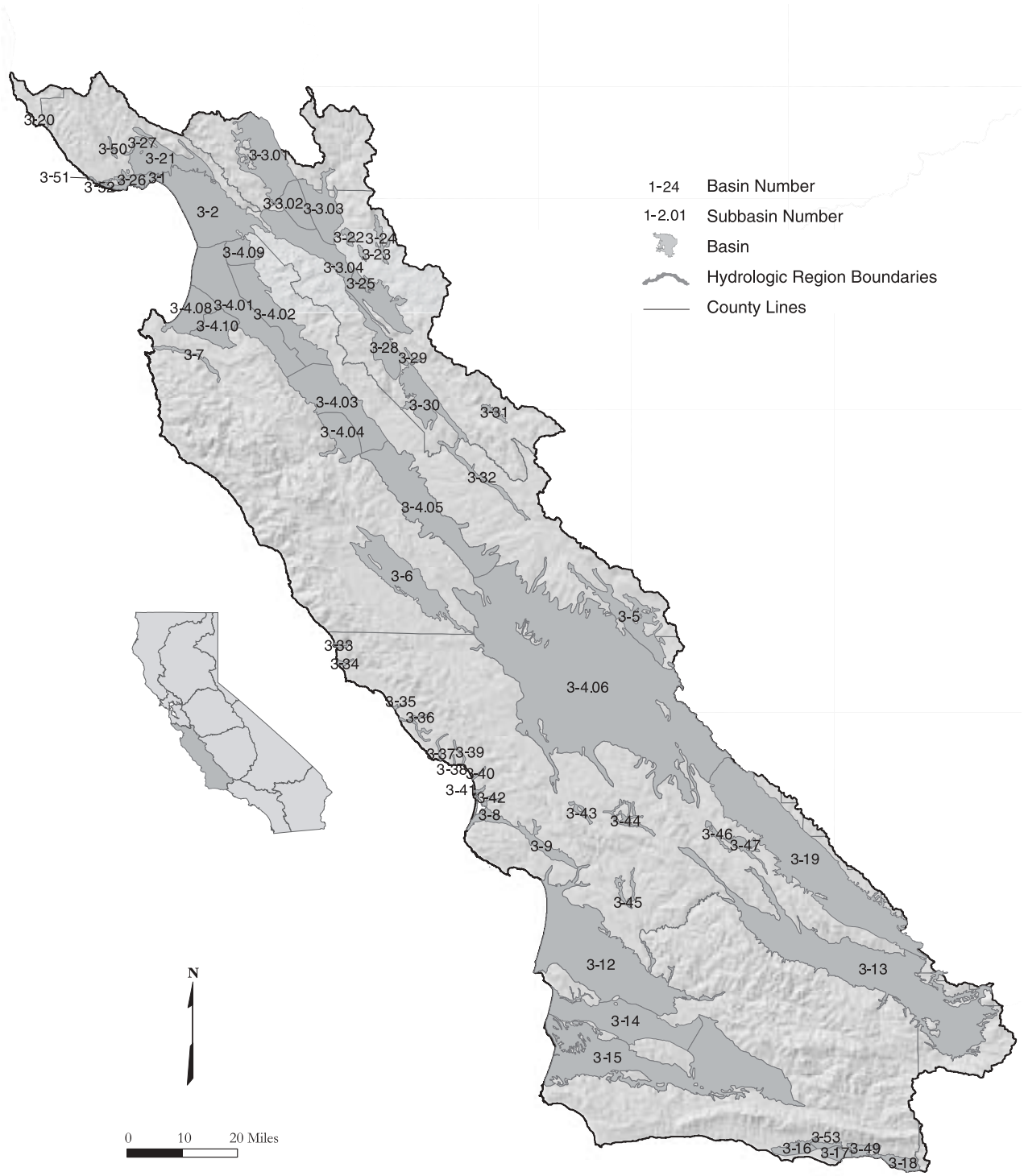

Figure 29 Central Coast Hydrologic Region

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Basins and Subbasins of Central Coast Hydrologic Region

RegionBasin/ subbasin	Basin name
3-1	Soquel Valley
3-2	Pajaro Valley
3-3	Gilroy-Hollister Valley
3-3.01	Llagas Area
3-3.02	Bolsa Area
3-3.03	Hollister Area
3-3.04	San Juan Bautista Area
3-4	Salinas Valley
3-4.01	180/400 Foot Aquifer
3-4.02	East Side Aquifer
3-4.04	Forebay Aquifer
3-4.05	Upper Valley Aquifer
3-4.06	Paso Robles Area
3-4.08	Seaside Area
3-4.09	Langley Area
3-4.10	Corral de Tierra Area
3-5	Cholame Valley
3-6	Lockwood Valley
3-7	Carmel Valley
3-8	Los Osos Valley
3-9	San Luis Obispo Valley
3-12	Santa Maria River Valley
3-13	Cuyama Valley
3-14	San Antonio Creek Valley
3-15	Santa Ynez River Valley
3-16	Goleta
3-17	Santa Barbara
3-18	Carpinteria
3-19	Carrizo Plain
3-20	Ano Nuevo Area
3-21	Santa Cruz Purisima Formation
3-22	Santa Ana Valley
3-23	Upper Santa Ana Valley
3-24	Quien Sabe Valley
3-25	Tres Pinos Valley
3-26	West Santa Cruz Terrace
3-27	Scotts Valley
3-28	San Benito River Valley
3-29	Dry Lake Valley
3-30	Bitter Water Valley
3-31	Hernandez Valley
3-32	Peach Tree Valley
3-33	San Carpoforo Valley
3-34	Arroyo de la Cruz Valley
3-35	San Simeon Valley
3-36	Santa Rosa Valley
3-37	Villa Valley
3-38	Cayucos Valley
3-39	Old Valley
3-40	Toro Valley
3-41	Morro Valley
3-42	Chorro Valley
3-43	Rinconada Valley
3-44	Pozo Valley
3-45	Huasna Valley
3-46	Rafael Valley
3-47	Big Spring Area
3-49	Montecito
3-50	Felton Area
3-51	Majors Creek
3-52	Needle Rock Point
3-53	Foothill

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Description of the Region

The Central Coast HR covers approximately 7.22 million acres (11,300 square miles) in central California (Figure 29). This HR includes all of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties, most of San Benito County, and parts of San Mateo, Santa Clara, and Ventura counties. Significant geographic features include the Pajaro, Salinas, Carmel, Santa Maria, Santa Ynez, and Cuyama valleys; the coastal plain of Santa Barbara; and the Coast Range. Major drainages in the region include the Salinas, Cuyama, Santa Ynez, Santa Maria, San Antonio, San Lorenzo, San Benito, Pajaro, Nacimiento, Carmel, and Big Sur Rivers.

Population data from the 2000 Census suggest that about 1.4 million people or about 4 percent of the population of the State live in this HR. Major population centers include Santa Barbara, Santa Maria, San Luis Obispo, Gilroy, Hollister, Morgan Hill, Salinas, and Monterey.

The Central Coast HR has 50 delineated groundwater basins. Within this region, the Gilroy-Hollister Valley and Salinas Valley groundwater basins are divided into four and eight subbasins, respectively. Groundwater basins in this HR underlie about 2.390 million acres (3,740 square miles) or about one-third of the HR.

Groundwater Development

Locally, groundwater is an extremely important source of water supply. Within the region, groundwater accounted for 83 percent of the annual supply used for agricultural and urban purposes in 1995. For an average year, groundwater in the region accounts for about 8.4 percent of the statewide groundwater supply and about 1.3 percent of the total state water supply for agricultural and urban needs. In drought years, groundwater in this region is expected to account for about 7.2 percent of the statewide groundwater supply and about 1.9 percent of the total State water supply for agricultural and urban needs (DWR 1998).

Aquifers are varied and range from large extensive alluvial valleys with thick multilayered aquifers and aquitards to small inland valleys and coastal terraces. Several of the larger basins provide a dependable and drought-resistant water supply to coastal cities and farms.

Conjunctive use of surface water and groundwater is a long-standing practice in the region. Several reservoirs including Hernandez, Twitchell, Lake San Antonio, and Lake Nacimiento are operated primarily for the purpose of groundwater recharge. The concept is to maintain streamflow over a longer period than would occur without surface water storage and thus provide for increased recharge of groundwater. Seawater intrusion is a major problem throughout much of the region. In the Salinas Valley Groundwater Basin, seawater intrusion was first documented in the 1930s and has been observed more than 5 miles inland.

Groundwater Quality

Much of the groundwater in the region is characterized by calcium sulfate to calcium sodium bicarbonate sulfate water types because of marine sedimentary rock in the watersheds. Aquifers intruded by seawater are typically characterized by sodium chloride to calcium chloride, and have chloride concentrations greater than 500 mg/L. In several areas, groundwater exceeds the MCL for nitrate.

Water Quality in Public Supply Wells

From 1994 through 2000, 711 public supply water wells were sampled in 38 of the 60 basins and subbasins in the Central Coast HR. Analyzed samples indicate that 587 wells, or 83 percent, met the state primary MCLs for drinking water. One-hundred-twenty-four wells, or 17 percent, have constituents that exceed one or more MCL. Figure 30 shows the percentages of each contaminant group that exceeded MCLs in the 124 wells.

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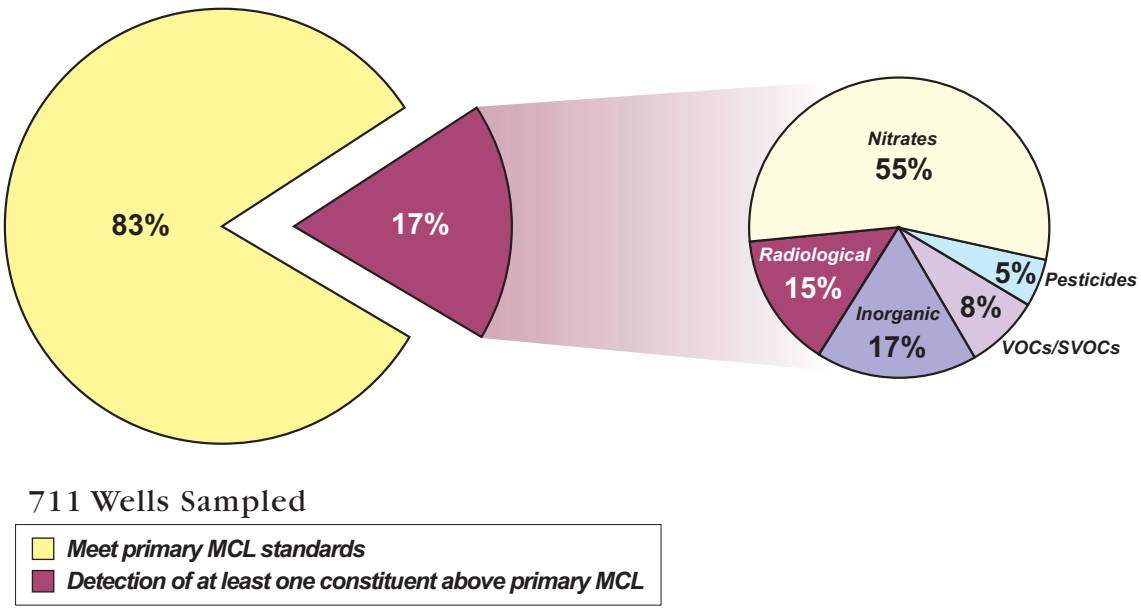

Figure 30 MCL exceedances in public supply wells in the Central Coast Hydrologic Region

Table 19 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 19 Most frequently occurring contaminants by contaminant group in the Central Coast Hydrologic Region

Contaminant group wells	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of
Inorganics – Primary	Antimony – 6	Aluminum – 4	Chromium (Total) – 4
Inorganics – Secondary	Iron – 145	Manganese – 135	TDS – 11
Radiological	Gross Alpha – 15	Radium 226 – 3	Uranium – 3
Nitrates	Nitrate (as NO_3) – 69	Nitrate + Nitrite – 24	
Pesticides	Heptachlor – 4	Di (2-Ethylhexyl) phthalate – 2	
VOCs/SVOCs	TCE – 3	3 are tied at 2 exceedances	

TCE = Trichloroethylene
VOC = Volatile Organic Compound
SVOC= Semivolatile Organic Compound

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Changes from Bulletin 118-80

Four new basins have been defined since Bulletin 118-80. They are Felton Area, Majors Creek, Needle Rock Point, and Foothill groundwater basins. Additionally, new subbasins have been broken out in both the Gilroy-Hollister Valley Groundwater Basin (3-3) and the Salinas Valley Groundwater Basin (3-4) (Table 20).

Table 20 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Central Coast Hydrologic Region

Subbasin name	New number	Old number
Llagas Area	3-3.01	3-3
Bolsa Area	3-3.02	3-3
Hollister Area	3-3.03	3-3
San Juan Bautista Area	3-3.04	3-3
180/400 Foot Aquifer	3-4.01	3-4
East Side Aquifer	3-4.02	3-4
Upper Forebay Aquifer	3-4.04	3-4
Upper Valley Aquifer	3-4.05	3-4
Pismo Creek Valley Basin	3-12	3-10
Arroyo Grande Creek Basin	3-12	3-11
Careaga Sand Highlands Basin	3-12 and 3-14	3-48
Felton Area	3-50	
Majors Creek	3-51	
Needle Rock Point	3-52	
Foothill	3-53	

Pismo Creek Valley Basin (3-10) and Arroyo Grande Creek Basin (3-11) have been merged into the Santa Maria River Valley Basin (3-12).
Careaga Sand Highlands Basin (3-48) has been merged into the Santa Maria River Valley Basin (3-12) and San Antonio Creek Valley Basin (3-14).

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Table 21 Central Coast Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
3-1	SOQUEL VALLEY	2,500	C	1,421	665	6	6	16	482	270-990
3-2	PAJARO VALLEY	76,800	A	2,000	500	185	185	149	580-910	300-30,000
3-3	GILROY-HOLLISTER VALLEY									
3-3.01	LLAGAS AREA	55,600	C	-	-	-	-	95	-	-
3-3.02	BOLSA AREA	21,000	A	-	400	11	<11	3	-	400-1800
3-3.03	HOLLISTER AREA	32,700	A	-	400	42	<42	35	-	400-1600
3-3.04	SAN JUAN BAUTISTA AREA	74,300	A	-	400	37	<37	40	-	460-1700
3-4	SALINAS VALLEY									
3-4.01	180/400 FOOT AQUIFER	84,400	A	-	-	166	218	82	478	223-1,013
3-4.02	EAST SIDE AQUIFER	57,500	A	-	-	74	67	53	450	168-977
3-4.04	FOREBAY AQUIFER	94,100	A	-	-	89	91	35	624	300-1,100
3-4.05	UPPER VALLEY AQUIFER	98,200	A	4,000	-	36	37	17	443	140-3,700
3-4.06	PASO ROBLES AREA	597,000	A	3,300	-	183	-	58	614	165-3,868
3-4.08	SEASIDE AREA	25,900	B	3,500	1,000		7	24	400	200-900
3-4.09	LANGLEY AREA	15,400	B	1,570	450	-	-	52	-	52-348
3-4.10	CORRAL DE TIERRA AREA	22,300	C	948	450	-	3	26	-	355-679
3-5	CHOLAME VALLEY	39,800	C	3,000	1,000	1	-	1	-	-
3-6	LOCKWOOD VALLEY	59,900	C	1,500	100	-	-	9	-	-
3-7	CARMEL VALLEY	5,160	C	1,000	600	50	23	12	260-670	220-1,200
3-8	LOS OSOS VALLEY	6,990	A	700	230	-	-	10	354	78-33,700
3-9	SAN LUIS OBISPO VALLEY	12,700	A	600	300	-	-	11	583	278-1,949
3-12	SANTA MARIA RIVER VALLEY	184,000	A	2,500	1,000	286	10	108	598	139-1,200
3-13	CUYAMA VALLEY	147,000	A	4,400	1,100	17	2	8	-	206-3,905
3-14	SAN ANTONIO CREEK VALLEY	81,800	A	-	400	30	-	9	415	129-8,040
3-15	SANTA YNEZ RIVER VALLEY	204,000	A	1,300	750	163	21	76	507	400-700
3-16	GOLETA	9,210	A	800	500	49	11	17	755	617-929
3-17	SANTA BARBARA	6,160	A	625	560	75	36	5	-	217-385
3-18	CARPINTERIA	8,120	A	500	300	41	41	4	557	317-1,780
3-19	CARRIZO PLAIN	173,000	C	1,000	500	-	-	1	-	-
3-20	ANO NUEVO AREA	2,032	C	-	-	-	-	2	-	-
3-21	SANTA CRUZ PURISIMA FORMATION	40,200	C	200	20	-	-	39	440	380-560
3-22	SANTA ANA VALLEY	2,720	C	130	-	-	-	-	-	-
3-23	UPPER SANTA ANA VALLEY	1,430	C	-	-	-	-	-	-	-
3-24	QUIEN SABE VALLEY	4,710	C	122	122	-	-	-	-	-
3-25	TRES PINOS VALLEY	3,390	C	1,225	-	-	-	3	-	-
3-26	WEST SANTA CRUZ TERRACE	7,870	C	550	200	-	-	7	480	378-684
3-27	SCOTTS VALLEY	774	C	410	100-900	26	7	7	360	100-980
3-28	SAN BENITO RIVER VALLEY	24,200	C	2,000	-	-	-	3	-	-
3-29	DRY LAKE VALLEY	1,420	C	-	-	-	-	-	-	-
3-30	BITTER WATER VALLEY	32,200	C	-	-	-	-	-	-	-
3-31	HERNANDEZ VALLEY	2,860	C	160	58	-	-	-	-	-

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Table 21 Central Coast Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
3-32	PEACH TREE VALLEY	9,790	C	117	84	-	-	-	-	-
3-33	SAN CARPOFORO VALLEY	200	C	-	-	-	-	-	-	217-385
3-34	ARROYO DE LA CRUZ VALLEY	750	C	-	-	-	-	-	-	211-381
3-35	SAN SIMEON VALLEY	620	A	170	100	-	-	4	413	46-2,210
3-36	SANTA ROSA VALLEY	4,480	A	708	400	-	-	2	-	298-2,637
3-37	VILLA VALLEY	980	C	-	-	-	-	-	-	260-1,635
3-38	CAYUCOS VALLEY	530	C	166	100	-	-	-	-	815-916
3-39	OLD VALLEY	750	C	335	200	-	-	-	-	346-2,462
3-40	TORO VALLEY	721	C	500	0	-	-	-	-	458-732
3-41	MORRO VALLEY	1,200	C	442	300	-	-	6	1150	469-5,100
3-42	CHORRO VALLEY	3,200	C	700	200	-	-	6	656	60-3,606
3-43	RINCONADA VALLEY	2,580	C	0	0	-	-	-	-	-
3-44	POZO VALLEY	6,840	C	230	100	-	-	5	-	287-676
3-45	HUASNA VALLEY	4,700	C	0	0	-	-	-	-	-
3-46	RAFAEL VALLEY	2,990	C	0	0	-	-	-	-	-
3-47	BIG SPRING AREA	7,320	C	0	0	-	-	-	-	-
3-49	MONTECITO	6,270	A	1,000	750	88	2	4	700	600-1,100
3-50	FELTON AREA	1,160	C	825	244	6	-	2	-	69-400
3-51	MAJORS CREEK	364	C	50	38	-	-	-	-	-
3-52	NEEDLE ROCK POINT	480	C	450	320	-	-	-	-	-
3-53	FOOTHILL	3,120	A	-	-	-	8	7	828	554-1,118

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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South Coast Hydrologic Region

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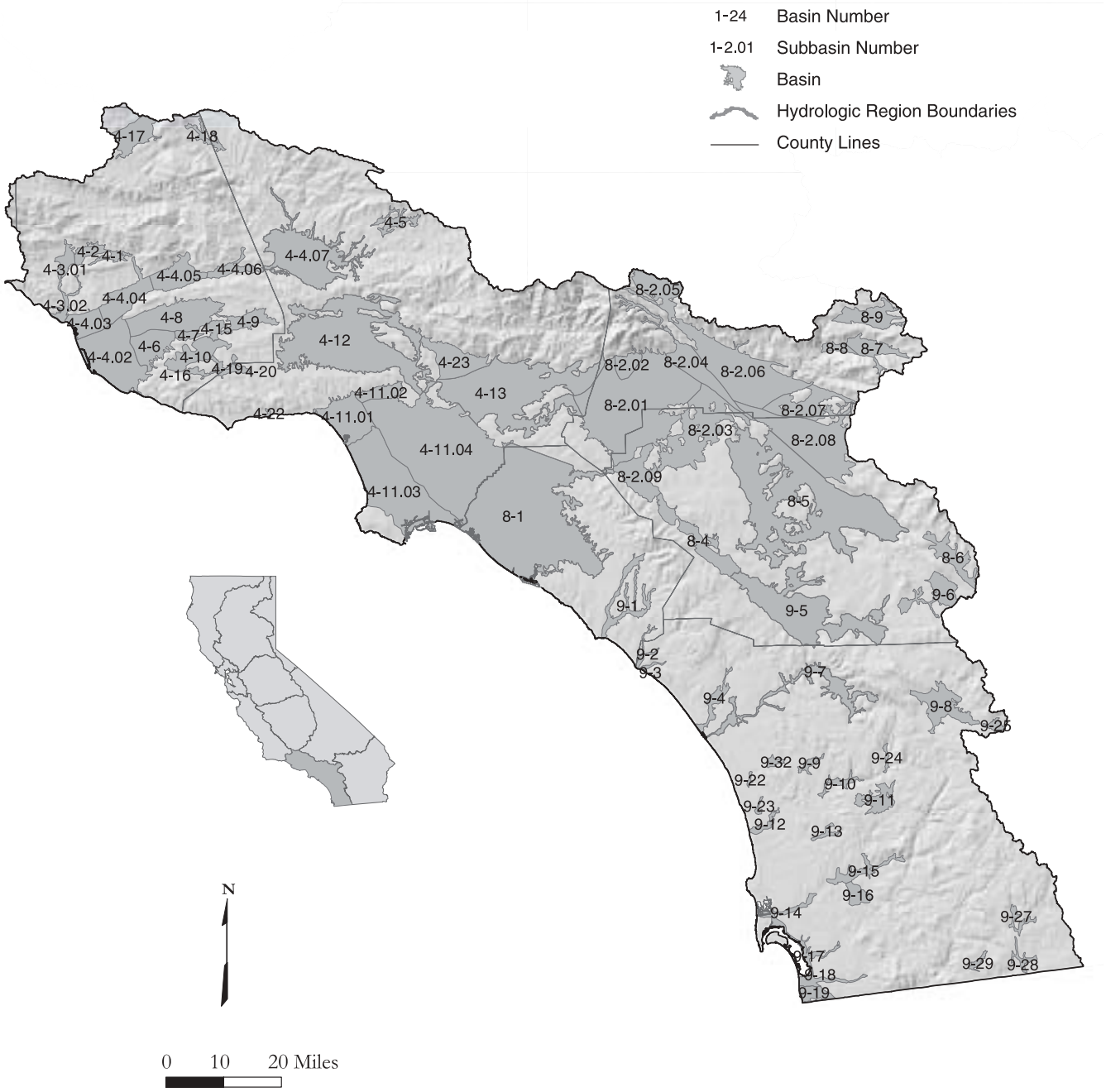

Figure 31 South Coast Hydrologic Region

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Basins and Subbasins of the South Coast Hydrologic Region

Basin/subbasin	Basin name
4-1	Upper Ojai Valley
4-2	Ojai Valley
4-3	Ventura River Valley
4-3.01	Upper Ventura River
4-3.02	Lower Ventura River
4-4	Santa Clara River Valley
4-4.02	Oxnard
4-4.03	Mound
4-4.04	Santa Paula
4-4.05	Fillmore
4-4.06	Piru
4-4.07	Santa Clara River Valley East
4-5	Acton Valley
4-6	Pleasant Valley
4-7	Arroyo Santa Rosa Valley
4-8	Las Posas Valley
4-9	Simi Valley
4-10	Conejo Valley
4-11	Coastal Plain of Los Angeles
4-11.01	Santa Monica
4-11.02	Hollywood
4-11.03	West Coast
4-11.04	Central
4-12	San Fernando Valley
4-13	San Gabriel Valley
4-15	Tierre Rejada
4-16	Hidden Valley
4-17	Lockwood Valley
4-18	Hungry Valley
4-19	Thousand Oaks Area
4-20	Russell Valley
4-22	Malibu Valley
4-23	Raymond
8-1	Coastal Plain of Orange County
8-2	Upper Santa Ana Valley
8-2.01	Chino
8-2.02	Cucamonga
8-2.03	Riverside-Arlington
8-2.04	Rialto-Colton
8-2.05	Cajon
8-2.06	Bunker Hill
8-2.07	Yucaipa
8-2.08	San Timoteo
8-2.09	Temescal
8-4	Elsinore
8-5	San Jacinto
8-6	Hemet Lake Valley
8-7	Big Meadows Valley
8-8	Seven Oaks Valley
8-9	Bear Valley
9-1	San Juan Valley
9-2	San Mateo Valley
9-3	San Onofre Valley
9-4	Santa Margarita Valley
9-5	Temecula Valley
9-6	Coahuila Valley
9-7	San Luis Rey Valley
9-8	Warner Valley
9-9	Escondido Valley
9-10	San Pasqual Valley
9-11	Santa Maria Valley
9-12	San Dieguito Creek
9-13	Poway Valley
9-14	Mission Valley
9-15	San Diego River Valley
9-16	El Cajon Valley
9-17	Sweetwater Valley
9-18	Otay Valley
9-19	Tijuana Basin
9-22	Batiquitos Lagoon Valley
9-23	San Elijo Valley
9-24	Pamo Valley
9-25	Ranchita Town Area
9-27	Cottonwood Valley
9-28	Campo Valley
9-29	Potrero Valley
9-32	San Marcos Area

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Description of the Region

The South Coast HR covers approximately 6.78 million acres (10,600 square miles) of the southern California watershed that drains to the Pacific Ocean (Figure 31). The HR is bounded on the west by the Pacific Ocean and the watershed divide near the Ventura-Santa Barbara County line. The northern boundary corresponds to the crest of the Transverse Ranges through the San Gabriel and San Bernardino mountains. The eastern boundary lies along the crest of the San Jacinto Mountains and low-lying hills of the Peninsular Range that form a drainage boundary with the Colorado River HR. The southern boundary is the international boundary with the Republic of Mexico. Significant geographic features include the coastal plain, the central Transverse Ranges, the Peninsular Ranges, and the San Fernando, San Gabriel, Santa Ana River, and Santa Clara River valleys.

The South Coast HR includes all of Orange County, most of San Diego and Los Angeles Counties, parts of Riverside, San Bernardino, and Ventura counties, and a small amount of Kern and Santa Barbara Counties. This HR is divided into Los Angeles, Santa Ana and San Diego subregions, RWQCBs 4, 8, and 9 respectively. Groundwater basins are numbered according to these subregions. Basin numbers in the Los Angeles subregion are preceded by a 4, in Santa Ana by an 8, and in San Diego by a 9. The Los Angeles subregion contains the Ventura, Santa Clara, Los Angeles, and San Gabriel River drainages, Santa Ana encompasses the Santa Ana River drainage, and San Diego includes the Santa Maria River, San Luis Rey River and the San Diego River and other drainage systems.

According to 2000 census data, about 17 million people live within the boundaries of the South Coast HR, approximately 50 percent of the population of California. Because this HR amounts to only about 7 percent of the surface area of the State, this has the highest population density of any HR in California (DWR 1998). Major population centers include the metropolitan areas surrounding Ventura, Los Angeles, San Diego, San Bernardino, and Riverside.

The South Coast HR has 56 delineated groundwater basins. Twenty-one basins are in subregion 4 (Los Angeles), eight basins in subregion 8 (Santa Ana), and 27 basins in subregion 9 (San Diego).

The Los Angeles subregion overlies 21 groundwater basins and encompasses most of Ventura and Los Angeles counties. Within this subregion, the Ventura River Valley, Santa Clara River Valley, and Coastal Plain of Los Angeles basins are divided into subbasins. The basins in the Los Angeles subregion underlie 1.01 million acres (1,580 square miles) or about 40 percent of the total surface area of the subregion.

The Santa Ana subregion overlies eight groundwater basins and encompasses most of Orange County and parts of Los Angeles, San Bernardino, and Riverside counties. The Upper Santa Ana Valley Groundwater Basin is divided into nine subbasins. Groundwater basins underlie 979,000 acres (1,520 square miles) or about 54 percent of the Santa Ana subregion.

The San Diego subregion overlies 27 groundwater basins, encompasses most of San Diego County, and includes parts of Orange and Riverside counties. Groundwater basins underlie about 277,000 acres (433 square miles) or about 11 percent of the surface of the San Diego subregion.

Overall, groundwater basins underlie about 2.27 million acres (3,530 square miles) or about 33 percent of the South Coast HR.

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Groundwater Development

Groundwater has been used in the South Coast HR for well over 100 years. High demand and use of groundwater in Southern California has given rise to many disputes over management and pumping rights, with the resolution of these cases playing a large role in the establishment and clarification of water rights law in California. Raymond Groundwater Basin, located in this HR, was the first adjudicated basin in the State. Of the 16 adjudicated basins in California, 11 are in the South Coast HR. Groundwater provides about 23 percent of water demand in normal years and about 29 percent in drought years (DWR 1998).

Groundwater is found in unconfined alluvial aquifers in most of the basins of the San Diego subregion and the inland basins of the Santa Ana and Los Angeles subregions. In some larger basins, typified by those underlying the coastal plain, groundwater occurs in multiple aquifers separated by aquitards that create confined groundwater conditions. Basins range in depth from tens or hundreds of feet in smaller basins, to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this HR depending on aquifer characteristics and well location, size, and use. Some aquifers are capable of yielding thousands of gallons per minute to municipal wells.

Conjunctive Use

Conjunctive use of surface water and groundwater is a long-standing practice in the region. At present, much of the potable water used in Southern California is imported from the Colorado River and from sources in the eastern Sierra and Northern California. Several reservoirs are operated primarily for the purpose of storing surface water for domestic and irrigation use, but groundwater basins are also recharged from the outflow of some reservoirs. The concept is to maintain streamflow over a longer period of time than would occur without regulated flow and thus provide for increased recharge of groundwater basins. Most of the larger basins in this HR are highly managed, with many conjunctive use projects being developed to optimize water supply.

Coastal basins in this HR are prone to intrusion of seawater. Seawater intrusion barriers are maintained along the Los Angeles and Orange County sections of the coastal plain. In Orange County, recycled water is injected into the ground to form a mound of groundwater between the coast and the main groundwater basin. In Los Angeles County, imported and recycled water is injected to maintain a seawater intrusion barrier.

Groundwater Quality

Groundwater in basins of the Los Angeles subregion is mainly calcium sulfate and calcium bicarbonate in character. Nitrate content is elevated in some parts of the subregion. Volatile organic compounds (VOCs) have created groundwater impairments in some of the industrialized portions of the region. The San Gabriel Valley and San Fernando Valley groundwater basins both have multiple sites of contamination from VOCs. The main constituents in the contamination plumes are trichloroethylene (TCE) and tetrachloroethylene (PCE). Some of the locations have been declared federal Superfund sites. Contamination plumes containing high concentrations of TCE and PCE also occur in the Bunker Hill Subbasin of the Upper Santa Ana Valley Groundwater Basin. Some of these plumes are also designated as Superfund sites. Perchlorate is emerging as an important contaminant in several areas in the South Coast HR.

Groundwater in basins of the Santa Ana subregion is primarily calcium and sodium bicarbonate in character. Local impairments from excess nitrate or VOCs have been recognized. Groundwater and surface water in the Chino Subbasin of the Santa Ana River Valley Groundwater Basin have elevated nitrate concentrations, partly derived from a large dairy industry in that area. In Orange County, water from the Santa Ana River provides a large part of the groundwater replenishment. Wetlands maintained along the Santa Ana River near the boundary of the Upper Santa Ana River and Orange County Groundwater Basins provide effective removal of nitrate from surface water, while maintaining critical habitat for endangered species.

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Groundwater in basins of the San Diego subregion has mainly calcium and sodium cations and bicarbonate and sulfate anions. Local impairments by nitrate, sulfate, and TDS are found. Camp Pendleton Marine Base, in the northwestern part of this subregion, is on the EPA National Priorities List for soil and groundwater contamination by many constituents.

Water Quality in Public Supply Wells

From 1994 through 2000, 2,342 public supply water wells were sampled in 47 of the 73 basins and subbasins in the South Coast HR. Analyzed samples indicate that 1,360 wells, or 58 percent, met the state primary MCLs for drinking water. Nine-hundred-eighty-two wells, or 42 percent, have constituents that exceed one or more MCL. Figure 32 shows the percentages of each contaminant group that exceeded MCLs in the 982 wells.

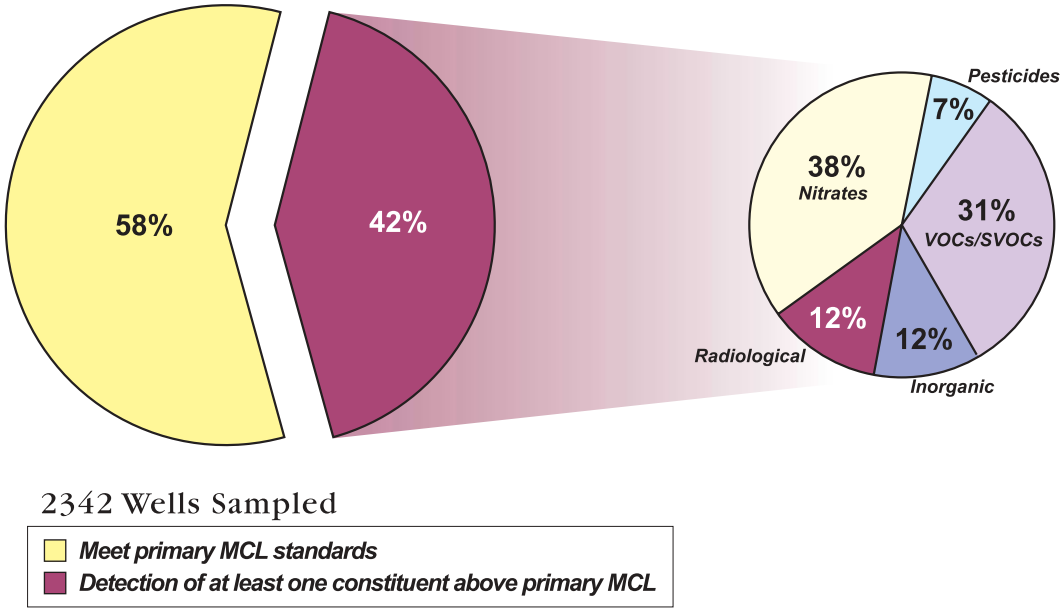

Figure 32 MCL exceedances in public supply wells in the South Coast Hydrologic Region

Table 22 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 23). The Cajalco Valley (8-3), Jamul Valley (9-20), Las Pulgas Valley (9-21), Pine Valley (9-26), and Tecate Valley (9-30) Groundwater Basins have been deleted in this report because they have thin deposits of alluvium and well completion reports indicate that groundwater production is from underlying fractured bedrock. The Conejo Tierra Rejada Volcanic (4-21) is a volcanic aquifer and was not assigned a basin number in this bulletin. This is considered to be groundwater source area as discussed in Chapter 6.

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Table 22 Most frequently occurring contaminants by contaminant group in the South Coast Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Fluoride – 56	Thallium – 13	Aluminum – 12
Inorganics – Secondary	Iron – 337	Manganese – 335	TDS – 36
Radiological	Gross Alpha – 104	Uranium – 40	Radium 226 – 9 Radium 228 – 9
Nitrates	Nitrate (as NO_3) – 364	Nitrate + Nitrite – 179	Nitrate Nitrogen (NO_3-N) – 14
Pesticides	DBCP – 61	Di(2-Ethylhexyl)phthalate –5	Heptachlor – 2 EDB – 2
VOCs/SVOCs	TCE – 196	PCE – 152	1,2 Dichloroethane – 89

DBCP = Dibromochloropropane
EDB = Ethylene Dibromide
VOCs = Volatile Organic Compounds
SVOCs = Semivolatile Organic Compounds

The Ventura River Valley (4-3), Santa Clara River Valley (4-4), Coastal Plain of Los Angeles (4-11), and Upper Santa Ana Valley (8-2) Groundwater Basins have been divided into subbasins in this report. The extent of the San Jacinto Groundwater Basin (8-5) has been decreased because completion of Diamond Valley Reservoir has inundated the valley. Paloma Valley has been removed because well logs indicate groundwater production is solely from fractured bedrock. The Raymond Groundwater Basin (4-23) is presented as an individual basin instead of being incorporated into the San Gabriel Valley Groundwater Basin (4-13) because it is bounded by physical barriers and has been managed as a separate and individual groundwater basin for many decades. In Bulletin 118-75, groundwater basins in two different subregions were designated the Upper Santa Ana Valley Groundwater Basin (4-14 and 8-2). To alleviate this confusion, basin 4-14 has been divided, with parts of the basin incorporated into the neighboring San Gabriel Valley Groundwater Basin (4-13) and the Chino subbasin of the Upper Santa Ana Valley Groundwater Basin (8-2.01). The San Marcos Area Groundwater Basin (9-32) in central San Diego County is presented as a new basin in this report.

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Table 23 Modifications since Bulletin 118-80 of groundwater basins and subbasins in South Coast Hydrologic Region

Basin/subbasin name	Number	Old number
Upper Ventura River	4-3.01	4-3
Lower Ventura River	4-3.02	4-3
Oxnard	4-4.02	4-4
Mound	4-4.03	4-4
Santa Paula	4-4.04	4-4
Fillmore	4-4.05	4-4
Piru	4-4.06	4-4
Santa Clara River Valley East	4-4.07	4-4
Santa Monica	4-11.01	4-11
Hollywood	4-11.02	4-11
West Coast	4-11.03	4-11
Central	4-11.04	4-11
Upper Santa Ana Valley	Incorporated into 8-2.01 and 4-13	4-14
Conejo-Tierra Rejada Volcanic	deleted	4-21
Raymond	4-23	4-13
Chino	8-2.01	8-2
Cucamonga	8-2.02	8-2
Riverside-Arlington	8-2.03	8-2
Rialto-Colton	8-2.04	8-2
Cajon	8-2.05	8-2
Bunker Hill	8-2.06	8-2
Yucaipa	8-2.07	8-2
San Timoteo	8-2.08	8-2
Temescal	8-2.09	8-2
Cajalco Valley	deleted	8-3
Tijuana Basin	9-19	
Jamul Valley	deleted	9-20
Las Pulgas Valley	deleted	9-21
Batiquitos Lagoon Valley	9-22	
San Elijo Valley	9-23	
Pamo Valley	9-24	
Ranchita Town Area	9-25	
Pine Valley	deleted	9-26
Cottonwood Valley	9-27	
Campo Valley	9-28	
Potrero Valley	9-29	
Tecate Valley	deleted	9-30
San Marcos Area	9-32	Not previously identified

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Table 24 South Coast Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Active Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
4-1	UPPER OJAI VALLEY	3,800	A	200	50	4	-	1	707	438-1,249
4-2	OJAI VALLEY	6,830	A	600	383	24	-	22	640	450-1,140
4-3	VENTURA RIVER VALLEY									
4-3.01	UPPER VENTURA RIVER	7,410	C	-	600	17	-	18	706	500-1,240
4-3.02	LOWER VENTURA RIVER	5,300	A	-	20	-	-	2	-	760-3,000
4-4	SANTA CLARA RIVER VALLEY									
4-4.02	OXNARD	58,000	A	1,600	-	127	127	69	1,102	160-1,800
4-4.03	MOUND	14,800	A	-	700	11	11	4	1,644	1,498-1,908
4-4.04	SANTA PAULA	22,800	A	-	700	60	50	10	1,198	470-3,010
4-4.05	FILLMORE	20,800	A	2,100	700	23	-	10	1,100	800-2,400
4-4.06	PIRU	8,900	A	-	800	19	-	3	1,300	608-2,400
4-4.07	SANTA CLARA RIVER VALLEY EAST	66,200	C	-	-	-	-	62	-	-
4-5	ACTON VALLEY	8,270	A	1,000	140	-	-	7	-	-
4-6	PLEASANT VALLEY	21,600	A	-	1,000	9	-	12	1,110	597-3,490
4-7	ARROYO SANTA ROSA VALLEY	3,740	A	1,200	950	6	-	7	1,006	670-1,200
4-8	LAS POSAS VALLEY	42,200	A	750	-	-	-	24	742	338-1,700
4-9	SIMI VALLEY	12,100	A	-	394	13	-	1	-	1,580
4-10	CONEJO VALLEY	28,900	A	1,000	100	-	-	3	631	335-2,064
4-11	COASTAL PLAIN OF LOS ANGELES									
4-11.01	SANTA MONICA	32,100	C	4,700	-	-	-	12	916	729-1,156
4-11.02	HOLLYWOOD	10,500	A	-	-	5	5	1	-	526
4-11.03	WEST COAST	91,300	A	1,300	-	67	58	33	456	-
4-11.04	CENTRAL	177,000	A	11,000	1,730	302	64	294	453	200-2,500
4-12	SAN FERNANDO VALLEY	145,000	A	3,240	1,220	1398	2385	126	499	176-1,16
4-13	SAN GABRIEL VALLEY	154,000	A	4,850	1,000	67	296	259	367	90-4,288
4-15	TIERRA REJADA	4,390	A	1,200	172	4	1	-	-	619-930
4-16	HIDDEN VALLEY	2,210	C	-	-	-	-	1	453	289-743
4-17	LOCKWOOD VALLEY	21,800	A	350	25	-	-	1	-	-
4-18	HUNGRY VALLEY	5,310	C	-	28	-	-	-	<350	-
4-19	THOUSAND OAKS AREA	3,110	C	-	39	2	-	-	1,410	1,200-2,300
4-20	RUSSELL VALLEY	3,100	A	-	25	-	-	-	-	-
4-22	MALIBU VALLEY	613	C	1,060	1,030	-	-	-	-	-
4-23	RAYMOND	26,200	A	3,620	1,880	88	-	70	346	138-780
8-1	COASTAL PLAIN OF ORANGE COUNTY	224,000	A	4,500	2,500	521	411	240	475	232-661
8-2	UPPER SANTA ANA VALLEY									
8-2.01	CHINO	154,000	A	1,500	1,000	12	8	187	484	200-600
8-2.02	CUCAMONGA	9,530	C	4,400	2,115	1	1	21	-	-
8-2.03	RIVERSIDE-ARLINGTON	58,600	A	-	-	11	3	43	-	370-756
8-2.04	RIALTO-COLTON	30,100	A	5,000	545	50	5	41	337	
8-2.05	CAJON	23,200	C	200	60	-	-	5	-	-
8-2.06	BUNKER HILL	89,600	A	5,000	1,245	398	169	204	-	150-550
8-2.07	YUCAIPA	25,300	A	2,800	206	19	3	45	334	-

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Table 24 South Coast Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Active Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
8-2.08	SAN TIMOTEO	73,100	A	-	-	67	12	36	-	-
8-2.09	TEMESCAL	23,500	C	-	-	2	2	20	753	373-950
8-4	ELSINORE	25,700	C	5,400	-	1	1	18	-	
8-5	SAN JACINTO	188,000	C	-	-	150	115	56	463	160-12,000
8-6	HEMET LAKE VALLEY	16,700	C	820	196	-	-	9	-	-
8-7	BIG MEADOWS VALLEY	14,200	C	120	34	-	-	8	-	-
8-8	SEVEN OAKS VALLEY	4,080	C	-	-	-	-	1	-	-
8-9	BEAR VALLEY	19,600	A	1,000	500	57	57	52	-	-
9-1	SAN JUAN VALLEY	16,700	C	1,000	-	-	-	8	760	430-12,880
9-2	SAN MATEO VALLEY	2,990	A	-	-	-	-	5	586	490-770
9-3	SAN ONOFRE VALLEY	1,250	A	-	-	-	-	2	-	600-1,500
9-4	SANTA MARGARITA VALLEY	626	A	1,980	-	4	-	-	-	337-9,030
9-5	TEMECULA VALLEY	87,800	C	1,750	-	140	4	67	476	220-1,500
9-6	COAHUILA VALLEY	18,200	C	500	-	2	-	1	-	304-969
9-7	SAN LUIS REY VALLEY	37,000	C	2,000	500	-	-	28	1,258	530-7,060
9-8	WARNER VALLEY	24,000	C	1,800	800	-	-	4	-	263
9-9	ESCONDIDO VALLEY	2,890	C	190	50	-	-	1	-	250-5,000
9-10	SAN PASQUAL VALLEY	4,540	C	1,700	1,000	-	-	2	-	500-1,550
9-11	SANTA MARIA VALLEY	12,300	A	500	36	3	-	2	1,000	324-1,680
9-12	SAN DIEGUITO CREEK	3,560	A	1,800	700	-	-	-	-	2,000
9-13	POWAY VALLEY	2,470	C	200	100	-	-	1	-	610-1,500
9-14	MISSION VALLEY	7,350	C	-	1,000	-	-	-	-	-
9-15	SAN DIEGO RIVER VALLEY	9,890	C	2,000	-	-	-	5	-	260-2,870
9-16	EL CAJON VALLEY	7,160	C	300	50	1	-	2,340		
9-17	SWEETWATER VALLEY	5,920	C	1,500	300	7	7	9	2,114	300-50,000
9-18	OTAY VALLEY	6,830	C	1,000	185	-	-	-	-	500->2,000
9-19	TIJUANA BASIN	7,410	A	2,000	350	-	-	-	-	380-3,620
9-22	BATIQUITOS LAGOON VALLEY	741	C	-	-	-	-	-	1,280	788-2,362
9-23	SAN ELIJO VALLEY	883	C	1,800	-	-	-	-	-	1,170-5,090
9-24	PAMO VALLEY	1,500	C	-	-	-	-	-	369	279-455
9-25	RANCHITA TOWN AREA	3,130	C	125	22	-	-	-	-	283-305
9-27	COTTONWOOD VALLEY	3,850	C	-	-	-	-	1	-	-
9-28	CAMPO VALLEY	3,550	C	-	<40	-	-	4	-	800
9-29	POTRERO VALLEY	2,020	C	-	-	-	-	4	-	-
9-32	SAN MARCOS VALLEY	2,130	C	60	-	-	-	-	-	500-700

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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Sacramento River Hydrologic Region

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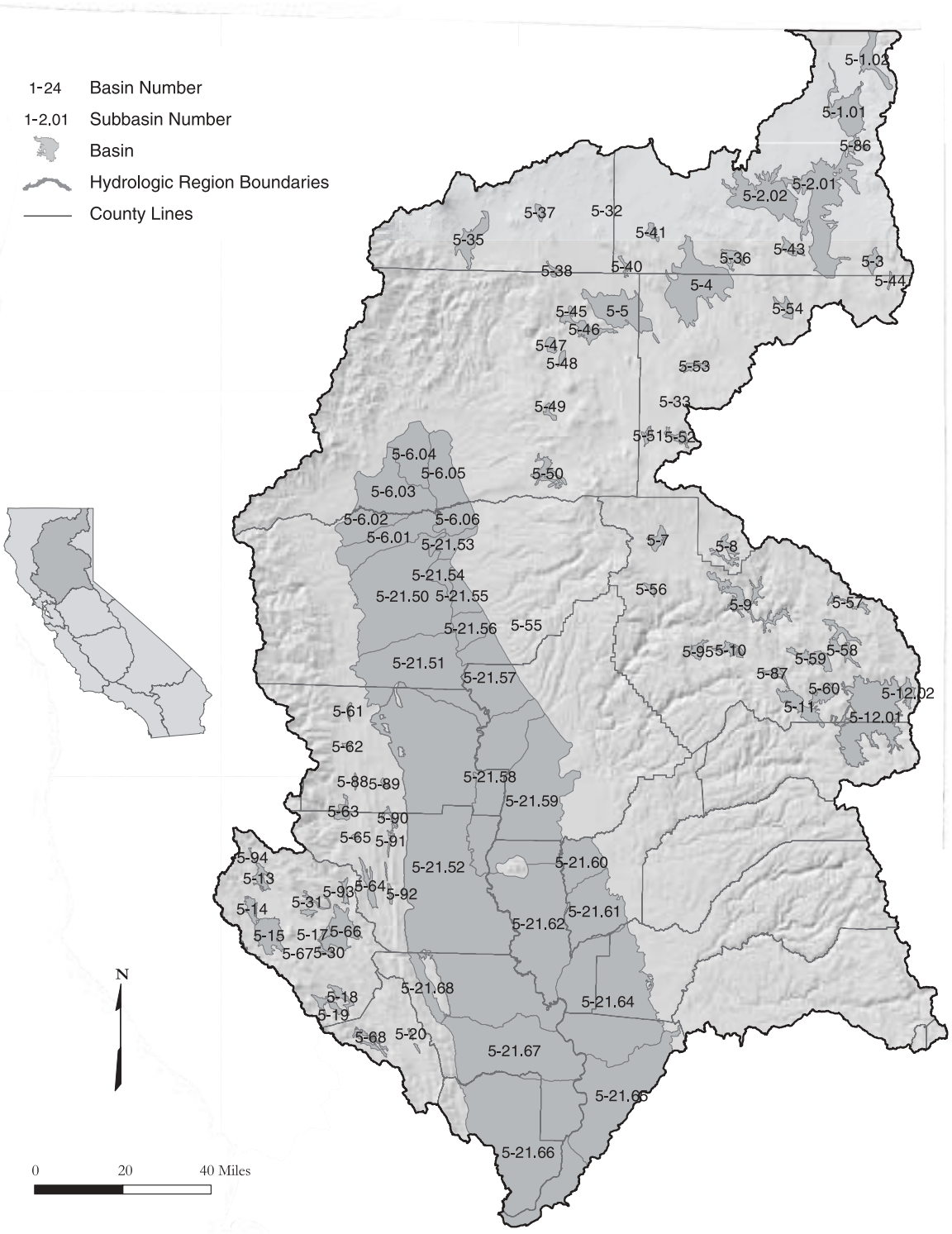

Figure 33 Sacramento River Hydrologic Region

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Basins and Subbasins of the Sacramento River Hydrologic Region

Basin/subbasins	Basin name
5-1	Goose Lake Valley
5-1.01	Lower Goose Lake Valley
5-1.02	Fandango Valley
5-2	Alturas Area
5-2.01	South Fork Pitt River
5-2.02	Warm Springs Valley
5-3	Jess Valley
5-4	Big Valley
5-5	Fall River Valley
5-6	Redding Area
5-6.01	Bowman
5-6.02	Rosewood
5-6.03	Anderson
5-6.04	Enterprise
5-6.05	Millville
5-6.06	South Battle Creek
5-7	Lake Almanor Valley
5-8	Mountain Meadows Valley
5-9	Indian Valley
5-10	American Valley
5-11	Mohawk Valley
5-12	Sierra Valley
5-12.01	Sierra Valley
5-12.02	Chilcoot
5-13	Upper Lake Valley
5-14	Scotts Valley
5-15	Big Valley
5-16	High Valley
5-17	Burns Valley
5-18	Coyote Valley
5-19	Collayomi Valley
5-20	Berryessa Valley
5-21	Sacramento Valley
5-21.50	Red Bluff
5-21.51	Corning
5-21.52	Colusa
5-21.53	Bend
5-21.54	Antelope
5-21.55	Dye Creek
5-21.56	Los Molinos
5-21.57	Vina
5-21.58	West Butte
5-21.59	East Butte
5-21.60	North Yuba
5-21.61	South Yuba
5-21.62	Sutter
5-21.64	North American
5-21.65	South American
5-21.66	Solano
5-21.67	Yolo
5-21.68	Capay Valley

Basin/subbasins	Basin name
5-30	Lower Lake Valley
5-31	Long Valley
5-35	Mccloud Area
5-36	Round Valley
5-37	Toad Well Area
5-38	Pondosa Town Area
5-40	Hot Springs Valley
5-41	Egg Lake Valley
5-43	Rock Prairie Valley
5-44	Long Valley
5-45	Cayton Valley
5-46	Lake Britton Area
5-47	Goose Valley
5-48	Burney Creek Valley
5-49	Dry Burney Creek Valley
5-50	North Fork Battle Creek
5-51	Butte Creek Valley
5-52	Gray Valley
5-53	Dixie Valley
5-54	Ash Valley
5-56	Yellow Creek Valley
5-57	Last Chance Creek Valley
5-58	Clover Valley
5-59	Grizzly Valley
5-60	Humbug Valley
5-61	Chrome Town Area
5-62	Elk Creek Area
5-63	Stonyford Town Area
5-64	Bear Valley
5-65	Little Indian Valley
5-66	Clear Lake Cache Formation
5-68	Pope Valley
5-86	Joseph Creek
5-87	Middle Fork Feather River
5-88	Stony Gorge Reservoir
5-89	Squaw Flat
5-90	Funks Creek
5-91	Antelope Creek
5-92	Blanchard Valley
5-93	North Fork Cache Creek
5-94	Middle Creek
5-95	Meadow Valley

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Description of the Region

The Sacramento River HR covers approximately 17.4 million acres (27,200 square miles). The region includes all or large portions of Modoc, Siskiyou, Lassen, Shasta, Tehama, Glenn, Plumas, Butte, Colusa, Sutter, Yuba, Sierra, Nevada, Placer, Sacramento, El Dorado, Yolo, Solano, Lake, and Napa counties (Figure 33). Small areas of Alpine and Amador counties are also within the region. Geographically, the region extends south from the Modoc Plateau and Cascade Range at the Oregon border, to the Sacramento-San Joaquin Delta. The Sacramento Valley, which forms the core of the region, is bounded to the east by the crest of the Sierra Nevada and southern Cascades and to the west by the crest of the Coast Range and Klamath Mountains. Other significant features include Mount Shasta and Lassen Peak in the southern Cascades, Sutter Buttes in the south central portion of the valley, and the Sacramento River, which is the longest river system in the State of California with major tributaries the Pit, Feather, Yuba, Bear and American rivers. The region corresponds approximately to the northern half of RWQCB 5. The Sacramento metropolitan area and surrounding communities form the major population center of the region. With the exception of Redding, cities and towns to the north, while steadily increasing in size, are more rural than urban in nature, being based in major agricultural areas. The 1995 population of the entire region was 2.372 million.

The climate in the northern, high desert plateau area of the region is characterized by cold snowy winters with only moderate precipitation and hot dry summers. This area depends on adequate snowpack to provide runoff for summer supply. Annual precipitation ranges from 10 to 20 inches. Other mountainous areas in the northern and eastern portions of the region have cold wet winters with large amounts of snow, which typically provide abundant runoff for summer supplies. Annual precipitation ranges from 40 to more than 80 inches. Summers are generally mild in these areas. The Coast Range and southern Klamath Mountains receive copious amounts of precipitation, but most of the runoff flows to the coast in the North Coastal drainage. Sacramento Valley comprises the remainder of the region. At a much lower elevation than the rest of the region, the valley has mild winters with moderate precipitation. Annual precipitation varies from about 35 inches in Redding to about 18 inches in Sacramento. Summers in the valley are hot and dry.

Most of the mountainous portions of the region are heavily forested and sparsely populated. Three major national forests (Mendocino, Trinity, and Shasta) make up the majority of lands in the Coast Range, southern Klamath Mountains, and the southern Cascades; these forests and the region's rivers and lakes provide abundant recreational opportunities. In the few mountain valleys with arable land, alfalfa, grain and pasture are the predominant crops. In the foothill areas of the region, particularly adjacent to urban centers, suburban to rural housing development is occurring along major highway corridors. This development is leading to urban sprawl and is replacing the former agricultural production on those lands. In the Sacramento Valley, agriculture is the largest industry. Truck, field, orchard, and rice crops are grown on approximately 2.1 million acres. Rice represents about 23 percent of the total irrigated acreage.

The Sacramento River HR is the main water supply for much of California's urban and agricultural areas. Annual runoff in the HR averages about 22.4 maf, which is nearly one-third of the State's total natural runoff. Major water supplies in the region are provided through surface storage reservoirs. The two largest surface water projects in the region are USBR's Shasta Lake (Central Valley Project) on the upper Sacramento River and Lake Oroville (DWR's State Water Project) on the Feather River. In all, there are more than 40 major surface water reservoirs in the region. Municipal, industrial, and agricultural supplies to the region are about 8 maf, with groundwater providing about 2.5 maf of that total. Much of the remainder of the runoff goes to dedicated natural flows, which support various environmental requirements, including in-stream fishery flows and flushing flows in the Delta.

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Groundwater Development

Groundwater provides about 31 percent of the water supply for urban and agricultural uses in the region, and has been developed in both the alluvial basins and the hard rock uplands and mountains. There are 88 basins/subbasins delineated in the region. These basins underlie 5.053 million acres (7,900 square miles), about 29 percent of the entire region. The reliability of the groundwater supply varies greatly. The Sacramento Valley is recognized as one of the foremost groundwater basins in the State, and wells developed in the sediments of the valley provide excellent supply to irrigation, municipal, and domestic uses. Many of the mountain valleys of the region also provide significant groundwater supplies to multiple uses.

Geologically, the Sacramento Valley is a large trough filled with sediments having variable permeabilities; as a result, wells developed in areas with coarser aquifer materials will produce larger amounts of water than wells developed in fine aquifer materials. In general, well yields are good and range from one-hundred to several thousand gallons per minute. Because surface water supplies have been so abundant in the valley, groundwater development for agriculture primarily supplement the surface supply. With the changing environmental laws and requirements, this balance is shifting to a greater reliance on groundwater, and conjunctive use of both supplies is occurring to a greater extent throughout the valley, particularly in drought years. Groundwater provides all or a portion of municipal supply in many valley towns and cities. Redding, Anderson, Chico, Marysville, Sacramento, Olivehurst, Wheatland, Willows, and Williams rely to differing degrees on groundwater. Red Bluff, Corning, Woodland, Davis, and Dixon are completely dependent on groundwater. Domestic use of groundwater varies, but in general, rural unincorporated areas rely completely on groundwater.

In the mountain valleys and basins with arable land, groundwater has been developed to supplement surface water supplies. Most of the rivers and streams of the area have adjudicated water rights that go back to the early 1900s, and diversion of surface water has historically supported agriculture. Droughts and increased competition for supply have led to significant development of groundwater for irrigation. In some basins, the fractured volcanic rock underlying the alluvial fill is the major aquifer for the area. In the rural mountain areas of the region, domestic supplies come almost entirely from groundwater. Although a few mountain communities are supplied in part by surface water, most rely on groundwater. These groundwater supplies are generally quite reliable in areas that have sufficient aquifer storage or where surface water replenishes supply throughout the year. In areas that depend on sustained runoff, water levels can be significantly depleted in drought years and many old, shallow wells can be dewatered. During 2001, an extreme drought year on the Modoc Plateau, many well owners experienced problems with water supply.

Groundwater development in the fractured rocks of the foothills of the southern Cascades and Sierra Nevada is fraught with uncertainty. Groundwater supplies from fractured rock sources are highly variable in terms of water quantity and water quality and are an uncertain source for large-scale residential development. Originally, foothill development relied on water supply from springs and river diversions with flumes and ditches for conveyance that date back to gold mining era operations. Current development is primarily based on individual private wells, and as pressures for larger scale development increase, questions about the reliability of supply need to be addressed. Many existing foothill communities have considerable experience with dry or drought year shortages. In Butte County residents in Cohasset, Forest Ranch, and Magalia have had to rely on water brought up the ridges in tanker trucks. The suggested answer has been the development of regional water supply projects. Unfortunately, the area's development pattern of small, geographically dispersed population centers does not lend itself to the kind of financial base necessary to support such projects.

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Groundwater Quality

Groundwater quality in the Sacramento River HR is generally excellent. However, there are areas with local groundwater problems. Natural water quality impairments occur at the north end of the Sacramento Valley in the Redding subbasin, and along the margins of the valley and around the Sutter Buttes, where Cretaceous-age marine sedimentary rocks containing brackish to saline water are near the surface. Water from the older underlying sediments mixes with the fresh water in the younger alluvial aquifer and degrades the quality. Wells constructed in these areas typically have high TDS. Other local natural impairments are moderate levels of hydrogen sulfide in groundwater in the volcanic and geothermal areas in the western portion of the region. In the Sierra foothills, there is potential for encountering uranium and radon-bearing rock or sulfide mineral deposits containing heavy metals. Human-induced impairments are generally associated with individual septic system development in shallow unconfined portions of aquifers or in fractured hard rock areas where insufficient soil depths are available to properly leach effluent before it reaches the local groundwater supply.

Water Quality in Public Supply Wells

From 1994 through 2000, 1,356 public supply water wells were sampled in 51 of the 88 basins and subbasins in the Sacramento River HR. Samples analyzed indicate that 1,282 wells, or 95 percent, met the state primary MCLs for drinking water. Seventy-four wells, or 5 percent, have constituents that exceed one or more MCL. Figure 34 shows the percentages of each contaminant group that exceeded MCLs in the 74 wells.

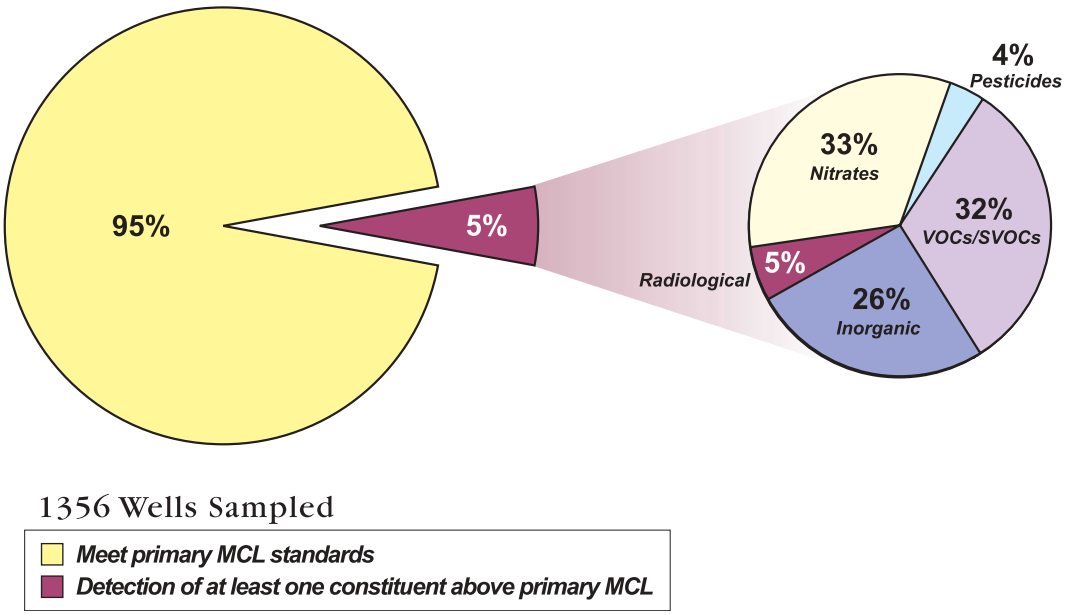

Figure 34 MCL exceedances in public supply wells in the Sacramento River Hydrologic Region

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Table 25 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 25 Most frequently occurring contaminants by contaminant group in the Sacramento River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Cadmium – 4	Chromium (Total) – 3	3 tied at 2
Inorganics – Secondary	Manganese – 221	Iron – 166	Specific Conductance – 3
Radiological	Gross Alpha – 4		
Nitrates	Nitrate (as NO_3) – 22	Nitrate + Nitrite – 5	Nitrate Nitrogen (NO_3-N) – 2
Pesticides	Di(2-Ethylhexyl)phthalate – 4		
VOCs/SVOCs	PCE – 11	TCE – 7	Benzene – 4

PCE = Tetrachloroethylene
TCE = Trichloroethylene
VOC = Volatile Organic Compounds
SVOC = Semivolatile Organic Compound

Changes from Bulletin 118-80

Some modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report. These are listed in Table 26.

Table 26 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Sacramento River Hydrologic Region

Basin name	New number	Old number
Fandango Valley	5-1.02	5-39
Bucher Swamp Valley	deleted	5-42
Modoc Plateau Recent Volcanic Areas	deleted	5-32
Modoc Plateau Pleistocene Volcanic Areas	deleted	5-33
Mount Shasta Area	deleted	5-34
Sacramento Valley Eastside Tuscan Formation Highlands	deleted	5-55
Clear Lake Pleistocene Volcanics	deleted	5-67

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No additional basins were assigned to the Sacramento River HR in this revision. However, four basins have been divided into subbasins. Goose Lake Valley Groundwater Basin (5-1) has been subdivided into two subbasins, Fandango Valley (5-39) was modified to be a subbasin of Goose Lake Valley. Redding Area Groundwater Basin has been subdivided into six subbasins, Sierra Valley Groundwater Basin has been subdivided into two subbasins, and the Sacramento Valley Groundwater Basin has been subdivided into 18 subbasins.

There are several deletions of groundwater basins from Bulletin 118-80. Bucher Swamp Valley Basin (5-42) was deleted due to a thin veneer of alluvium over rock. Modoc Plateau Recent Volcanic Areas (5-32), Modoc Plateau Pleistocene Volcanic Areas (5-33), Mount Shasta Area (5-34), Sacramento Valley Eastside Tuscan Formation Highlands (5-55), and Clear Lake Pleistocene Volcanics (5-67) are volcanic aquifers and were not assigned basin numbers in this bulletin. These are considered to be groundwater source areas as discussed in Chapter 6.

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Table 27 Sacramento River Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5-1	GOOSE LAKE VALLEY									
5-1.01	LOWER GOOSE LAKE	36,000	B	-	400	9	9	-	183	68 - 528
5-1.02	FANDANGO VALLEY	18,500	B	2,000	-	3	-	-	-	-
5-2	ALTURAS AREA								357	180 - 800
5-2.01	SOUTH FORK PITT RIVER	114,000	B	5,000	1,075	9	-	8	-	-
5-2.02	WARM SPRINGS VALLEY	68,000	B	400	314	3	-	11	-	-
5-3	JESS VALLEY	6,700	B		3,000	-	-	-	-	-
5-4	BIG VALLEY	92,000	B	4,000	880	19	9	10	260	141 - 633
5-5	FALL RIVER VALLEY	54,800	B	1,500	266	16	7	3	174	115 - 232
5-6	REDDING AREA									
5-6.01	BOWMAN	85,330	B	2,000	589	8	2	13	-	70 - 247
5-6.02	ROSEWOOD	45,320	B	-	-	4	-	-	-	118 - 218
5-6.03	ANDERSON	98,500	B	1,800	46	11	10	69	194	109-320
5-6.04	ENTERPRISE	60,900	B	700	266	11	3	43	-	160 - 210
5-6.05	MILLVILLE	67,900	B	500	254	6	5	4	140	-
5-6.06	SOUTH BATTLE CREEK	32,300	B	-	-	0	0	0	360	-
5-7	LAKE ALMANOR VALLEY	7,150	B	-	-	10	4	4	105	53 - 260
5-8	MOUNTAIN MEADOWS VALLEY	8,150	B	-	-	-	-	-	-	-
5-9	INDIAN VALLEY	29,400	B	-	-	-	4	9	-	-
5-10	AMERICAN VALLEY	6,800	B	40	40		4	11	-	-
5-11	MOHAWK VALLEY	19,000	B	-	500	1	2	15	248	210 - 285
5-12	SIERRA VALLEY									
5-12.01	SIERRA VALLEY	117,700	B	1,500	640	34	15	9	312	110 - 1,620
5-12.02	CHILCOOT	7,550	B	-	-	15	-	8	-	-
5-13	UPPER LAKE VALLEY	7,260	B	900	302	12	3	6	-	-
5-14	SCOTTS VALLEY	7,320	B	1,200	171	9	1	9	158	140 - 175
5-15	BIG VALLEY	24,210	B	1,470	475	49	11	7	535	270 - 790
5-16	HIGH VALLEY	2,360	B	100	37	5	2	-	598	480 - 745
5-17	BURNS VALLEY	2,900	B	-	30	1	5	-	335	280 - 455
5-18	COYOTE VALLEY	6,530	B	800	446	6	3	3	288	175 - 390
5-19	COLLAYOMI VALLEY	6,500	B	1,000	121	10	4	3	202	150 - 255
5-20	BERRYESSA VALLEY	1,400	C	-	-	0	-	0	-	-
5-21	SACRAMENTO VALLEY									
5-21.50	RED BLUFF	266,750	B	1,200	363	30	10	56	207	120 - 500
5-21.51	CORNING	205,640	B	3,500	977	29	7	30	286	130 - 490
5-21.52	COLUSA	918,380	B	5,600	984	98	30	134	391	120 - 1,220
5-21.53	BEND	20,770	B	-	275	0	3	9		334-360
5-21.54	ANTELOPE	18,710	B	800	575	4	5	22	296	-
5-21.55	DYE CREEK	27,730	B	3,300	890	8	1	3	240	159 - 396
5-21.56	LOS MOLINOS	33,170	B	1,000	500	3	3	9	217	
5-21.57	VINA	125,640	B	3,850	1,212	23	5	69	285	48 - 543
5-21.58	WEST BUTTE	181,600	B	4,000	1,833	32	8	36	293	130 - 676

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Table 27 Sacramento River Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5-21.59	EAST BUTTE	265,390	B	4,500	1,019	43	4	44	235	122 - 570
5-21.60	NORTH YUBA	100,400	C	4,000	-	21	-	32	-	-
5-21.61	SOUTH YUBA	107,000	C	4,000	1,650	56	-	6	-	-
5-21.62	SUTTER	234,000	C	-	-	34	-	115	-	-
5-21.64	NORTH AMERICAN	351,000	A	-	800	121	-	339	300	150 - 1,000
5-21.65	SOUTH AMERICAN	248,000	C	-	-	105	-	247	221	24-581
5-21.66	SOLANO	425,000	C	-	-	123	23	136	427	150 - 880
5-21.67	YOLO	226,000	B	4,000+	1,000	127	20	185	880	480 - 2,060
5-21.68	CAPAY VALLEY	25,000	C	-	-	11	-	3	-	-
5-30	LOWER LAKE VALLEY	2,400	B	100	37		3	5	568	290 - 1,230
5-31	LONG VALLEY	2,600	B	100	63	-	-	-	-	-
5-35	MCCLOUD AREA	21,320	B	-	380	-	-	1	-	-
5-36	ROUND VALLEY	7,270	B	2,000	800	2				148 - 633
5-37	TOAD WELL AREA	3,360	B	-	-	-	-	-	-	-
5-38	PONDOSA TOWN AREA	2,080	B	-	-	-	-	-	-	-
5-40	HOT SPRINGS VALLEY	2,400	B	-	-	-	-	-	-	-
5-41	EGG LAKE VALLEY	4,100	B	-	20	-	-	-	-	-
5-43	ROCK PRAIRIE VALLEY	5,740	B	-	-	-	-	-	-	-
5-44	LONG VALLEY	1,090	B	-	-	-	-	-	-	-
5-45	CAYTON VALLEY	1,300	B	-	400	-	-	-	-	-
5-46	LAKE BRITTON AREA	14,060	B	-	-	-	-	2	-	-
5-47	GOOSE VALLEY	4,210	B	-	-	-	-	-	-	-
5-48	BURNEY CREEK VALLEY	2,350	B	-	-	-	-	2	-	-
5-49	DRY BURNEY CREEK VALLEY	3,070	B	-	-	-	-	-	-	-
5-50	NORTH FORK BATTLE CREEK VALLEY	12,760	B	-	-	-	-	3	-	-
5-51	BUTTE CREEK VALLEY	3,230	B	-	-	-	-	-	-	-
5-52	GRAYS VALLEY	5,440	B	-	-	-	-	-	-	-
5-53	DIXIE VALLEY	4,870	B	-	-	-	-	-	-	-
5-54	ASH VALLEY	6,010	B	3,000	2,200	-	-	-	-	-
5-56	YELLOW CREEK VALLEY	2,310	B	-	-	-	-	-	-	-
5-57	LAST CHANCE CREEK VALLEY	4,660	B	-	-	-	-	-	-	-
5-58	CLOVER VALLEY	16,780	B	-	-	-	-	-	-	-
5-59	GRIZZLY VALLEY	13,400	B	-	-	-	-	1	-	-
5-60	HUMBUG VALLEY	9,980	B	-	-	-	-	8	-	-
5-61	CHROME TOWN AREA	1,410	B	-	-	-	-	-	-	-
5-62	ELK CREEK AREA	1,440	B	-	-	-	-	-	-	-
5-63	STONYFORD TOWN AREA	6,440	B	-	-	-	-	-	-	-
5-64	BEAR VALLEY	9,100	B	-	-	-	-	-	-	-
5-65	LITTLE INDIAN VALLEY	1,270	B	-	-	-	-	-	-	-
5-66	CLEAR LAKE CACHE FORMATION	30,000	B	245	52		-	4	-	-
5-68	POPE VALLEY	7,180	C	-	-	-	-	1	-	-
5-86	JOSEPH CREEK	4,450	B	-	-	-	-		-	-

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Table 27 Sacramento River Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5-87	MIDDLE FORK FEATHER RIVER	4,340	B	-	-	-	-	2	-	-
5-88	STONY GORGE RESERVOIR	1,070	B	-	-	-	-	-	-	-
5-89	SQUAW FLAT	1,300	C	-	-	-	-	-	-	-
5-90	FUNKS CREEK	3,000	C	-	-	-	-	-	-	-
5-91	ANTELOPE CREEK	2,040	B	-	-	-	-	-	-	-
5-92	BLANCHARD VALLEY	2,200	B	-	-	-	-	-	-	-
5-93	NORTH FORK CACHE CREEK	3,470	C	-	-	-	-	-	-	-
5-94	MIDDLE CREEK	700	B	-	75	-	-	1	-	-
5-95	MEADOW VALLEY	5,730	B	-	-	-	-	1	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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San Joaquin River Hydrologic Region

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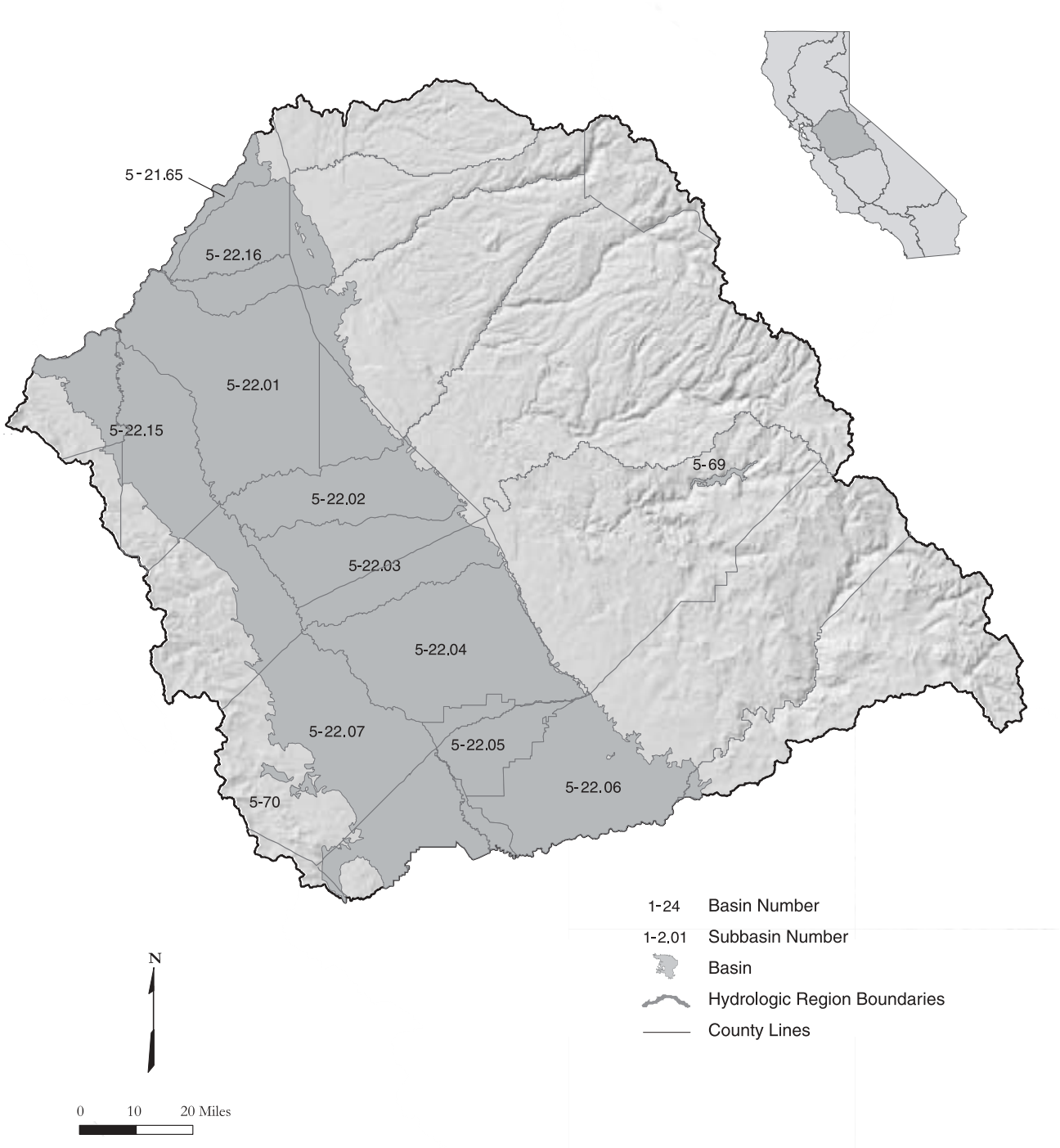

Figure 35 San Joaquin River Hydrologic Region

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Basins and Subbasins of the San Joaquin River Hydrologic Region

Basin/subbasin	Basin name
5-22	San Joaquin Valley
5-22.01	Eastern San Joaquin
5-22.02	Modesto
5-22.03	Turlock
5-22.04	Merced
5-22.05	Chowchilla
5-22.06	Madera
5-22.07	Delta-Mendota
5-22.15	Tracy
5-22.16	Cosumnes
5-69	Yosemite Valley
5-70	Los Banos Creek Valley

Description of the Region

The San Joaquin River HR covers approximately 9.7 million acres (15,200 square miles) and includes all of Calaveras, Tuolumne, Mariposa, Madera, San Joaquin, and Stanislaus counties, most of Merced and Amador counties, and parts of Alpine, Fresno, Alameda, Contra Costa, Sacramento, El Dorado, and San Benito counties (Figure 35). The region corresponds to a portion near the middle of RWQCB 5. Significant geographic features include the northern half of the San Joaquin Valley, the southern part of the Sacramento-San Joaquin Delta, the Sierra Nevada and Diablo Range. The region is home to about 1.6 million people (DWR 1998). Major population centers include Merced, Modesto, and Stockton. The Merced area is entirely dependent on groundwater for its supply, as will be the new University of California at Merced campus.

Groundwater Development

The region contains two entire groundwater basins and part of the San Joaquin Valley Groundwater Basin, which continues south into the Tulare Lake HR. The San Joaquin Valley Groundwater Basin is divided into nine subbasins in this region. The basins underlie 3.73 million acres (5,830 square miles) or about 38 percent of the entire HR area.

The region is heavily groundwater reliant. Within the region groundwater accounts for about 30 percent of the annual supply used for agricultural and urban purposes. Groundwater use in the region accounts for about 18 percent of statewide groundwater use for agricultural and urban needs. Groundwater use in the region accounts for 5 percent of the State's overall supply from all sources for agricultural and urban uses (DWR 1998).

The aquifers are generally quite thick in the San Joaquin Valley subbasins, with groundwater wells commonly extending to depths of up to 800 feet. Aquifers include unconsolidated alluvium and consolidated rocks with unconfined and confined groundwater conditions. Typical well yields in the San Joaquin Valley range from 300 to 2,000 gpm with yields of 5,000 gpm possible. The region's only significant basin located outside of San Joaquin Valley is Yosemite Valley. Yosemite Valley Basin supplies water to Yosemite National Park and has substantial well yields.

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Conjunctive Use

Since near the beginning of the region's agricultural development, groundwater has been used conjunctively with surface water to meet water needs. Groundwater was and is used when and where surface water is unable to fully meet demands either in time or area. For several decades, this situation was more of an incidental conjunctive use than a formal one. Historical groundwater use has resulted in some land subsidence in the southwest portion of the region.

Groundwater Quality

In general, groundwater quality throughout the region is suitable for most urban and agricultural uses with only local impairments. The primary constituents of concern are TDS, nitrate, boron, chloride, and organic compounds. The Yosemite Valley Groundwater Basin has exceptionally high quality groundwater.

Areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. The high TDS content of west-side groundwater is due to recharge of streamflow originating from marine sediments in the Coast Range. High TDS content in the trough of the valley is the result of concentration of salts due to evaporation and poor drainage. Nitrates may occur naturally or as a result of disposal of human and animal waste products and fertilizer. Boron and chloride are likely a result of concentration from evaporation near the valley trough. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected in groundwater throughout the region, but primarily along the east side of the San Joaquin Valley where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is dibromochloropropane (DBCP), a now-banned soil fumigant and known carcinogen once used extensively on grapes and cotton. Industrial organic contaminants include TCE, dichloroethylene (DCE), and other solvents. They are found in groundwater near airports, industrial areas, and landfills.

Water Quality in Public Supply Wells

From 1994 through 2000, 689 public supply water wells were sampled in 10 of the 11 basins and subbasins in the San Joaquin River HR. Samples analyzed indicate that 523 wells, or 76 percent, met the state primary MCLs for drinking water. One-hundred-sixty-six wells, or 24 percent, have constituents that exceed one or more MCL. Figure 36 shows the percentages of each contaminant group that exceeded MCLs in the 166 wells.

Table 28 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Changes from Bulletin 118-80

The subbasins of the San Joaquin Valley, which were delineated as part of the 118-80 update, are given their first numeric designation in this report. Additionally, the Cosumnes Subbasin has been added to the subbasins within the San Joaquin River HR. It is worth noting that the southern portion of the South American Subbasin of the Sacramento Valley Groundwater Basin is also included as part of this HR. The subbasin names and numbers within the region are listed in Table 29.

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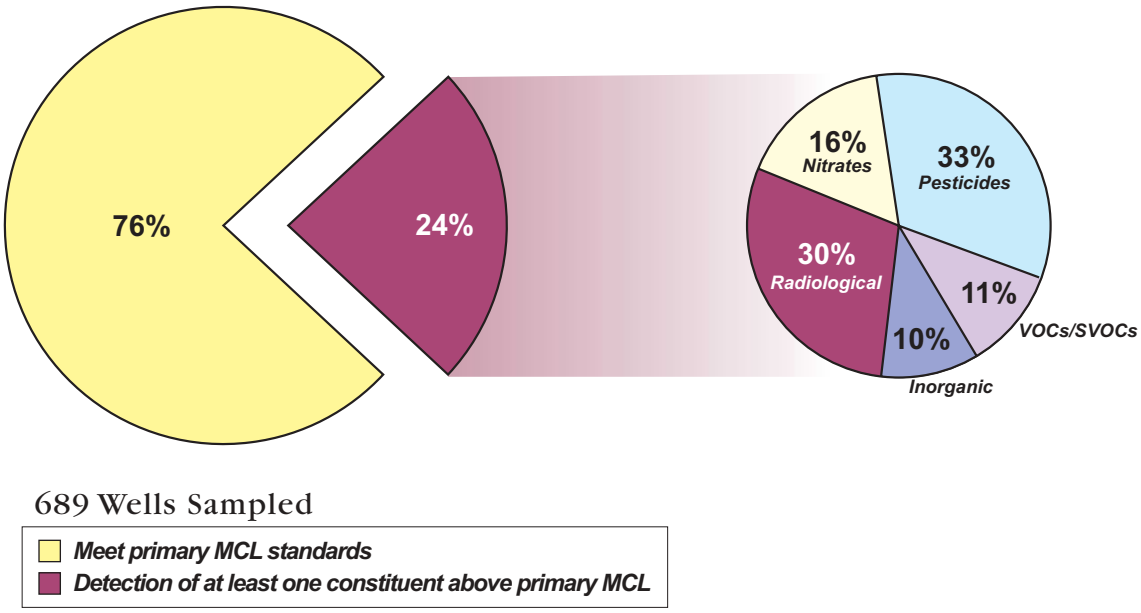

Figure 36 MCL exceedances in public supply wells in the San Joaquin River Hydrologic Region

Table 28 Most frequently occurring contaminants by contaminant group in the San Joaquin River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Aluminum – 4	Arsenic – 4	4 tied at 2 exceedances
Inorganics – Secondary	Manganese – 123	Iron – 102	TDS – 9
Radiological	Uranium – 33	Gross Alpha – 26	Radium 228 – 6
Nitrates	Nitrate (as NO_3) – 23	Nitrate + Nitrite – 6	Nitrate Nitrogen (NO_3-N) – 3
Pesticides	DBCP – 44	Di(2-Ethylhexyl)phthalate – 11	EDB – 6
VOCs	PCE – 8	Dichloromethane – 3	TCE – 3

DBCP = Dibromochloropropane
EDB = Ethylenedibromide
PCE = Tetrachloroethylene
TCE = Trichloroethylene
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

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Table 29 Modifications since Bulletin 118-80 of groundwater basins and subbasins in San Joaquin Hydrologic Region

Subbasin name	New number	Old number
Eastern San Joaquin	5-22.01	5-22
Modesto	5-22.02	5-22
Turlock	5-22.03	5-22
Merced	5-22.04	5-22
Chowchilla	5-22.05	5-22
Madera	5-22.06	5-22
Delta-Mendota	5-22.07	5-22
Tracy	5-22.15	5-22
Cosumnes	5-22.16	5-22

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Table 30 San Joaquin River Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5-22	SAN JOAQUIN VALLEY									
5-22.01	EASTERN SAN JOAQUIN	707,000	A	1,500	-	345	69	540	310	30 - 1,632
5-22.02	MODESTO	247,000	B	4,500	1000-2000	230	15	209	60-500	200-8300
5-22.03	TURLOCK	347,000	B	4,500	1000-2000	307	0	163	200-500	100-8300
5-22.04	MERCED	491,000	B	4,450	1500-1900	378	0	142	200-400	100-3600
5-22.05	CHOWCHILLA	159,000	B	4,750	750-2000	203	0	28	200-500	120-6400
5-22.06	MADERA	394,000	B	4,750	750-2000	378	0	127	200-400	100-6400
5-22.07	DELTA-MENDOTA	747,000	B	5,000	800-2000	816	0	120	770	210-86,000
5-22.15	TRACY	345,000	C	3,000	500-3,000	18	14	183	1,190	210-7,800
5-22.16	COSUMNES	281,000	A	1,500	-	75	13	72	218	140-438
5-69	YOSEMITE VALLEY	7,500	C	1,200	900	0	0	3	54	43-73
5-70	LOS BANOS CREEK VALLEY	4,840	C	-	-	0	0	0	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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Tulare Lake Hydrologic Region

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Figure 37 Tulare Lake Hydrologic Region

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Basins and Subbasins of Tulare Lake Hydrologic Region

Basin/subbasin	Basin name
5-22	San Joaquin Valley
5-22.08	Kings
5-22.09	Westside
5-22.10	Pleasant Valley
5-22.11	Kaweah
5-22.12	Tulare Lake
5-22.13	Tule
5-22.14	Kern County
5-23	Panoche Valley
5-25	Kern River Valley
5-26	Walker Basin Creek Valley
5-27	Cummings Valley
5-28	Tehachapi Valley West
5-29	Castaic Lake Valley
5-71	Vallecitos Creek Valley
5-80	Brite Valley
5-82	Cuddy Canyon Valley
5-83	Cuddy Ranch Area
5-84	Cuddy Valley
5-85	Mil Potrero Area

Description of the Region

The Tulare Lake HR covers approximately 10.9 million acres (17,000 square miles) and includes all of Kings and Tulare counties and most of Fresno and Kern counties (Figure 37). The region corresponds to approximately the southern one-third of RWQCB 5. Significant geographic features include the southern half of the San Joaquin Valley, the Temblor Range to the west, the Tehachapi Mountains to the south, and the southern Sierra Nevada to the east. The region is home to more than 1.7 million people as of 1995 (DWR, 1998). Major population centers include Fresno, Bakersfield, and Visalia. The cities of Fresno and Visalia are entirely dependent on groundwater for their supply, with Fresno being the second largest city in the United States reliant solely on groundwater.

Groundwater Development

The region has 12 distinct groundwater basins and 7 subbasins of the San Joaquin Valley Groundwater Basin, which crosses north into the San Joaquin River HR. These basins underlie approximately 5.33 million acres (8,330 square miles) or 49 percent of the entire HR area.

Groundwater has historically been important to both urban and agricultural uses, accounting for 41 percent of the region's total annual supply and 35 percent of all groundwater use in the State. Groundwater use in the region represents about 10 percent of the State's overall supply for agricultural and urban uses (DWR 1998).

The aquifers are generally quite thick in the San Joaquin Valley subbasins with groundwater wells commonly exceeding 1,000 feet in depth. The maximum thickness of freshwater-bearing deposits (4,400 feet) occurs at the southern end of the San Joaquin Valley. Typical well yields in the San Joaquin Valley range from 300 gpm to 2,000 gpm with yields of 4,000 gpm possible. The smaller basins in the mountains surrounding the San Joaquin Valley have thinner aquifers and generally lower well yields averaging less than 500 gpm.

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The cities of Fresno, Bakersfield, and Visalia have groundwater recharge programs to ensure that groundwater will continue to be a viable water supply in the future. Extensive groundwater recharge programs are also in place in the south valley where water districts have recharged several million acre-feet for future use and transfer through water banking programs.

The extensive use of groundwater in the San Joaquin Valley has historically caused subsidence of the land surface primarily along the west side and south end of the valley.

Groundwater Quality

In general, groundwater quality throughout the region is suitable for most urban and agricultural uses with only local impairments. The primary constituents of concern are high TDS, nitrate, arsenic, and organic compounds.

The areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the trough of the valley. High TDS content of west-side water is due to recharge of stream flow originating from marine sediments in the Coast Range. High TDS content in the trough of the valley is the result of concentration of salts because of evaporation and poor drainage. In the central and west-side portions of the valley, where the Corcoran Clay confining layer exists, water quality is generally better beneath the clay than above it. Nitrates may occur naturally or as a result of disposal of human and animal waste products and fertilizer. Areas of high nitrate concentrations are known to exist near the town of Shafter and other isolated areas in the San Joaquin Valley. High levels of arsenic occur locally and appear to be associated with lakebed areas. Elevated arsenic levels have been reported in the Tulare Lake, Kern Lake and Buena Vista Lake bed areas. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected throughout the valley, but primarily along the east side where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is DBCP, a now-banned soil fumigant and known carcinogen once used extensively on grapes. Industrial organic contaminants include TCE, DCE, and other solvents. They are found in groundwater near airports, industrial areas, and landfills.

Water Quality in Public Supply Wells

From 1994 through 2000, 1,476 public supply water wells were sampled in 14 of the 19 groundwater basins and subbasins in the Tulare Lake HR. Evaluation of analyzed samples shows that 1,049 of the wells, or 71 percent, met the state primary MCLs for drinking water. Four-hundred-twenty-seven wells, or 29 percent, exceeded one or more MCL. Figure 38 shows the percentages of each contaminant group that exceeded MCLs in the 427 wells.

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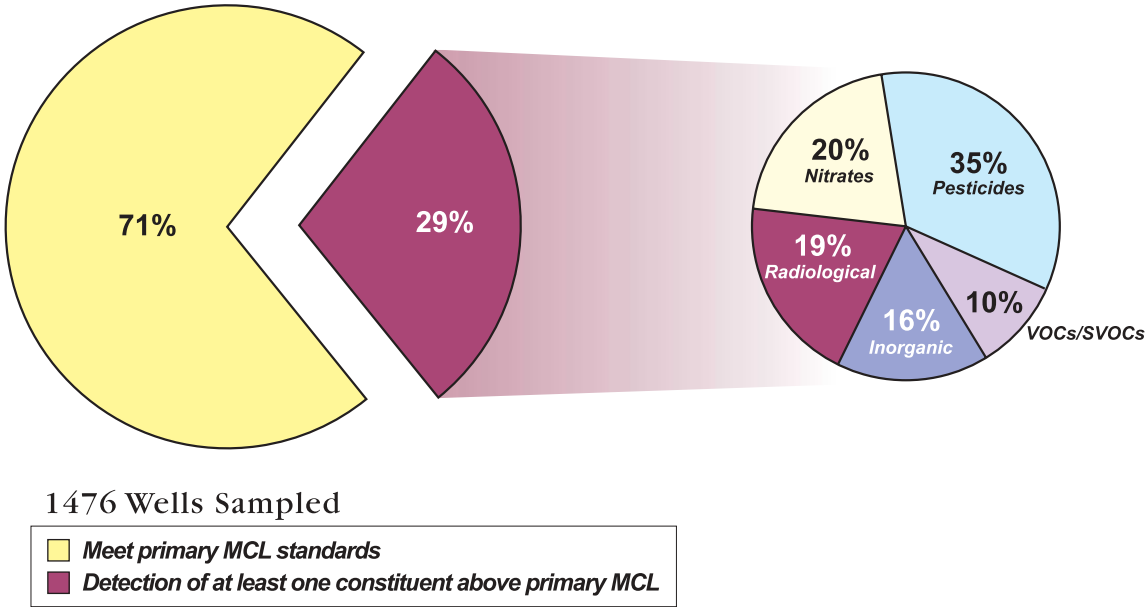

Figure 38 MCL exceedances by contaminant group in public supply wells in the Tulare Lake Hydrologic Region

Table 31 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 31 Most frequently occurring contaminants by contaminant group in the Tulare Lake Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics - Primary	Fluoride – 32	Arsenic – 16	Aluminum – 13
Inorganics - Secondary	Iron – 155	Manganese – 82	TDS – 9
Radiological	Gross Alpha – 74	Uranium – 24	Radium 228 – 8
Nitrates	Nitrate(as NO_3) – 83	Nitrate + Nitrite – 14	Nitrite(as N) – 3
Pesticides	DBCP – 130	EDB – 24	Di(2-Ethylhexyl)phthalate – 7
VOCs/SVOCs	TCE – 17	PCE – 16	Benzene – 6 MTBE – 6

DBCP = Dibromochloropropane
EDB = Ethylenedibromide
TCE = Trichloroethylene
PCE = Tetrachloroehylene
VOC = Volatile organic compound
SVOC = Semivolatile organic compound

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Changes from Bulletin 118-80

There are no newly defined basins since Bulletin 118-80. However, the subbasins of the San Joaquin Valley, which were delineated as part of the 118-80 update, are given their first numeric designation in this report (Table 32).

Table 32 Modifications since Bulletin 118-80 of groundwater basins and subbasins in Tulare Lake Hydrologic Region

Subbasin name	New number	Old number
Kings	5-22.08	5-22
Westside	5-22.09	5-22
Pleasant Valley	5-22.10	5-22
Kaweah	5-22.11	5-22
Tulare Lake	5-22.12	5-22
Tule	5-22.13	5-22
Kern County	5-22.14	5-22
Squaw Valley	deleted	5-24
Cedar Grove Area	deleted	5-72
Three Rivers Area	deleted	5-73
Springville Area	deleted	5-74
Templeton Mountain Area	deleted	5-75
Manache Meadow Area	deleted	5-76
Sacator Canyon Valley	deleted	5-77
Rockhouse Meadows Valley	deleted	5-78
Inns Valley	deleted	5-79
Bear Valley	deleted	5-81

Several basins have been deleted from the Bulletin 118-80 report. In Squaw Valley (5-24) all 118 wells are completed in hard rock. Cedar Grove Area (5-72) is a narrow river valley in Kings Canyon National Park with no wells. Three Rivers Area (5-73) has a thin alluvial terrace deposit but 128 of 130 wells are completed in hard rock. Springville Area (5-74) is this strip of alluvium adjacent to Tule River and all wells are completed in hard rock. Templeton Mountain Area (5-75), Manache Meadow Area (5-76), and Sacator Canyon Valley (5-77) are all at the crest of mountains with no wells. Rockhouse Meadows Valley (5-78) is in wilderness with no wells. Inns Valley (5-79) and Bear Valley (5-81) both have all wells completed in hard rock.

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Table 33 Tulare Lake Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
5-22	SAN JOAQUIN VALLEY									
5-22.08	KINGS	976,000	C	3,000	500-1,500	909	-	722	200-700	40-2000
5-22.09	WESTSIDE	640,000	C	2,000	1,100	960	-	50	520	220-35,000
5-22.10	PLEASANT VALLEY	146,000	B	3,300	-	151	-	2	1,500	1000-3000
5-22.11	KAWEAH	446,000	B	2,500	1,000-2,000	568	-	270	189	35-580
5-22.12	TULARE LAKE	524,000	B	3,000	300-1,000	241	-	86	200-600	200-40,000
5-22.13	TULE	467,000	B	3,000	-	459	-	150	256	200-30,000
5-22.14	KERN COUNTY	1,950,000	A	4,000	1,200-1,500	2,258	249	476	400-450	150-5000
5-23	PANOCHE VALLEY	33,100	C	-	-	48	-	-	1,300	394-3530
5-25	KERN RIVER VALLEY	74,000	C	3,650	350	-	-	92	378	253-480
5-26	WALKER BASIN CREEK VALLEY	7,670	C	650	-	-	-	1	-	-
5-27	CUMMINGS VALLEY	10,000	A	150	56	51	-	15	344	-
5-28	TEHACHAPI VALLEY WEST	14,800	A	1,500	454	64	-	19	315	280-365
5-29	CASTAC LAKE VALLEY	3,600	C	400	375	-	-	3	583	570-605
5-71	VALLECITOS CREEK VALLEY	15,100	C	-	-	-	-	0	-	-
5-80	BRITE VALLEY	3,170	A	500	50	-	-	-	-	-
5-82	CUDDY CANYON VALLEY	3,300	C	500	400	-	-	3	693	695
5-83	CUDDY RANCH AREA	4,200	C	300	180	-	-	4	550	480-645
5-84	CUDDY VALLEY	3,500	A	160	135	3	-	3	407	325-645
5-85	MIL POTRERO AREA	2,300	C	3,200	240	7	-	7	460	372-657

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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North Lahontan Hydrologic Region

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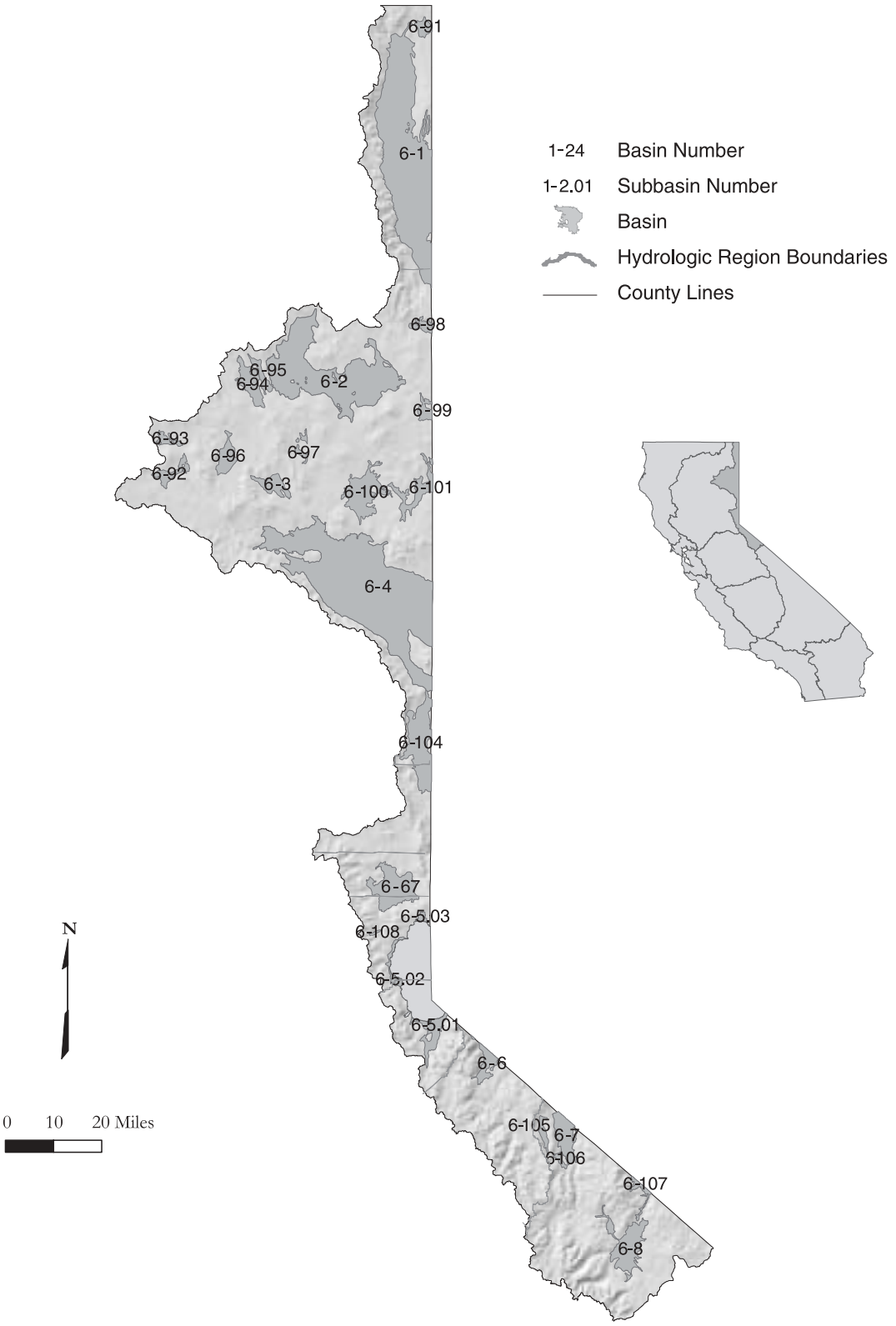

Figure 39 North Lahontan Hydrologic Region

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Basins and Subbasins of the North Lahontan Hydrologic Region

Basin/subbasin	Basin name
6-1	Surprise Valley
6-2	Madeline Plains
6-3	Willow Creek Valley
6-4	Honey Lake Valley
6-5	Tahoe Valley
6-5.01	Tahoe Valley South
6-5.02	Tahoe Valley West
6-5.03	Tahoe Valley North
6-6	Carson Valley
6-7	Antelope Valley
6-8	Bridgeport Valley
6-67	Martis (Truckee) Valley
6-91	Cow Head Lake Valley
6-92	Pine Creek Valley
6-93	Harvey Valley
6-94	Grasshopper Valley
6-95	Dry Valley
6-96	Eagle Lake Area
6-97	Horse Lake Valley
6-98	Tuledad Canyon
6-99	Painters Flat
6-100	Secret Valley
6-101	Bull Flat
6-104	Long Valley
6-105	Slinkard Valley
6-106	Little Antelope Valley
6-107	Sweetwater Flat
6-108	Olympic Valley

Description of the Region

The North Lahonton HR covers approximately 3.91 million acres (6,110 square miles) and includes portions of Modoc, Lassen, Sierra, Nevada, Placer, El Dorado, Alpine, Mono, and Tuolumne counties (Figure 39). Reaching south from the Oregon border almost to Mono Lake on the east side of the Sierra, this region encompasses portions of two geomorphic provinces. From Long Valley north, most of the groundwater basins of the region were formed by basin and range block faulting near the western extent of the province. South from Long Valley, most of the basins are in the alpine valleys of the Sierra Nevada or are at the foot of the Sierra along the California-Nevada border where streams and rivers draining the eastern Sierran slopes terminate in desert sinks or lakes. The region corresponds to approximately the northern half of RWQCB 6. Significant geographic features include the Sierra Nevada, the volcanic terrane of the Modoc Plateau, Honey Lake Valley, and Lake Tahoe. The latter two areas are the major population centers in the region. The 1995 population of the entire region was about 84,000 people (DWR, 1998).

The northern portion of the region is rural and sparsely populated. Cattle ranching and associated hay cropping are the predominant land uses in addition to some pasture irrigation. Less than 4 percent of the entire region is irrigated. About 75 percent of the irrigated lands are in Modoc and Lassen counties, and most of the remainder is in Alpine and Mono counties. Much of the southern portion of the region is federally owned and managed as national forest lands where tourism and recreation constitute much of the economic base.

Much of the North Lahontan HR is chronically short of water due to the arid, high desert climate, which predominates in the region. Throughout the northern portion of the region where annual precipitation can be as low as 4 inches, runoff is typically scant and streamflows decrease rapidly during the irrigation season as the snowpack in the higher elevations melts. In the southern portion of the region, annual precipitation ranges from more than 70 inches (mostly snow in the higher elevations of the mountains) to as little as 8 inches in the low elevation valleys. In wet years, surface water can meet much of the agricultural demand, but in dry years, most of the region relies heavily on groundwater to meet water supply needs.

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Groundwater Development

There are 24 groundwater basins in the region, one of which is divided into three subbasins. Thirteen of these basins are shared with Nevada and one with Oregon. These basins underlie approximately 1.03 million acres (1,610 square miles) or about 26 percent of the entire region. Although the groundwater basins were delineated based on mapped alluvial fill, much of the groundwater produced in many of them actually comes from underlying fractured rock aquifers. This is particularly true in the volcanic areas of Modoc and Lassen counties where, in many basins, volcanic flows are interstratified with lake sediments and alluvium. Wells constructed in the volcanics commonly produce large amounts of groundwater, whereas wells constructed in fine-grained lake deposits produce less. Because the thickness and lateral extent the of the hard rocks outside of the defined basin are generally not known, actual groundwater in storage in these areas is unknown.

Locally, groundwater is an important resource accounting for about 28 percent of the annual supply for agricultural and urban uses. Groundwater use in the region represents less than 1 percent of the State's overall supply for agricultural and urban uses (DWR 1998).

In the northern portion of the region, a sizable quantity of groundwater (nearly 130,000 acre-feet) is extracted annually for agricultural and municipal purposes. Groundwater extracted from the Honey Lake Valley Basin accounts for 41,900 acre-feet of the agricultural supply and 12,000 acre-feet of the municipal supply (based on normalized data from 1990). An additional 3,100 acre-feet is extracted to meet the demands of the Honey Lake Wildlife Area, which provides habitat for several threatened species (Bald Eagle, Sandhill Crane, Bank Swallow, and Peregrine Falcon).

Well yields in the Honey Lake Valley Basin are greatest in alluvial and volcanic deposits. Wells drawing from these deposits may have yields that vary from 10 gpm to more than 2,000 gpm, but drawdown in these cases is generally high. Eight wells in the Honey Lake Wildlife Area have an average yield of between 1,260 and 2,100 gpm. Depths of completed wells in the region range from 20 to 720 feet.

The Honey Lake Valley Basin is very close to exceeding prudent perennial yield, and future development could come at the expense of water for agriculture. A 1987 agreement between DWR, the state of Nevada, and the U.S. Geological Survey resulted in a study of the groundwater flow system in eastern Honey Lake Valley. Upon conclusion of the study in September 1990, a Nevada state engineer ruled that only about 13,000 acre-feet could be safely transferred from the basin.

No major changes in water use are anticipated in the near future in the northern portion of the region. Irrigated agriculture is already constrained by economically available water supplies. A small amount of agricultural expansion is expected but only in areas that can support minor additional groundwater development. Likewise, the modest need for additional municipal and irrigation supplies can be met by minor expansion of present surface systems or by increased use of groundwater.

The principal drainages in the southern portion of the region are the Truckee, Walker and Carson rivers. Water rights in these drainages historically have been heavily contested, and allocations are limited by interstate agreements with Nevada, in-stream environmental requirements, and miscellaneous private rights holders. In the Lake Tahoe Basin, further development is strictly limited because of concerns regarding water quality in the lake. Surface water storage developed in the region's drainages provides urban and agricultural supply to the Reno/Sparks area and to the many smaller communities in the eastern Sierra and at the foot of the mountain slopes. Most communities rely on a combination of surface water and groundwater supply.

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In the upper Truckee drainage, the primary groundwater basins underlie the areas around Lake Tahoe and Martis Valley, where the Town of Truckee is located. Both areas use surface water and groundwater for urban and surrounding rural domestic supplies.

Little is known about the small groundwater basins developed along the foot of the eastern Sierra. Most communities overlying these basins are along the streams and rivers flowing down the mountains, and groundwater is extracted from the underlying alluvium. Groundwater augments surface supplies for agricultural purposes and supports municipal and rural domestic supplies.

Groundwater Quality

In basins in the northern portion of the region, groundwater quality ranges widely from excellent to poor. Wells that obtain their water supply from lake deposits can have high concentrations of boron, arsenic, fluoride, nitrate, and TDS. TDS content generally increases toward the central portions of these basins where concentrations have accumulated over time. The groundwater quality along the margins of most of these basins tends to be of much better quality. There is a potential for future groundwater pollution occurring in urban/suburban areas where single-family septic systems have been installed, especially in hard rock areas. Groundwater quality in the alpine basins is good to excellent; but, as in any area where single-family septic systems have been installed, there is potential for degradation of groundwater quality.

Water Quality in Public Supply Wells

From 1994 through 2000, 169 public supply water wells were sampled in 8 of the 26 basins and subbasins in the North Lahontan HR. Evaluation of the analyzed samples indicates that 147 wells, or 87 percent, met the state primary MCLs for drinking water. Twenty-two wells, or 13 percent, have constituents that exceed one or more MCL. Figure 40 shows the percentages of each contaminant group that exceeded MCLs in the 22 wells.

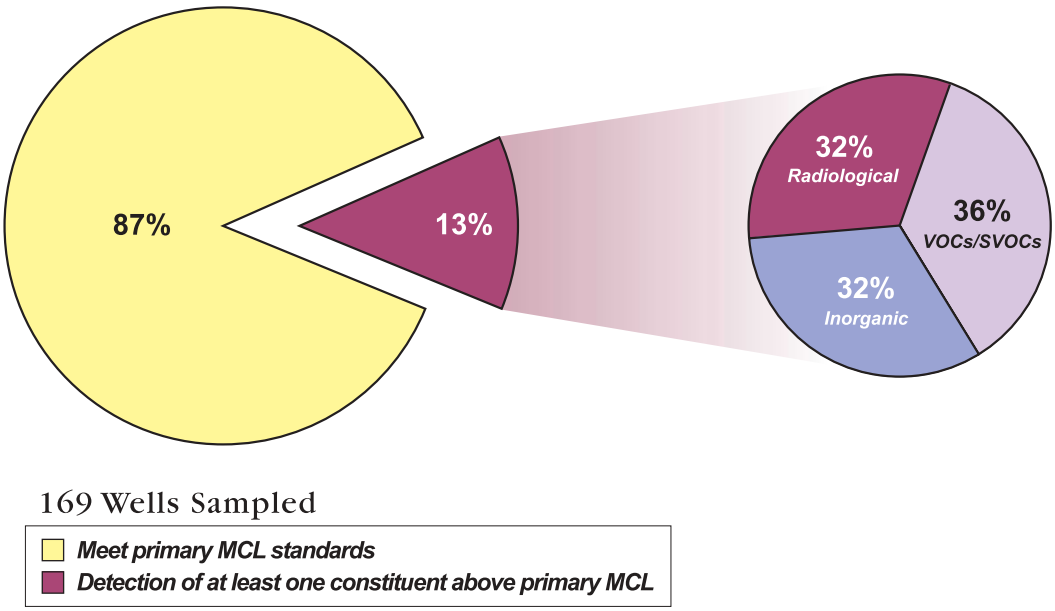

Figure 40 MCL exceedances in public supply wells in the North Lahontan Hydrologic Region

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Table 34 lists the three most frequently occurring contaminants in each contaminant group and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 34 Most frequently occurring contaminants by contaminant group in the North Lahontan Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Fluoride – 3	Thallium – 3	3 tied at 1 exceedance
Inorganics – Secondary	Iron – 14	Manganese – 13	TDS – 1
Radiological	Gross Alpha – 7	Uranium – 5	Radium 226 – 1
VOCs/SVOCs	1,2 Dichloroethane – 8	TCE – 2	MTBE – 1

TCE = Trichloroethylene
MTBE = Methyltertiarybutylether
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

Changes from Bulletin 118-80

There are no newly defined basins since Bulletin 118-80. The only delineated areas removed from the list of region basins are the Recent and Pleistocene volcanic areas of the Modoc Plateau, previously numbered 6-102 and 6-103, respectively.

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Table 35 North Lahontan Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
6-1	SURPRISE VALLEY	228,000	B	2,500	1,383	16	11	4	224	87 - 1,800
6-2	MADELINE PLAINS	156,150	B	-	450	2	6	-	402	81 - 1,790
6-3	WILLOW CREEK VALLEY	11,700	B	-	-	7	4	-	401	90 - 1,200
6-4	HONEY LAKE VALLEY	311,150	B	2,500	784	39	24	49	518	89 - 2,500
6-5	TAHOE VALLEY									
6-5.01	TAHOE SOUTH	14,800	C	4,000	-	6	-	54	-	59 - 206
6-5.02	TAHOE WEST	6,000	C	-	-	-	9	3	103	68 - 128
6-5.03	TAHOE VALLEY NORTH	2,000	C	900	-	-	-	-	141	-
6-6	CARSON VALLEY	10,700	C	-	-	-	-	-	-	-
6-7	ANTELOPE VALLEY	20,100	A	-	-	-	-	12	-	-
6-8	BRIDGEPORT VALLEY	32,500	C	-	-	-	-	6	-	-
6-67	MARTIS VALLEY	35,600	C	-	-	-	-	-	-	-
6-91	COW HEAD LAKE VALLEY	5,600	B	-	-	-	-	-	-	-
6-92	PINE CREEK VALLEY	9,530	B	-	-	-	-	1	-	-
6-93	HARVEY VALLEY	4,500	B	-	-	-	-	-	-	-
6-94	GRASSHOPPER VALLEY	17,670	B	-	-	-	-	-	-	-
6-95	DRY VALLEY	6,500	B	-	-	-	-	-	-	-
6-96	EAGLE LAKE AREA	-	B	-	-	-	4	4	-	-
6-97	HORSE LAKE VALLEY	3,800	B	-	-	-	-	-	-	-
6-98	TULEDAD CANYON	5,200	B	-	-	-	-	-	-	-
6-99	PAINTERS FLAT	6,400	B	-	-	-	-	-	-	-
6-100	SECRET VALLEY	33,680	B	-	-	2	2	-	-	125 - 3,200
6-101	BULL FLAT	18,100	B	-	-	-	-	-	-	-
6-104	LONG VALLEY	46,840	B	-	-	31	4		302	127 - 570
6-105	SLINKARD VALLEY	4,500	C	-	-	-	-	-	-	-
6-106	LITTLE ANTELOPE VALLEY	2,500	C	-	-	-	-	-	-	-
6-107	SWEETWATER FLAT	4,700	C	-	-	-	-	-	-	-
6-108	OLYMPIC VALLEY	700	C	600	330	-	-	2	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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South Lahontan Hydrologic Region

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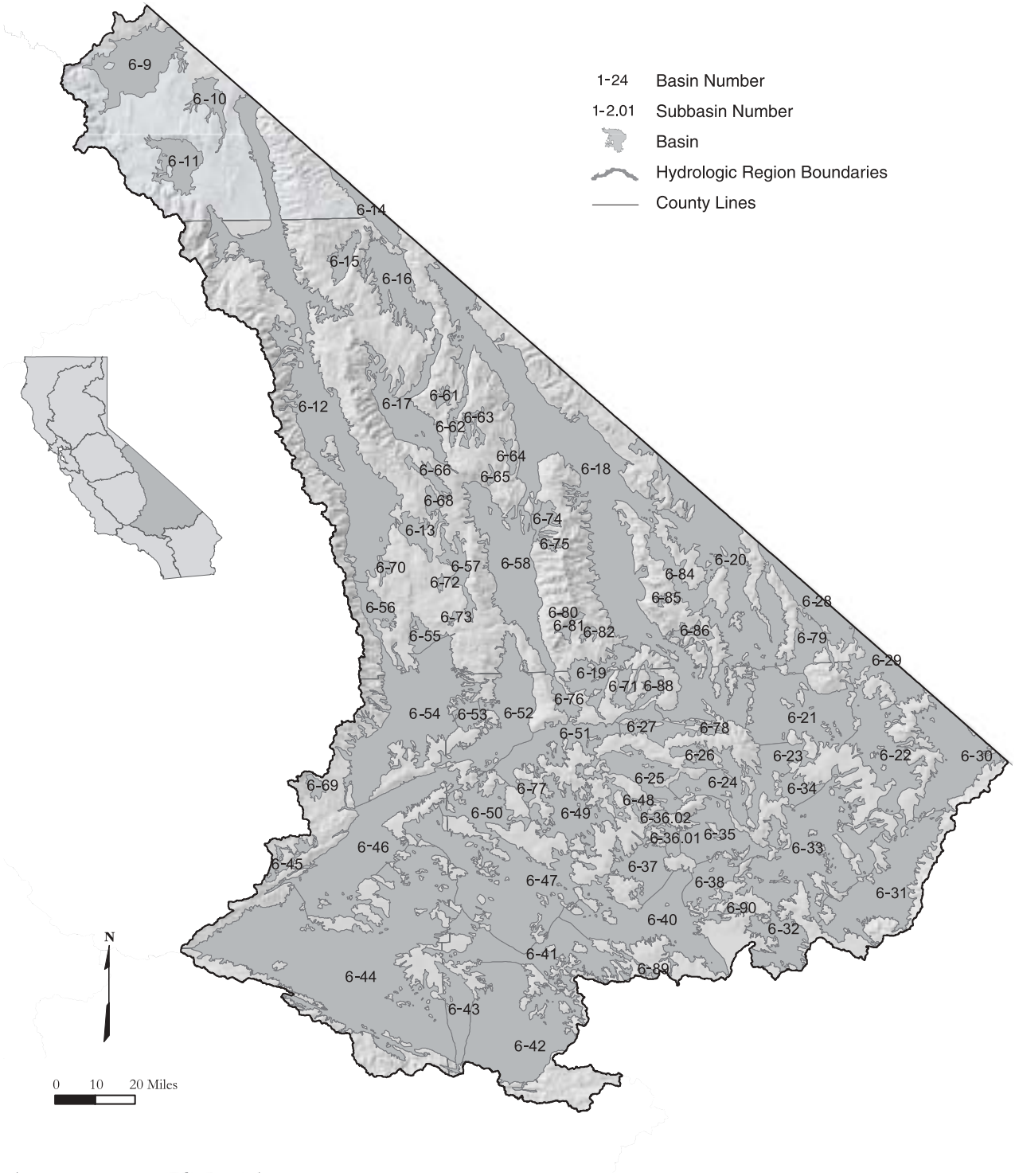

Figure 41 South Lahontan Hydrologic Region

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Basins and Subbasins of the South Lahontan Hydrologic Region

Basin/subbasin	Basin name
6-9	Mono Valley
6-10	Adobe Lake Valley
6-11	Long Valley
6-12	Owens Valley
6-13	Black Springs Valley
6-14	Fish Lake Valley
6-15	Deep Springs Valley
6-16	Eureka Valley
6-17	Saline Valley
6-18	Death Valley
6-19	Wingate Valley
6-20	Middle Amargosa Valley
6-21	Lower Kingston Valley
6-22	Upper Kingston Valley
6-23	Riggs Valley
6-24	Red Pass Valley
6-25	Bicycle Valley
6-26	Avawatz Valley
6-27	Leach Valley
6-28	Pahrump Valley
6-29	Mesquite Valley
6-30	Ivanpah Valley
6-31	Kelso Valley
6-32	Broadwell Valley
6-33	Soda Lake Valley
6-34	Silver Lake Valley
6-35	Cronise Valley
6-36	Langford Valley
6-36.01	Langford Well Lake
6-36.02	Irwin
6-37	Coyote Lake Valley
6-38	Caves Canyon Valley
6-40	Lower Mojave River Valley
6-41	Middle Mojave River Valley
6-42	Upper Mojave River Valley
6-43	El Mirage Valley
6-44	Antelope Valley
6-45	Tehachapi Valley East
6-46	Fremont Valley
6-47	Harper Valley
6-48	Goldstone Valley
6-49	Superior Valley
6-50	Cuddeback Valley
6-51	Pilot Knob Valley
6-52	Searles Valley
6-53	Salt Wells Valley
6-54	Indian Wells Valley
6-55	Coso Valley
6-56	Rose Valley
6-57	Darwin Valley
6-58	Panamint Valley
6-61	Cameo Area
6-62	Race Track Valley
6-63	Hidden Valley
6-64	Marble Canyon Area
6-65	Cottonwood Spring Area
6-66	Lee Flat
6-68	Santa Rosa Flat
6-69	Kelso Lander Valley
6-70	Cactus Flat
6-71	Lost Lake Valley
6-72	Coles Flat
6-73	Wild Horse Mesa Area
6-74	Harrisburg Flats
6-75	Wildrose Canyon
6-76	Brown Mountain Valley
6-77	Grass Valley
6-78	Denning Spring Valley
6-79	California Valley
6-80	Middle Park Canyon
6-81	Butte Valley
6-82	Spring Canyon Valley
6-84	Greenwater Valley
6-85	Gold Valley
6-86	Rhodes Hill Area
6-88	Owl Lake Valley
6-89	Kane Wash Area
6-90	Cady Fault Area

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Description of the Region

The South Lahontan HR covers approximately 21.2 million acres (33,100 square miles) in eastern California. This region includes about 21 percent of the surface area of California and both the highest (Mount Whitney) and lowest (Death Valley) surface elevations of the contiguous United States. The HR is bounded on the west by the crest of the Sierra Nevada and on the north by the watershed divide between Mono Lake and East Walker River drainages; on the east by Nevada and the south by the crest of the San Gabriel and San Bernardino mountains and the divide between watersheds draining south toward the Colorado River and those draining northward. This HR includes the Owens, Mojave, and Amargosa River systems, the Mono Lake drainage system, and many other internally drained basins. Average annual precipitation is about 7.9 inches, and runoff is about 1.3 maf per year (DWR 1994).

The South Lahontan HR includes Inyo County, much of Mono and San Bernardino counties, and parts of Kern and Los Angeles counties (Figure 41). National forests, national and state parks, military bases and other public lands comprise most of the land in this region. The Los Angeles Department of Water and Power is also a major landowner in the northern part of the HR and controls rights to much of the water draining the eastern Sierra Nevada.

According to 2000 census data, the South Lahontan HR is home to about 530,000 people, or 1.6 percent of the state's population. The major population centers are in the southern part of the HR and include Palmdale, Lancaster, Victorville, Apple Valley, and Hesperia.

Groundwater Development

In this report, 76 groundwater basins are delineated in the South Lahontan HR, and the Langford Valley Groundwater Basin (6-36) is divided into two subbasins. The groundwater basins underlie about 11.60 million acres (18,100 square miles) or about 55 percent of the HR.

Most of the groundwater production is concentrated, along with the population, in basins in the southern part of this region. Groundwater provides 41 percent of water supply for agriculture and urban uses (DWR 1998). Much of this HR is public land with very low population density, within these areas there has been little groundwater development and little is known about the basins.

In most smaller basins, groundwater is found in unconfined alluvial aquifers; however, in some of the larger basins, or near dry lakes, aquifers may be separated by aquitards that cause confined groundwater conditions. Depths of the basins range from tens or hundreds of feet in smaller basins to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this region depending on aquifer characteristics and well location, size, and use.

Conjunctive use of surface water and groundwater is practiced in the more heavily pumped basins. Some water used in the southern part of the HR is imported from Northern California by the State Water Project. Some of this imported water is used to recharge groundwater in the Mojave River Valley basins (6-40, 6-41, and 6-42). Surface water and groundwater are exported from the South Lahontan HR to the South Coast HR by the Los Angeles Department of Water and Power.

Groundwater Quality

The chemical character of the groundwater varies throughout the region, but most often is calcium or sodium bicarbonate. Near and beneath dry lakes, sodium chloride and sodium sulfate-chloride water is common. In general, groundwater near the edges of valleys contains lower TDS content than water beneath the central part of the valleys or near dry lakes.

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Drinking water standards are most often exceeded for TDS, fluoride, and boron content. The EPA lists 13 sites of contamination in this HR. Of these, three military installations in the Antelope Valley and Mojave River Valley groundwater basins are federal Superfund sites because of VOCs and other hazardous contaminants.

Water Quality in Public Supply Wells

From 1994 through 2000, 605 public supply water wells were sampled in 19 of the 77 basins and subbasins in the South Lahontan HR. Analyzed samples indicate that 506 wells, or 84 percent, met the state primary MCLs for drinking water. Ninety-nine wells, or 16 percent, have constituents that exceed one or more MCL. Figure 42 shows the percentages of each contaminant group that exceeded MCLs in the 99 wells.

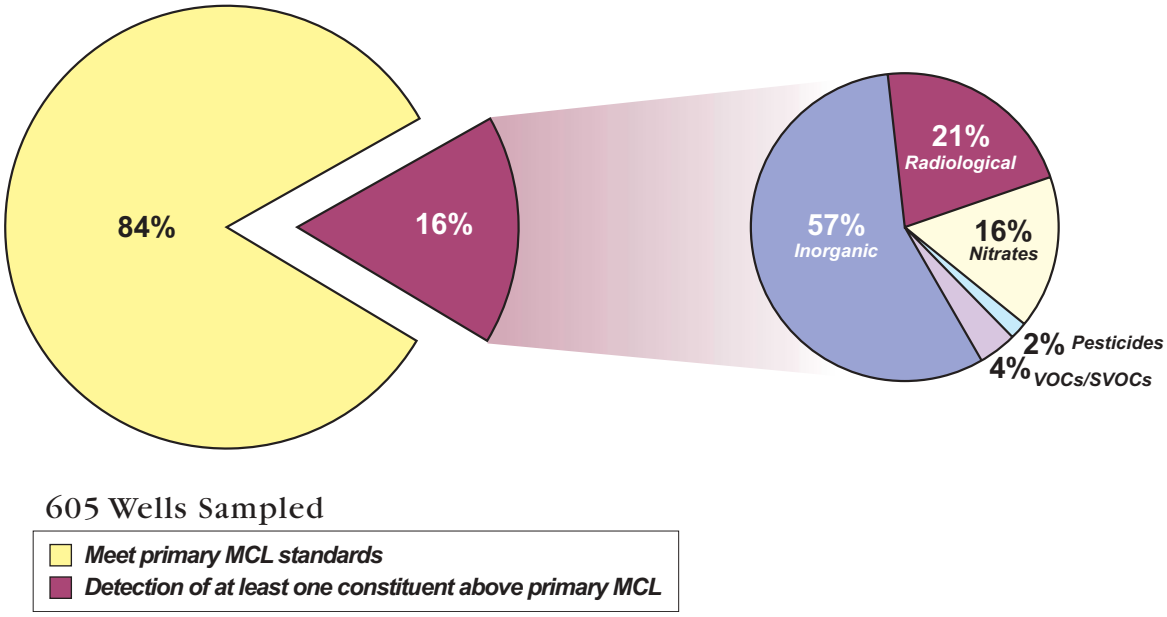

Figure 42 MCL exceedances in public supply wells in the South Lahontan Hydrologic Region

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Table 36 lists the three most frequently occurring contaminants in each of the six contaminant groups and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 36 Most frequently occurring contaminants by contaminant group in the South Lahontan Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Fluoride – 30	Arsenic – 19	Antimony – 5
Inorganics – Secondary	Iron – 82	Manganese – 36	Specific Conductance – 5 TDS – 5
Radiological	Gross Alpha – 18	Uranium – 7	Radium 228 – 2
Dissolved Nitrogen	Nitrate (as NO_3) – 12	Nitrate + Nitrite–6	Nitrite (as N) – 4
Pesticides	Di(2-Ethylhexyl)phthalate) – 2		
VOCs/SVOCs	MTBE – 2	TCE – 2	Carbon Tetrachloride – 2

TCE = Trichloroethylene
MTBE = Methyltertiarybutylether
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound

Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 37). Langford Valley Groundwater Basin (6-36) has been divided into two subbasins. Granite Mountain Area (6-59) and Fish Slough Valley (6-60) groundwater basins have been deleted because no information was found concerning wells or groundwater in these basins or because well completion reports indicate that groundwater production is derived from fractured rocks beneath the basin. Furnace Creek Area Groundwater Basin (6-83) has been incorporated into Death Valley Groundwater Basin (6-18), and Butterbread Canyon Valley Groundwater Basin (6-87) has been incorporated into Lost Lake Valley Groundwater Basin (6-71).

Table 37 Modifications since Bulletin 118-80 of groundwater basins and subbasins in South Lahontan Hydrologic Region

Basin/subbasin name	New number	Old number
Langford Well Lake	6-36.01	6-36
Irwin	6-36.02	6-36
Troy Valley	Incorporated into 6-40 and 7-14.	6-39
Granite Mountain Area	Deleted	6-59
Fish Slough Valley	Deleted	6-60
Furnace Creek Area	Deleted – incorporated into 6-18	6-83
Butterbread Canyon Valley	Deleted – incorporated into 6-71	6-87

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Troy Valley Groundwater Basin (6-39) has been split at the Pisgah fault, which is a groundwater barrier, and has been incorporated into Lower Mojave River Valley (6-40) and Lavic Valley (7-14) groundwater basins. This change incorporates part of the South Lahontan HR into a basin in the Colorado River HR[1]. The Middle Mojave River Valley Groundwater Basin (6-41) has changed boundaries along the north (Harper Valley; 6-47) and east sides (Lower Mojave River Valley; 6-40). The new boundaries are along the Camp Rock-Harper Lake fault zone, Waterman fault, and Helendale fault. Groundwater level elevations indicate that these faults are likely strong barriers to groundwater movement.

The boundary between the Upper Mojave River Valley Groundwater Basin (6-42) and the Lucerne Valley Groundwater Basin (7-19) was changed from the regional surface divide to the southern part of the Helendale fault, which is a groundwater barrier. This change incorporates part of the Colorado Desert HR into a basin in the South Lahontan HR[2].

[1] The boundaries of the hydrologic regions are defined by surface drainage patterns. In this case, faults impede groundwater flow causing it to flow beneath the surface drainage divide into the adjacent hydrologic region.
[2] See previous note.

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Table 38 South Lahontan Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
6-09	MONO VALLEY	173,000	A	800	480	-	-	-	-	2060
6-10	ADOBE LAKE VALLEY	39,800	C	-	-	-	-	-	-	-
6-11	LONG VALLEY	71,800	A	250	90	20	-	5	-	-
6-12	OWENS VALLEY	661,000	A	8,100	1,870	700	7	89	-	300-450,000
6-13	BLACK SPRINGS VALLEY	30,800	C	-	-	-	-	-	-	-
6-14	FISH LAKE VALLEY	48,100	C	-	-	-	-	-	-	-
6-15	DEEP SPRINGS VALLEY	29,900	C	700	390	-	-	-	-	-
6-16	EUREKA VALLEY	129,000	C	-	-	-	-	1	-	-
6-17	SALINE VALLEY	146,000	C	-	-	-	-	-	-	-
6-18	DEATH VALLEY	921,000	C	-	-	28	-	6	-	-
6-19	WINGATE VALLEY	71,400	C	-	-		-		-	-
6-20	MIDDLE AMARGOSA VALLEY	390,000	C	3,000	2,500	2	-	4	-	-
6-21	LOWER KINGSTON VALLEY	240,000	C	-	-	-	-	-	-	-
6-22	UPPER KINGSTON VALLEY	177,000	C	24	-	-	-	5	-	-
6-23	RIGGS VALLEY	87,700	C	-	-	-	-	-	-	-
6-24	RED PASS VALLEY	96,500	C	-	-	-	-	-	-	-
6-25	BICYCLE VALLEY	89,600	C	710	-	-	12	6	618	508-810
6-26	AVAWATZ VALLEY	27,700	C	-	-	-	-	-	-	-
6-27	LEACH VALLEY	61,300	C	-	-	-	-	-	-	-
6-28	PAHRUMP VALLEY	93,100	C	300	150	-	-	-	-	-
6-29	MESQUITE VALLEY	88,400	C	1,500	1,020	-	-	-	-	-
6-30	IVANPAH VALLEY	199,000	C	600	400	-	-	9	-	-
6-31	KELSO VALLEY	255,000	C	370	290	-	-		-	-
6-32	BROADWELL VALLEY	92,100	C	-	-	-	-	1	-	-
6-33	SODA LAKE VALLEY	381,000	C	2,100	1,100	-	-	3	-	-
6-34	SILVER LAKE VALLEY	35,300	C	-	-	-	-		-	-
6-35	CRONISE VALLEY	127,000	C	600	340	-	-	-	-	-
6-36	LANGFORD VALLEY									
6-36.01	LANGFORD WELL LAKE	19,300	C	1,700	410	11	7	3	498	440-568
6-36.02	IRWIN	10,500	C	550	-	40	-	3	528	496-598
6-37	COYOTE LAKE VALLEY	88,200	A	1,740	660	5	-	-	-	300-1000
6-38	CAVES CANYON VALLEY	73,100	A	300	-	4	1	4	-	300-1000
6-40	LOWER MOJAVE RIVER VALLEY	286,000	A	2,700	770	70	21	52	300	-
6-41	MIDDLE MOJAVE RIVER VALLEY	211,000	A	4,000	1,000	74	3	14	500	-
6-42	UPPER MOJAVE RIVER VALLEY	413,000	A	5,500	1,030	120	22	153	500	1105
6-43	EL MIRAGE VALLEY	75,900	A	1,000	230	50	3	21	-	-
6-44	ANTELOPE VALLEY	1,110,000	A	7,500	286	262	10	248	300	200-800
6-45	TEHACHAPI VALLEY EAST	24,000	C	150	31	31	-	9	361	298-405
6-46	FREMONT VALLEY	2,370,000	C	4,000	500	23	-	13	596	350-100,000
6-47	HARPER VALLEY	410,000	A	3,000	725	11	3	19	-	179-2391
6-48	GOLDSTONE VALLEY	28,100	C	-	-	-	-	-	-	-
6-49	SUPERIOR VALLEY	120,000	C	450	100	-	-	-	-	-

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Table 38 South Lahontan Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
6-50	CUDDEBACK VALLEY	94,900	C	500	300	-	-	-	-	-
6-51	PILOT KNOB VALLEY	139,000	C	-	-	-	-	1	-	-
6-52	SEARLES VALLEY	197,000	C	1,000	300	-	-	-	-	-
6-53	SALT WELLS VALLEY	29,500	C	-	-	-	-	-	-	-
6-54	INDIAN WELLS VALLEY	382,000	A	3,800	815	116	20	63	312	110-1620
6-55	COSO VALLEY	25,600	C	-	-	-	-	-	-	-
6-56	ROSE VALLEY	42,500	C	-	-	-	-	1	-	-
6-57	DARWIN VALLEY	44,200	C	130	43	-	-	-	-	-
6-58	PANAMINT VALLEY	259,000	C	35	30	-	-	-	-	-
6-61	CAMEO AREA	9,310	C	-	-	-	-	-	-	-
6-62	RACE TRACK VALLEY	14,100	C	-	-	-	-	-	-	-
6-63	HIDDEN VALLEY	18,000	C	-	-	-	-	-	-	-
6-64	MARBLE CANYON AREA	10,400	C	-	-	-	-	-	-	-
6-65	COTTONWOOD SPRING AREA	3,900	C	-	-	-	-	-	-	-
6-66	LEE FLAT	20,300	C	-	-	-	-	-	-	-
6-68	SANTA ROSA FLAT	312	C	-	-	-	-	-	-	-
6-69	KELSO LANDER VALLEY	11,200	C	-	-	-	-	-	-	-
6-70	CACTUS FLAT	7,030	C	-	-	-	-	-	-	-
6-71	LOST LAKE VALLEY	23,300	C	-	-	-	-	-	-	-
6-72	COLES FLAT	2,950	C	-	-	-	-	-	-	-
6-73	WILD HORSE MESA AREA	3,320	C	-	-	-	-	-	-	-
6-74	HARRISBURG FLATS	24,900	C	-	-	-	-	1	-	-
6-75	WILDROSE CANYON	5,160	C	-	-	-	-	-	-	-
6-76	BROWN MOUNTAIN VALLEY	21,700	C	-	-	-	-	-	-	-
6-77	GRASS VALLEY	9,980	C	-	-	-	-	-	-	-
6-78	DENNING SPRING VALLEY	7,240	C	-	-	-	-	-	-	-
6-79	CALIFORNIA VALLEY	58,300	C	-	-	-	-	-	-	-
6-80	MIDDLE PARK CANYON	1,740	C	-	-	-	-	-	-	-
6-81	BUTTE VALLEY	8,810	C	-	-	-	-	-	-	-
6-82	ANVIL SPRING CANYON VALLEY	4,810	C	-	-	-	-	-	-	-
6-84	GREENWATER VALLEY	59,900	C	-	-	-	-	-	-	-
6-85	GOLD VALLEY	3,220	C	-	-	-	-	-	-	-
6-86	RHODES HILL AREA	15,600	C	-	-	-	-	-	-	-
6-88	OWL LAKE VALLEY	22,300	C	-	-	-	-	-	-	-
6-89	KANE WASH AREA	5,960	C	60	-	-	-	-	-	-
6-90	CADY FAULT AREA	7,960	C	-	-	-	-	-	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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Colorado River Hydrologic Region

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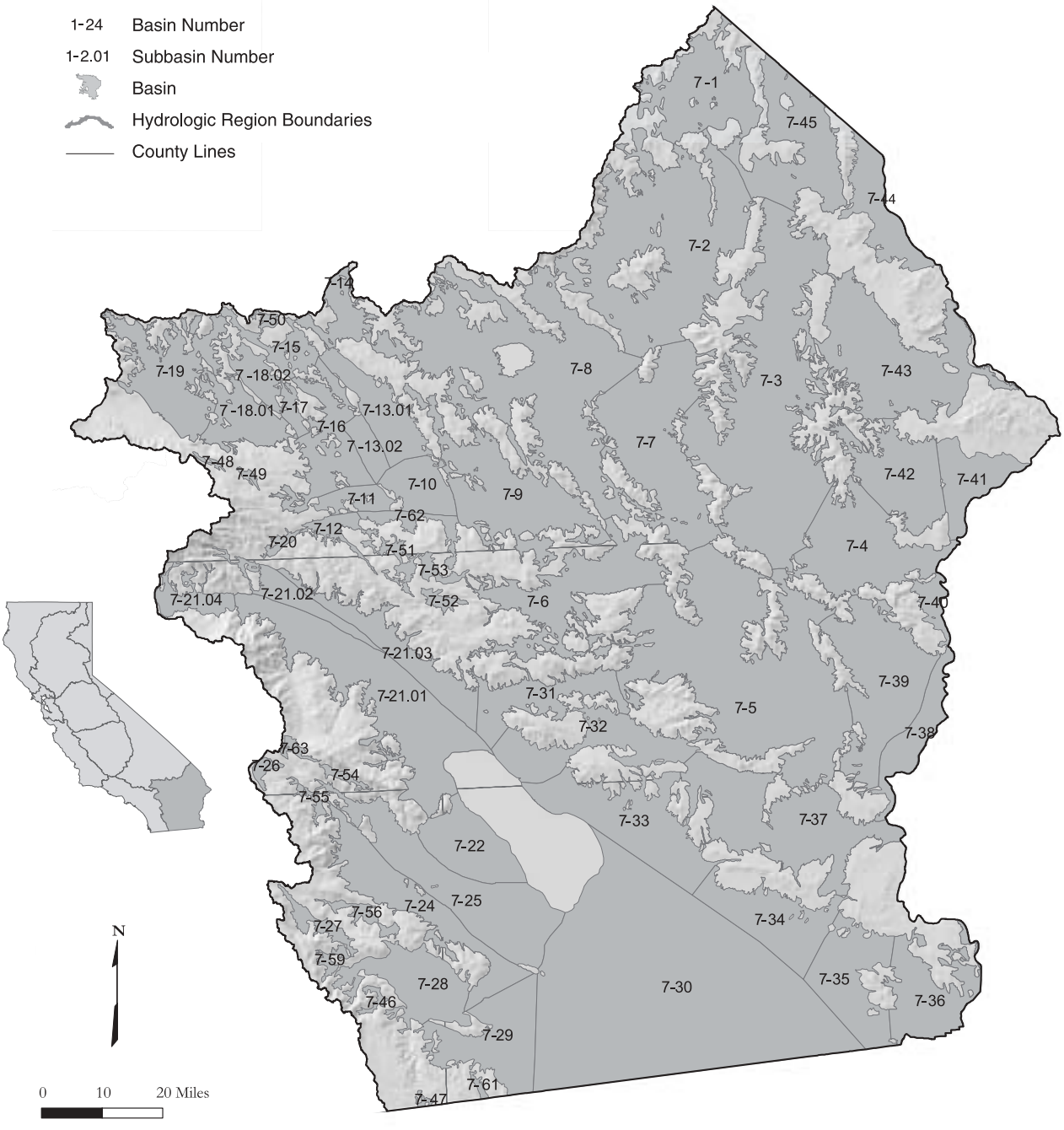

Figure 43 Colorado River Hydrologic Region

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Basins and Subbasins of Colorado River Hydrologic Region

Basin/subbasin	Basin name
7-1	Lanfair Valley
7-2	Fenner Valley
7-3	Ward Valley
7-4	Rice Valley
7-5	Chuckwalla Valley
7-6	Pinto Valley
7-7	Cadiz Valley
7-8	Bristol Valley
7-9	Dale Valley
7-10	Twentynine Palms Valley
7-11	Copper Mountain Valley
7-12	Warren Valley
7-13	Deadman Valley
7-13.01	Deadman Lake
7-13.02	Surprise Spring
7-14	Lavic Valley
7-15	Bessemer Valley
7-16	Ames Valley
7-17	Means Valley
7-18	Johnson Valley Area
7-18.01	Soggy Lake
7-18.02	Upper Johnson Valley
7-19	Lucerne Valley
7-20	Morongo Valley
7-21	Coachella Valley
7-21.01	Indio
7-21.02	Mission Creek
7-21.03	Desert Hot Springs
7-21.04	San Gorgonio Pass
7-22	West Salton Sea
7-24	Borrego Valley
7-25	Ocotillo-Clark Valley
7-26	Terwilliger Valley
7-27	San Felipe Valley
7-28	Vallecito-Carrizo Valley
7-29	Coyote Wells Valley
7-30	Imperial Valley
7-31	Orocopia Valley
7-32	Chocolate Valley
7-33	East Salton Sea
7-34	Amos Valley
7-35	Ogilby Valley
7-36	Yuma Valley
7-37	Arroyo Seco Valley
7-38	Palo Verde Valley
7-39	Palo Verde Mesa
7-40	Quien Sabe Point Valley
7-41	Calzona Valley
7-42	Vidal Valley
7-43	Chemehuevi Valley
7-44	Needles Valley
7-45	Piute Valley
7-46	Canebrake Valley
7-47	Jacumba Valley
7-48	Helendale Fault Valley
7-49	Pipes Canyon Fault Valley
7-50	Iron Ridge Area
7-51	Lost Horse Valley
7-52	Pleasant Valley
7-53	Hexie Mountain Area
7-54	Buck Ridge Fault Valley
7-55	Collins Valley
7-56	Yaqui Well Area
7-59	Mason Valley
7-61	Davies Valley
7-62	Joshua Tree
7-63	Vandeventer Flat

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Description of the Region

The Colorado River HR covers approximately 13 million acres (20,000 square miles) in southeastern California. It is bounded on the east by Nevada and Arizona, the south by the Republic of Mexico, the west by the Laguna, San Jacinto, and San Bernardino mountains, and the north by the New York, Providence, Granite, Old Dad, Bristol, Rodman, and Ord Mountain ranges. An average annual precipitation of 5.5 inches and average annual runoff of only 200,000 acre-feet makes this the most arid HR of California (DWR 1994). Surface runoff drains to many closed basins or to the Colorado River.

This HR includes all of Imperial, most of Riverside, much of San Bernardino, and part of San Diego counties (Figure 43). Many of the alluvial valleys in the region are underlain by groundwater aquifers that are the sole source of water for local communities.

About 533,000 people live within the Colorado River HR (DWR, 1998). The largest population centers are Palm Springs, Palm Desert, Indio, Coachella, and El Centro.

Groundwater Development

The earliest groundwater development in California may have been prehistoric water wells dug by the Cahuilla Indians in Coachella Valley of the Colorado River HR. In this report, 64 groundwater basins/subbasins are delineated in this HR. The Deadman Valley, Johnson Valley Area, and Coachella Valley groundwater basins have been divided into subbasins. Groundwater basins underlie about 8.68 million acres or about 26 percent of this HR.

In the Colorado River HR, groundwater provides about 8 percent of the water supply in normal years for agricultural and urban uses (DWR 1998). In most smaller basins, groundwater is found in unconfined alluvial aquifers. In some of the larger basins, particularly near dry lakes, aquifers may be separated by aquitards that create confined groundwater conditions. Depths of basins range from tens or hundreds of feet in smaller basins and along arms of ephemeral rivers to thousands of feet in larger basins. The thickness of aquifers varies from tens to hundreds of feet. Well yields vary in this region depending on aquifer characteristics and well location, size, and use. Some aquifers are capable of yielding thousands of gallons per minute to municipal wells.

Conjunctive use of surface water and groundwater is a long-standing practice in the region. Water is imported from the Colorado River for irrigation in Imperial, Coachella, and Palo Verde Valleys and from groundwater recharge in Coachella Valley. Water imported from Northern California is used to replenish Warren and Joshua Tree groundwater basins. Many agencies have erected systems of barriers to allow more efficient percolation of ephemeral runoff from surrounding mountains. The concept of utilizing groundwater basins in this sparsely populated HR for storing water that would be pumped during drought years is getting much attention.

Groundwater Quality

The chemical character of groundwater in the Colorado River HR is variable. Cation concentration is dominated by sodium with calcium common and magnesium appearing less often. Bicarbonate is usually the dominant anion, although sulfate and chloride waters are also common. In basins with closed drainages, water character often changes from calcium-sodium bicarbonate near the margins to sodium chloride or chloride-sulfate beneath a dry lake. It is not uncommon for concentrations of dissolved constituents to rise dramatically toward a dry lake where saturation of mineral salts is reached. An example of this is found at Bristol Valley Groundwater Basin, where the mineral halite (sodium chloride) is formed and then mined by

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evaporation of groundwater in trenches in Bristol (dry) Lake. The TDS content of groundwater is high in many of the basins in this region. High fluoride content is common; sulfate content occasionally exceeds drinking water standards; and high nitrate content is common, especially in agricultural areas.

Two of the primary challenges in the Colorado River HR are overdraft in the Coachella Valley and leaking underground storage tanks. The EPA has not yet placed any contamination sites in this HR on the Superfund National Priorities List; however, one site is under consideration because of high pesticide levels.

Water Quality in Public Supply Wells

From 1994 through 2000, 314 public supply water wells were sampled in 23 of the 64 basins and subbasins in the Colorado River HR. Analyzed samples indicate that 270 wells, or 86 percent, met the state primary MCLs for drinking water standards. Forty-four wells, or 14 percent, have constituents that exceed one or more MCL. Figure 44 shows the percentages of each contaminant group that exceeded MCLs in the 44 wells.

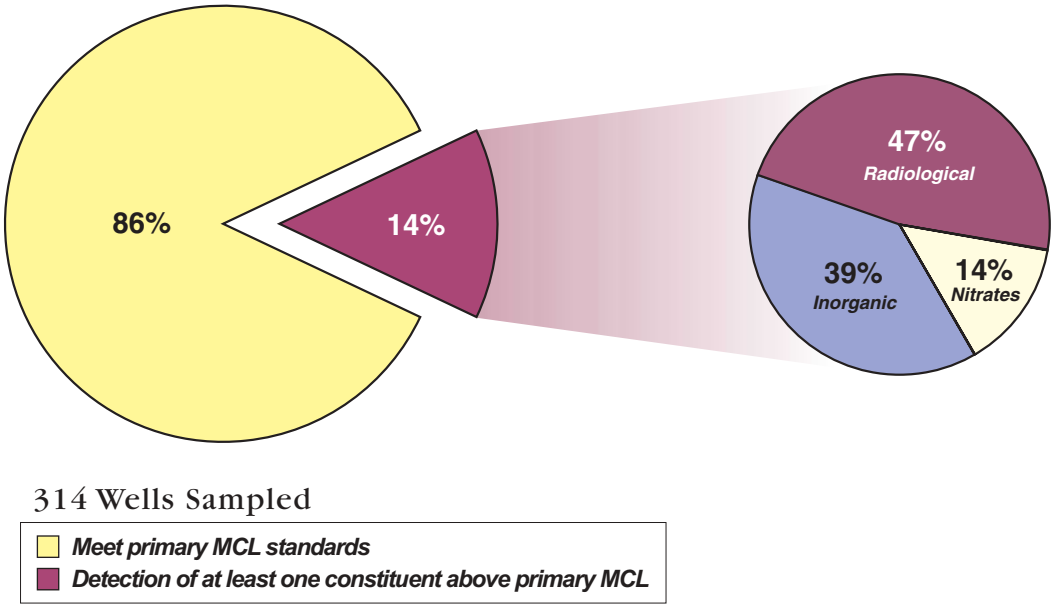

Figure 44 MCL exceedances in public supply wells in the Colorado River Hydrologic Region

Table 39 lists the three most frequently occurring contaminants in each contaminant group and shows the number of wells in the HR that exceeded the MCL for those contaminants.

Table 39 Most frequently occurring contaminants by contaminant group in the Colorado River Hydrologic Region

Contaminant group	Contaminant - # of wells	Contaminant - # of wells	Contaminant - # of wells
Inorganics – Primary	Fluoride – 17		
Inorganics – Secondary	Iron – 38	Manganese – 26	TDS – 5
Radiological	Radium 228 – 3	Combined RA226 + RA228 – 3	Radium 226 – 1
Nitrates	Nitrate (as NO_3) – 6	Nitrate + Nitrite – 1	

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Changes from Bulletin 118-80

Several modifications from the groundwater basins presented in Bulletin 118-80 are incorporated in this report (Table 40). Jacumba Valley East Groundwater Basin (7-60) has been deleted because of lack of information about groundwater in this basin. The Pinyon Wash Area (7-57) and Whale Peak Area (7-58) groundwater basin names have been deleted because they are now incorporated into other larger basins. Similarly, Clark Valley (7-23) and Ocotillo Valley (7-25) groundwater basins are now the combined Ocotillo-Clark Valley Groundwater Basin (7-25). The Deadman Valley (7-13), Johnson Valley Area (7-18), and Coachella Valley (7-21) groundwater basins have been subdivided into subbasins in this report. The western boundary of Lucerne Valley Groundwater Basin (7-19) has been moved eastward from the HR boundary to the Helendale fault. Groundwater level elevations indicate that this fault is a groundwater barrier and that groundwater flows westward back under the surface divide into the Upper Mojave River Groundwater Basin (6-42). The boundary between Lucerne Valley (7-19) and Johnson Valley Area (7-18) groundwater basins is delineated in this report.

The boundaries of Twentynine Palms Valley (7-10), Copper Mountain Valley (7-11), Warren Valley (7-12), Deadman Lake (7-13), and Ames Valley (7-16) groundwater basins have been redrawn in light of newer groundwater level data. These data indicate that the Pinto Mountain fault is a groundwater barrier. Joshua Tree Groundwater Basin (7-62) is a new basin that has been delineated from parts of Copper Mountain Valley and Twentynine Palms Valley Groundwater Basins because the Pinto Mountain fault is such a strong barrier. Buck Ridge Fault Valley Groundwater Basin (7-54) was presented in Bulletin 118-80 as two unconnected deposits of water-bearing alluvium separated by outcrop of nonwater-bearing rocks. These water-bearing deposits have been designated as separate groundwater basins in this report, with the Buck Ridge Fault Valley Groundwater Basin (7-54) as the northern basin and Vandeventer Flat Groundwater Basin (7-63) presented as the southern basin.

Table 40 Modifications since Bulletin 118-80 of groundwater basins in Colorado River Hydrologic Region

Basin name	New number	Old number
Clark Valley	Delete – combined with 7-25	7-23
Ocotillo-Clark Valley	7-25 (now combined)	7-25
Pinyon Wash Area	Incorporated into 7-56	7-57
Whale Peak Area	Incorporated into 7-28	7-58
Jacumba Valley East	Deleted	7-60
Joshua Tree	7-62 (new)	
Vandeventer Flat	7-63 (new)	

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Table 41 Colorado River Hydrologic Region groundwater data

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
7-1	LANFAIR VALLEY	157,000	C	70	16	-	-	9	515	173-2,260
7-2	FENNER VALLEY	454,000	A	200	100	-	-	4	515	173-2,260
7-3	WARD VALLEY	961,000	A	260	180	-	-	1	-	327-589
7-4	RICE VALLEY	189,000	C	65	-	-	-	-	-	-
7-5	CHUCKWALLA VALLEY	604,000	C	3,900	1,800	12	-	10	-	424
7-6	PINTO VALLEY	183,000	A	1,480	900	-	-	1	-	-
7-7	CADIZ VALLEY	270,000	C	167	66	-	-	-	400	300-3000
7-8	BRISTOL VALLEY	498,000	A	3,000	-	-	-	-		300-298,000
7-9	DALE VALLEY	213,000	C	380	275	-	-	2	-	-
7-10	TWENTYNINE PALMS VALLEY	62,400	C	3,000	540	27	-	2	640	-
7-11	COPPER MOUNTAIN VALLEY	30,300	A	2,450	250	2	-	2	-	180-214
7-12	WARREN VALLEY	17,200	A	4,000	350	27	18	17	196	129-269
7-13	DEADMAN VALLEY									
7-13.01	DEADMAN LAKE	89,200	C	2,000	-	28	3	1	-	311-985
7-13.02	SURPRISE SPRING	29,300	C	1,370	680	26	6	9	177	141-1,050
7-14	LAVIC VALLEY	102,000	C	140	80	-	-	-	-	-
7-15	BESSEMER VALLEY	39,100	C	0	-	-	-	-	-	-
7-16	AMES VALLEY	110,000	C	2,000	-	19	3	11	459	-
7-17	MEANS VALLEY	15,000	C	0	-	1	-	-	-	-
7-18	JOHNSON VALLEY AREA									
7-18.01	SOGGY LAKE	76,800	C	-	-	6	-	1	-	300-2,000
7-18.02	UPPER JOHNSON VALLEY	34,800	C	-	-	-	-	-	-	3,000
7-19	LUCERNE VALLEY	148,000	A	1,000	-	22	9	21	301	200-5,000
7-20	MORONGO VALLEY	7,240	C	600	90	-	-	5	-	-
7-21	COACHELLA VALLEY									
7-21.01	INDIO	336,000	A	1,880	650	30	-	204	300	-
7-21.02	MISSION CREEK	49,000	A	3,500	715	5	-	15	<500	-
7-21.03	DESERT HOT SPRINGS	101,000	C	2,500	985	10	-	2	-	800-1,000
7-21.04	SAN GORGONIO PASS	38,700	A	1,000	0	17	8	5	-	106-205
7-22	WEST SALTON SEA	106,000	C	540	400	v	-	-	-	-
7-24	BORREGO VALLEY	153,000	A	2,000	0	10	10	25	-	300-2,440
7-25	OCOTILLO-CLARK VALLEY	223,000	C	3,500	1,760	1	-	2	-	-
7-26	TERWILLIGER VALLEY	8,030	C	100	-	-	-	1	-	500
7-27	SAN FELIPE VALLEY	2,340	C	500	30	-	-	1	-	-
7-28	VALLECITO-CARRIZO VALLEY	122,000	C	2,500	260	-	-	1	-	-
7-29	COYOTE WELLS VALLEY	146,000	A	-	-	25	6	9	-	-
7-30	IMPERIAL VALLEY	961,000	A	1,000	-	19	-	45	1088	498-7,280
7-31	OROCOPIA VALLEY	96,500	A	210	165	0	-	1	-	-
7-32	CHOCOLATE VALLEY	130,000	C	0	0	0	-	-	-	-
7-33	EAST SALTON SEA	196,000	C	0	0	1	-	4	-	-
7-34	AMOS VALLEY	130,000	C	100	50	3	-	1	-	-
7-35	OGILBY VALLEY	134,000	C	4,000	50	27	1	3	-	-

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Table 41 Colorado River Hydrologic Region groundwater data (continued)

Basin/Subbasin	Basin Name	Area (acres)	Groundwater Budget Type	Well Yields (gpm)		Types of Monitoring			TDS (mg/L)	
				Maximum	Average	Levels	Quality	Title 22	Average	Range
7-36	YUMA VALLEY	3,780	C	100	40	59	0	15	-	-
7-37	ARROYO SECO VALLEY	258,000	C	-	-	2	0	0	-	-
7-38	PALO VERDE VALLEY	73,400	A	-	-	11	-	19	840	658-1,030
7-39	PALO VERDE MESA	226,000	C	2,750	1,650	20	-	13	-	-
7-40	QUIEN SABE POINT VALLEY	25,300	C	25	-	-	-	3	-	-
7-41	CALZONA VALLEY	81,000	C	2,340	500	0	0	0	-	
7-42	VIDAL VALLEY	138,000	C	1,800	675	-	-	1	-	-
7-43	CHEMEHUEVI VALLEY	273,000	A	0	0	1	0	1	-	-
7-44	NEEDLES VALLEY	88,400	A	1,500	980	34	-	11	-	-
7-45	PIUTE VALLEY	176,000	C	1,500	200	-	-	-	-	-
7-46	CANEBRAKE VALLEY	5,420	C	125	-	-	-	-	-	-
7-47	JACUMBA VALLEY	2,450	A	1,000	-	-	-	3		296-6,100
7-48	HELENDALE FAULT VALLEY	2,620	C	-	-	-	-	-	-	-
7-49	PIPES CANYON FAULT VALLEY	3,390	C	-	-	-	-	-	-	-
7-50	IRON RIDGE AREA	5,250	C	-	-	-	-	-	-	-
7-51	LOST HORSE VALLEY	17,300	C	-	-	-	-	-	-	-
7-52	PLEASANT VALLEY	9,670	C	-	-	-	-	-	-	-
7-53	HEXIE MOUNTAIN AREA	11,200	C	-	-	-	-	-	-	-
7-54	BUCK RIDGE FAULT VALLEY	6,930	C	-	-	-	-	-	-	-
7-55	COLLINS VALLEY	7,080	C	1,500	-	-	-	-	-	-
7-56	YAQUI WELL AREA	15,000	C	0	-	-	-	1	-	-
7-59	MASON VALLEY	5,530	C	0	0	0	0	1	-	-
7-61	DAVIES VALLEY	3,570	C	0	0	0	0	-	-	-
7-62	JOSHUA TREE	33,800	A	2,200	1,110	25	5	14	180	117-185
7-63	VANDEVENTER FLAT	6,750	C	50	17	-	-	-	-	-

gpm - gallons per minute
mg/L - milligram per liter
TDS -total dissolved solids

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Glossary

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Glossary

A

acre-foot (af) The volume of water necessary to cover one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

adjudication A case that has been heard and decided by a judge. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party to the decision.

alluvial Of or pertaining to or composed of alluvium.

alluvium A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi sorted sediment in the bed of the stream or on it's floodplain or delta, as a cone or fan at the base of a mountain slope**.**

anthropogenic Of human origin or resulting from human activity.

appropriative right The right to use water that is diverted or extracted by a nonriparian or nonoverlying party for nonriparian or nonoverlying uses. In California, surface water appropriative rights are subject to a statutory permitting process while groundwater appropriation is not.

aquitard A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores ground water.

aquifer A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

aridity A term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.

artesian aquifer A body of rock or sediment containing groundwater that is under greater than hydrostatic pressure; that is, a confined aquifer. When an artesian aquifer is penetrated by a well, the water level will rise above the top of the aquifer.

artesian pressure Hydrostatic pressure of artesian water, often expressed in terms of pounds per square inch; or the height, in feet above the land surface, of a column of water that would be supported by the pressure.

artificial recharge The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

available groundwater storage capacity The volume of a groundwater basin that is unsaturated and capable of storing groundwater.

average annual runoff The average value of total annual runoff volume calculated for a selected period of record, at a specified location, such as a dam or stream gage.

average year water demand Demand for water under average hydrologic conditions for a defined level of development.

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B

basin management objectives (BMOs) See management objectives

beneficial use One of many ways that water can be used either directly by people or for their overall benefit. The State Water Resources Control Board recognizes 23 types of beneficial use with water quality criteria for those uses established by the Regional Water Quality Control Boards.

borehole geophysics The general field of geophysics developed around the lowering of a variety of probes into a boring or well. Borehole logging provides additional information concerning physical, electrical, acoustic, nuclear and chemical aspects of the soils and rock encountered during drilling.

C

community water system A public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 year-long residents (DHS 2000).

confined aquifer An aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined ground water. See artesian aquifer.

conjunctive use The coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant Any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant).

critical conditions of overdraft A groundwater basin in which continuation of present practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts. The definition was created after an extensive public input process during the development of the Bulletin 118-80 report.

D

deep percolation Percolation of water through the ground and beyond the lower limit of the root zone of plants into groundwater.

desalination A process that converts seawater or brackish water to fresh water or an otherwise more usable condition through removal of dissolved solids.

domestic well A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

drinking water system See public water system

drought condition Hydrologic conditions during a defined period when rainfall and runoff are much less than average.

drought year supply The average annual supply of a water development system during a defined drought period.

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E

electrical conductivity (EC) The measure of the ability of water to conduct an electrical current, the magnitude of which depends on the dissolved mineral content of the water.

effective porosity The volume of voids or open spaces in alluvium and rocks that is interconnected and can transmit fluids.

environmental water Water serving environmental purposes, including instream fishery flow needs, wild and scenic river flows, water needs of fresh-water wetlands, and Bay-Delta requirements.

evapotranspiration (ET) The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

G

groundwater basin An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

groundwater budget A numerical accounting, the *groundwater equation*, of the recharge, discharge and changes in storage of an aquifer, part of an aquifer, or a system of aquifers.

groundwater in storage The quantity of water in the zone of saturation.

groundwater management The planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource.

groundwater management plan A comprehensive written document developed for the purpose of groundwater management and adopted by an agency having appropriate legal or statutory authority.

groundwater mining The process, deliberate or inadvertent, of extracting groundwater from a source at a rate in excess of the replenishment rate such that the groundwater level declines persistently, threatening exhaustion of the supply or at least a decline of pumping levels to uneconomic depths.

groundwater monitoring network A series of monitoring wells at appropriate locations and depths to effectively cover the area of interest. Scale and density of monitoring wells is dependent on the size and complexity of the area of interest, and the objective of monitoring.

groundwater overdraft The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions.

groundwater quality See water quality

groundwater recharge facility A structure that serves to conduct surface water into the ground for the purpose of replenishing groundwater. The facility may consist of dug or constructed spreading basins, pits, ditches, furrows, streambed modifications, or injection wells.

groundwater recharge The natural or intentional infiltration of surface water into the zone of saturation.

groundwater source area An area where groundwater may be found in economically retrievable quantities outside of normally defined groundwater basins, generally referring to areas of fractured bedrock in foothill and mountainous terrain where groundwater development is based on successful well penetration through interconnecting fracture systems. Well yields are generally lower in fractured bedrock than wells within groundwater basins.

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groundwater storage capacity volume of void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin.

groundwater subbasin A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

groundwater table The upper surface of the zone of saturation in an unconfined aquifer.

groundwater Water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

H

hazardous waste Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive or has some other property that produces substantial risk to life.

hydraulic barrier A barrier created by injecting fresh water to control seawater intrusion in an aquifer, or created by water injection to control migration of contaminants in an aquifer.

hydraulic conductivity A measure of the capacity for a rock or soil to transmit water; generally has the units of feet/day or cm/sec.

hydrograph A graph that shows some property of groundwater or surface water as a function of time.

hydrologic cycle The circulation of water from the ocean through the atmosphere to the land and ultimately back to the ocean.

hydrologic region A study area consisting of multiple planning subareas. California is divided into 10 hydrologic regions.

hydrostratigraphy A geologic framework consisting of a body of rock having considerable lateral extent and composing a reasonably distinct hydrologic system.

hyporheic zone The region of saturated sediments beneath and beside the active channel and that contain some proportion of surface water that was part of the flow in the surface channel and went back underground and can mix with groundwater.

I

infiltration The flow of water downward from the land surface into and through the upper soil layers.

infiltration capacity The maximum rate at which infiltration can occur under specific conditions of soil moisture.

in-lieu recharge The practice of providing surplus surface water to historic groundwater users, thereby leaving groundwater in storage for later use.

ISI Integrated Storage Investigations Program, an element of the CALFED Bay Delta initiative.

J

joint powers agreement (JPA) An agreement entered into by two or more public agencies that allows them to jointly exercise any power common to the contracting parties. The JPA is defined in Chapter 5 (commencing with Section 6500) of Division 7 of Title 1 of the California Government Code.

L

land subsidence The lowering of the natural land surface due to groundwater (or oil and gas) extraction.

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leaky confining layer A low-permeability layer that can transmit water at sufficient rates to furnish some recharge from an adjacent aquifer to a well.

lithologic log A record of the lithology of the soils, sediments and/or rock encountered in a borehole from the surface to the bottom.

lithology The description of rocks, especially in hand specimen and in outcrop, on the basis of such characteristics as color, mineralogic composition, and grain size.

losing stream A stream or reach of a stream that is losing water by seepage into the ground.

M

management objectives Objectives that set forth the priorities and measurable criteria of local groundwater basin management. For example, one management objective could be to minimize degradation of groundwater quality with a criteria set that groundwater will not be degraded by more than 100 mg/l in terms of TDS.

maximum contaminant level (MCL) The highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

N

natural recharge Natural replenishment of an aquifer generally from snowmelt and runoff; through seepage from the surface.

nonpoint source Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, etc., carried to lakes and streams by surface runoff.

O

operational yield An optimal amount of groundwater that should be withdrawn from an aquifer system or a groundwater basin each year. It is a dynamic quantity that must be determined from a set of alternative groundwater management decisions subject to goals, objectives, and constraints of the management plan.

ordinance A law set forth by a governmental authority.

overdraft See groundwater overdraft

overlying right Property owners above a common aquifer possess a mutual right to the reasonable and beneficial use of a groundwater resource on land overlying the aquifer from which the water is taken. Overlying rights are correlative (related to each other) and overlying users of a common water source must share the resource on a pro rata basis in times of shortage. A proper overlying use takes precedence over all non-overlying uses**.**

P

perched groundwater Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater.

perennial yield The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition.

perforated interval The depth interval where slotted casing or screen is placed in a well to allow entry of water from the aquifer formation.

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permeability The capability of soil or other geologic formations to transmit water. See hydraulic conductivity.

pesticide Any of a class of chemicals used for killing insects, weeds or other undesirable entities. Most commonly associated with agricultural activities, but has significant domestic use in California.

point source A specific site from which wastewater or polluted water is discharged into a water body.

pollution (of water) The alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

porosity The ratio of the voids or open spaces in alluvium and rocks to the total volume of the alluvium or rock mass.

possible contaminating activity (PCA) Human activities that are actual or potential origins of contamination for a drinking water source. PCAs include sources of both microbiological and chemical contaminants that could have an adverse effect upon human health (DHS 2000).

potentiometric surface The surface to which the water in a confined aquifer will rise in a tightly cased well.

prescriptive right rights obtained through the open and notorious adverse use of another's water rights. By definition, adverse use is not use of a surplus, but the use of non-surplus water to the direct detriment of the original rights holder.

primary porosity Voids or open spaces that were present when alluvium and rocks were originally deposited or formed.

public supply well A well used as a part of a public water system.

public water system A system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. (DHS 2000).

pueblo right A water right possessed by a municipality which, as a successor of a Spanish or Mexican pueblo, entitled to the beneficial use of all needed, naturally-occurring surface and groundwater of the original pueblo watershed Pueblo rights are paramount to all other claims.

R

recharge Water added to an aquifer or the process of adding water to an aquifer. Ground water recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence. See artificial recharge.

recharge basin A surface facility constructed to infiltrate surface water into a groundwater basin.

riparian right A right to use surface water, such right derived from the fact that the land in question abuts upon the banks of streams.

runoff The volume of surface flow from an area.

S

safe yield The maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect.

salinity Generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. See also total dissolved solids.

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saline intrusion The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater bodies.

saturated zone The zone in which all interconnected openings are filled with water, usually underlying the unsaturated zone.

seawater intrusion barrier A system designed to retard, cease or repel the advancement of seawater intrusion into potable groundwater supplies along coastal portions of California. The system may be a series of specifically placed injection wells where water is injected to form a hydraulic barrier.

secondary porosity Voids in a rock formed after the rock has been deposited; not formed with the genesis of the rock, but later due to other processes. Fractures in granite and caverns in limestone are examples of secondary openings.

seepage The gradual movement of water into, through or from a porous medium. Also the loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.

semi-confined aquifer A semi-confined aquifer or leaky confined aquifer is an aquifer that has aquitards either above or below that allow water to leak into or out of the aquifer depending on the direction of the hydraulic gradient.

service area The geographic area served by a water agency.

specific conductance See electrical conductivity

specific retention The ratio of the volume of water a rock or sediment will retain against the pull of gravity to the total volume of the rock or sediment.

specific yield the ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil**.**

spring a location where groundwater flows naturally to the land surface or a surface water body.

stakeholders Any individual or organization that has an interest in water management activities. In the broadest sense, everyone is a stakeholder, because water sustains life. Water resources stakeholders are typically those involved in protecting, supplying, or using water for any purpose, including environmental uses, who have a vested interest in a water-related decision.

stratigraphy The science of rocks. It is concerned with the original succession and age relations of rock strata and their form, distribution, lithologic composition, fossil content, geophysical and geochemical properties—all characters and attributes of rocks as strata—and their interpretation in terms of environment and mode of origin and geologic history.

subsidence See land subsidence

subterranean stream Subterranean streams "flowing through known and definite channels" are regulated by California's surface water rights system.

surface supply Water supply obtained from streams, lakes, and reservoirs.

sustainability Of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.

T

total dissolved solids (TDS) a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter. See also salinity

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toxic Poisonous, relating to or caused by a poison. Toxicity is determined for individual contaminants or for mixtures of contaminants as found in waste discharges.

transmissivity The product of hydraulic conductivity and aquifer thickness; a measure of a volume of water to move through an aquifer. Transmissivity generally has the units of ft^2/day or gallons per day/foot. Transmissivity is a measure of the subsurface's ability to transmit groundwater horizontally through its entire saturated thickness and affects the potential yield of wells.

transpiration An essential physiological process in which plant tissues give off water vapor to the atmosphere.

U

unconfined aquifer An aquifer which is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.

underground stream Body of water flowing as a definite current in a distinct channel below the surface of the ground, usually in an area characterized by joints or fissures. Application of the term to ordinary aquifers is incorrect.

unsaturated zone The zone below the land surface in which pore space contains both water and air.

urban water management plan (UWMP) An UWMP is required for all urban water suppliers having more than 3,000 connections or supplying more than 3,000 acre-feet of water. The plans include discussions on water supply, supply reliability, water use, water conservation, and water shortage contingency and serve to assist urban water suppliers with their long-term water resources planning to ensure adequate water supplies for existing and future demands.

usable storage capacity The quantity of groundwater of acceptable quality that can be economically withdrawn from storage.

V

vadose zone See unsaturated zone

volatile organic compound (VOC) A manmade organic compound that readily vaporizes in the atmosphere. These compounds are often highly mobile in the groundwater system and are generally associated with industrial activities.

W

water quality Description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

water table See groundwater table

water year A continuous 12-month period for which hydrologic records are compiled and summarized. Different agencies may use different calendar periods for their water years.

watershed The land area from which water drains into a stream, river, or reservoir.

well completion report A required, confidential report detailing the construction, alteration, abandonment, or destruction of any water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well. The reports were called *Water Well Drillers' Report* prior to 1991 and are often referred to as "driller's logs." The report requirements are described in the California Water Code commencing with Section 13750.

WQCP Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary.

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Metric Conversions

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	36.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (k/W)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific Capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

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Appendices

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Appendix A
Obtaining Copies of Supplemental Material

Bulletin 118 Update 2003 includes this report and supplemental material consisting of individual basin descriptions and a GIS-compatible map of each of the delineated groundwater basins in California. The supplemental material will be updated as new information becomes available and can be viewed or downloaded at http://www.waterplan.water.ca.gov/groundwater/118index.htm

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Appendix B
The Right to Use Groundwater in California

California does not have a statewide management program or statutory permitting system for groundwater. Some local agencies have adopted groundwater ordinances under their police powers, or have adopted groundwater management programs under a variety of statutory authorities.

Prior to a discussion of groundwater management, it is helpful to understand some of the laws governing the right to use groundwater in California. When the Water Commission Act of 1913 (Stats. 1913, Ch. 586) became effective in 1914, appropriative surface water rights became subject to a statutory permitting process. This appropriation procedure can be found in Water Code Section 1200 *et seq*. Groundwater classified as underflow of a surface stream, a "subterranean stream flowing through a known and definite channel," was made subject to the State permit system. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater which has escaped from streams. This percolating water is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in the early 20th century. Key cases are listed in Table B-1, and some of the most significant are discussed below.

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Table B-1 Significant court cases related to the right to use groundwater in California

Case	Issues addressed
Katz v. Walkinshaw, 141 Cal. 116 (1903)	Established Correlative Rights Doctrine. Correlative rights of overlying users, and surplus supply available for appropriation among non-overlying users.
Peabody v. City of Vallejo, 2 Cal. 2d 351 (1935)	Limited riparian rights under the reasonable and beneficial use requirement of the 1928 constitutional amendment; requirement of reasonable and beneficial use.
Pasadena v. Alhambra, 33 Cal. 2d 908 (1949)	First basin adjudication in California; established Doctrine of Mutual Prescription.
Niles Sand and Gravel Co. v. Alameda County Water District, 37 Cal. App. 3d 924 (1974)	Established right to store water underground as a servitude.
Techachapi-Cummings County Water District v. Armstrong, 49 Cal. App. 3d 992 (1975)	Modified the Mutual Prescription Doctrine articulated in Pasadena v. Alhambra. Overlying owners' water rights must be quantified on the basis of current, reasonable and beneficial need, not past use. By analogy to riparian rights, factors to be considered include: the amount of water available, the extent of ownership in the basin, and the nature of projected use.
Los Angeles v. San Fernando, 14 Cal. 3d 199 (1975)	Significantly modified Mutual Prescription Doctrine by disallowing it against public entities (Civil Code section 1007); established pueblo right above overlying owner right; established right to store imported water underground and recapture when needed above the right of overlying landowner.
Wright v. Goleta Water District, 174 Cal. App. 3d 74 (1985)	The unexercised water rights of overlying owners are protected from appropriators; notice and opportunity must be given to overlying owners to resist any interference with their rights.
Hi-Desert County Water District v. Blue Skies Country Club,	Retention of overlying right; no acquisition of prescriptive
23 Cal. App. 4th 1723 (1994)	right by overlying owner.
Baldwin v. Tehama County, 31 Cal. App. 4th 166 (1994)	City and County regulation of groundwater through police power. County limitations on export upheld.
City of Barstow v. Mojave Water Agency,	Held that in considering a stipulated physical solution
23 Cal. 4th 1224 (2000)	involving equitable apportionment, court must consider correlativerights of parties that did not join the stipulation.

This table modified from Bachman and others 1997

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Katz v. Walkinshaw (141 Cal. 116)

In the 1903 decision, *Katz v. Walkinshaw*, the California Supreme Court rejected the English Common Law doctrine of groundwater rights and established the Doctrine of Correlative Rights. Prior to the *Katz* decision, California had followed the doctrine articulated in the 1843 English decision of *Acton v. Blundell* (12 M. & W. 324, 152 Eng. Rep. 1223), which established that landowners enjoyed absolute ownership of groundwater underneath their property. The 1903 decision rejected the English Common Law approach as unsuitable for the "natural conditions" in California, and instead established the Correlative Rights Doctrine analogous to a riparian right. Each overlying landowner was entitled to make reasonable beneficial use of groundwater with a priority equal to all other overlying users. Water in excess of the needs of the overlying owners could be pumped and used on nonoverlying lands on a first-in-time, first-in-right basis under what is known as an appropriative right. An appropriative groundwater right, unlike its surface water counterpart, is not subject to a permitting process. Where overlying owners made full use of available supplies, appropriative rights were extinguished. Where there was insufficient water to meet even the needs of the overlying owners, the court applied the Correlative Rights Doctrine to apportion the available groundwater among the overlying landowners. Figure B-1 depicts the rights to use groundwater established in *Katz v. Walkinshaw*.

City of Pasadena v. City of Alhambra (33 Cal. 2d 908)

The 1949 decision, *Pasadena v. Alhambra*, added significant complexity to the right to use groundwater in California. This decision, involving the adjudication of the Raymond Basin, established the doctrine of mutual prescription. Groundwater levels in the basin had been declining for many years by the time court action was initiated. Most substantial pumpers, both overlying and appropriators, were joined in the action. Previously, appropriators only had a right to water surplus to the needs of overlying users. However, based upon a stipulation by most of the parties, the court in *Pasadena* adopted a program of proportionate reductions. These appropriators had each effectively gained a prescriptive right, similar to that of surface water rights, in which they had taken the water in an open, notorious, and hostile manner for at least five years. Mutual prescription provided groundwater rights to both overlying users and appropriators in depleted groundwater basins by prorating their rights based on the highest continuous amount of pumping during the five years following commencement of the overdraft. All of the users in the Raymond Basin were thus entitled to extract their portion of the court-approved safe yield of the basin.

City of Los Angeles v. City of San Fernando (14 Cal. 3d 199)

In 1975, in *Los Angeles v. San Fernando*, the California Supreme Court significantly limited the Mutual Prescription Doctrine introduced in Pasadena v. Alhambra. This opinion had far-reaching impacts on both the right to use groundwater and the practice of conjunctive use of groundwater and surface water to manage a basin. The case began in 1955, when the City of Los Angeles sued the cities of San Fernando, Glendale, Burbank and other pumpers, asserting a prior right to the San Fernando Valley groundwater basins in the northern part of the City of Los Angeles. The court, relying on Civil Code Section 1007, held that public agencies and public utilities cannot lose their groundwater rights by prescription. This holding effectively ruled out any future "mutual prescription" settlements or judgments involving rights held by public entities.

With respect to the native water supply of the San Fernando Basin, the court found that the City of Los Angeles had prior rights to all of this supply pursuant to its "pueblo right." Pueblo rights are traceable to rights recognized by the Spanish crown and the Mexican government. Under the Spanish/Mexican system, water rights were held in trust by pueblos for the benefit of all of its inhabitants. Under the Treaty of Guadalupe Hidalgo executed by Mexico and the United States in 1848, the municipal successors to Spanish/Mexican pueblos retained their pueblo rights upon the cession of California. In the San Fernando decision, the court confirmed Los Angeles' pueblo right, finding it superior to the rights of all overlying landowners. While a pueblo right is rare, it is an example of the complexity of the rights to use groundwater in California.

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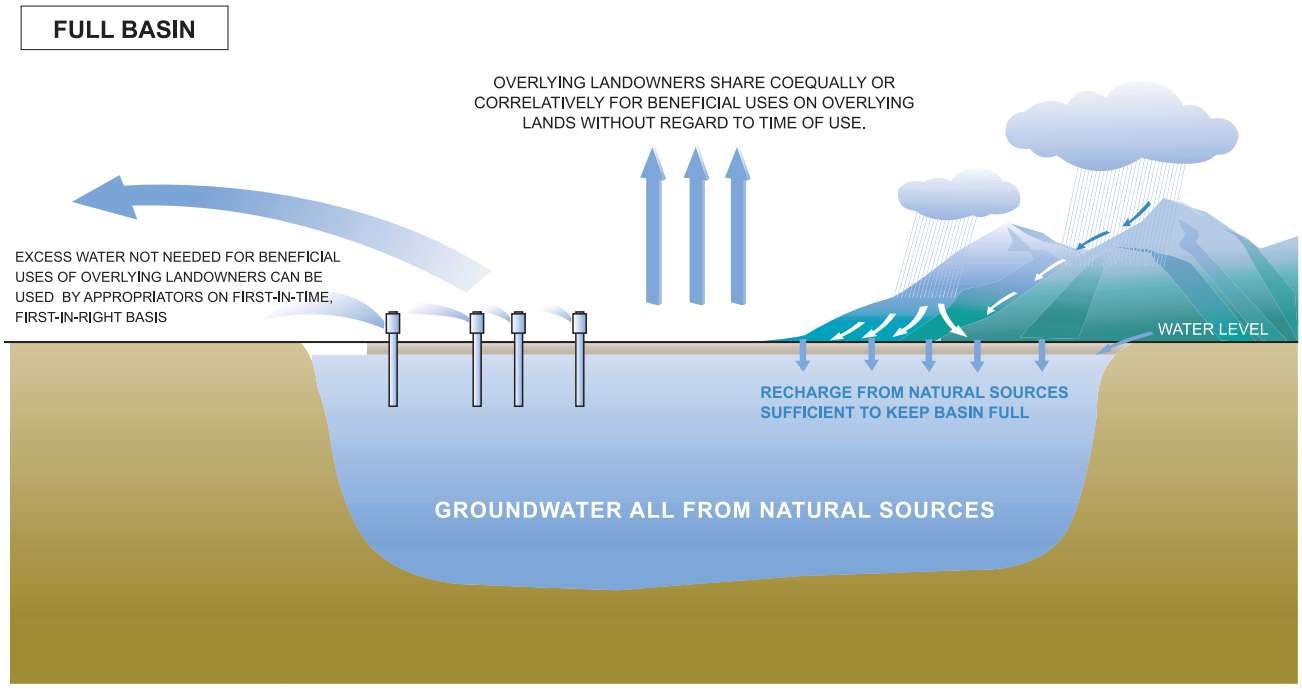

Figure B-1 Rights to groundwater use in full basin established in Katz v. Walkinshaw

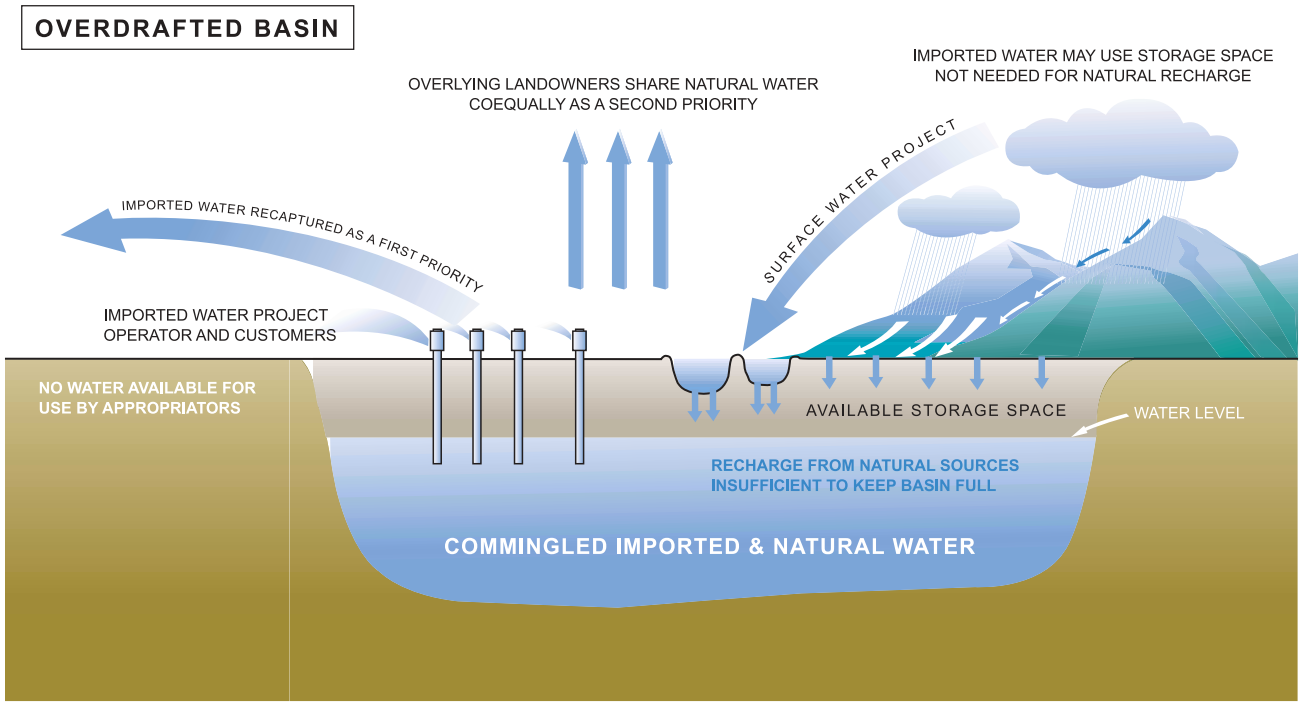

Figure B-2 Rights to groundwater use in overdrafted basin established in Los Angeles v. San Fernando

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For the future of conjunctive use of groundwater basins, the court's holding with respect to the rights to available storage space in the Basin is significant. The court upheld the right of public agencies – namely the cities of San Fernando, Los Angeles, Burbank, and Glendale–to recapture the imported water they added to the Basin. The court held that the rights of the respective public agencies to recover such imported water are of equal priority to the City of Los Angeles' pueblo right, and that all such public agency rights are "prior to the rights dependent on ownership of overlying land or based solely upon appropriation of groundwater from the basin." The court remanded the case, directing the trial court to apportion the safe yield of the Basin accordingly.

The court noted that there did not appear to be any shortage of underground storage space in relation to the demand and, hence, the court did not find it necessary to determine priorities as to the future use of such space. The Judgment issued by the trial court on remand, however, provided: "To the extent of any future spreading or in lieu storage of import water or reclaimed water by Los Angeles, Glendale, Burbank or San Fernando, the party causing said water to be so stored shall have a right to extract an equivalent amount of ground water from the San Fernando Basin." Pursuant to the Judgment, a court-appointed Watermaster now manages the groundwater extraction and storage rights within the ULARA. Figure B-2 depicts the rights to use groundwater established in Los Angeles v. San Fernando in an overdrafted basin where water has been stored.

City of Barstow v. Mojave Water Agency (23 Cal. 4th 1224)

In 2000, the California Supreme Court partially overturned the 1995 adjudication of the Mojave River Basin. The trial court had approved a negotiated settlement (or stipulated agreement) that failed to include a well-by-well determination of water rights. The trial court held the negotiated settlement to be binding on all users in the basin, including some pumpers who had not agreed to the settlement. The lower court decision was based on the doctrine of "equitable apportionment," in which the available water is shared based on concepts of equity and fairness. The Court of Appeal had partially reversed the lower court, and held that the trial court did not have the authority to ignore California's traditional water rights doctrine giving overlying users a priority right to beneficial and reasonable use of the groundwater. The Court of Appeal affirmed the trial court's negotiated settlement except as it applied to two of the parties. First, the Court of Appeal reversed the holding against a non-negotiating party since the trial court had ignored that party's existing overlying water rights. Secondly, the Court of Appeal reversed the trial court's judgment as it applied to a company, where the negotiated agreement did not give the company a water-allowance equal to its actual water use. The Supreme Court affirmed the Court of Appeal decision, but reversed the judgment applying to the company's water-allowance. The Supreme Court also affirmed that the trial court could not apply the doctrine of equitable apportionment when overlying water users had already established a prior water right. The Court stated that, while the trial court could impose a physical solution (such as the negotiated settlement), the court could not simply ignore affected owners' legal water rights. Equitable apportionment, thus, remains a tool for adjudicating basin groundwater rights, but only if all parties stipulate to its use.

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Appendix C
Required and Recommended Components of Local Groundwater Management Plans

Section 10750 et seq. of the Water Code, commonly referred to as Assembly Bill 3030, stipulates certain procedures that must be followed in adopting a groundwater management plan under this section.

Amendments to Section 10750 et seq. added the requirement that new groundwater management plans prepared under Section 10750 et seq. must include component 1 below (SB1938 (Stats 2002, Ch 603)).

In addition, the amendments mandate that if the agency preparing the groundwater management plan intends to apply for funding administered by the California Department of Water Resources (DWR) for groundwater or groundwater quality projects, the agency must prepare and implement a groundwater management plan that includes components 2, 3, 6, 7 and 9 below. DWR recommends that all the components below be included in any groundwater management plan to be adopted and implemented by a local managing entity.

Consideration and development of these components for the specific conditions of the basin to be managed under the plan will help to ensure effective groundwater management. In developing these criteria, DWR recognizes that the goal of a groundwater management plan and the goal of an ordinance to manage groundwater should be the same—assurance of a long-term, sustainable, reliable, good quality groundwater supply. Such efforts can benefit greatly from cooperative management within the basin or region.

None of the suggested data reporting in the components below should be construed as recommending disclosure of information that is confidential under State law.

1. Include documentation that a written statement was provided to the public "describing the manner in which interested parties may participate in developing the groundwater management plan," which may include appointing a technical advisory committee (Water Code § 10753.4 (b)).
2. Include a plan by the managing entity to "involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin." (Water Code § 10753.7 (a)(2)). A local agency includes "any local public agency that provides water service to all or a portion of its service area"
(Water Code § 10752 (g)).
3. Provide a map showing the area of the groundwater basin, as defined by DWR Bulletin 118, with the area of the local agency subject to the plan as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a groundwater management plan (Water Code § 10753.7 (a)(3)).
4. Establish an advisory committee of stakeholders (interested parties) within the plan area that will help guide the development and implementation of the plan and provide a forum for resolution of controversial issues.
5. Describe the area to be managed under the plan, including:
    a. The physical structure and characteristics of the aquifer system underlying the plan area in the context of the overall basin.

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b. A summary of the availability of historical data including, but not limited to, the components in Section 7 below.

c. Issues of concern including, but not limited to, issues related to the components in Section 7 below.

d. A general discussion of historical and projected water demands and supplies.

6. Establish management objectives (MOs) for the groundwater basin that is subject to the plan. (Water Code § 10753.7 (a)(1)).

7. Include components relating to the monitoring and management of groundwater levels, groundwater quality, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping. (Water Code § 10753.7 (a)(1)). Consider additional components listed in Water Code § 10753.8 (a) through (l).

8. For each MO, describe how meeting the MO will contribute to a more reliable supply for long-term beneficial uses of groundwater in the plan area, and describe existing or planned management actions to achieve MOs.

9. Adopt monitoring protocols for the components in Section 7 (Water Code § 10753.7 (a)(4)). Monitoring protocols are not defined in the Water Code, but the section is interpreted to mean developing a monitoring program capable of tracking changes in conditions for the purpose of meeting MOs.

10. Describe the monitoring program, including:

a. A map indicating the general locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence stations, or stream gages.

b. A summary of monitoring sites indicating the type (groundwater level, groundwater quality, subsidence, stream gage) and frequency of monitoring. For groundwater level and groundwater quality wells, indicate the depth interval(s) or aquifer zone monitored and the type of well (public, irrigation, domestic, industrial, monitoring).

11. Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities (Water Code § 10753.8 (k), (l)).

12. Provide for periodic report(s) summarizing groundwater basin conditions and groundwater management activities. The report(s), prepared annually or at other frequencies as determined by the local management agency, should include:

a. Summary of monitoring results, including a discussion of historical trends.

b. Summary of management actions during the period covered by the report.

c. A discussion, supported by monitoring results, of whether management actions are achieving progress in meeting MOs.

d. Summary of proposed management actions for the future.

e. Summary of any plan component changes, including addition or modification of MOs, during the period covered by the report.

f. Summary of actions taken to coordinate with other water management and land use agencies, and other government agencies.

13. Provide for the periodic re-evaluation of the entire plan by the managing entity.

14. For local agencies not overlying groundwater basins, plans should be prepared including the above listed components and using geologic and hydrologic principles appropriate to those areas (Water Code § 10753.7 (a)(5)).

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Appendix D
Groundwater Management Model Ordinance

In developing this model ordinance, the California Department of Water Resources recognizes that the goal of a groundwater management plan and the goal of an ordinance to manage groundwater should be the same—assurance of a long-term, sustainable, reliable, good quality groundwater supply. Such efforts require cooperative management within the region or sub-region.

Chapter X

Groundwater Management Ordinance

Sections:

X.01 Declaration of Findings
X.02 Purpose
X.03 Declaration of Intent
X.04 Definitions
X.05 Groundwater Management Program
X.06 Management Objectives
X.07 Monitoring Program Network
X.08 Monitoring Frequency
X.09 Changes in Monitoring
X.10 Review of Technical Data
X.11 Data Dissemination
X.12 Actions when MO Noncompliance is Reported
X.13 Regional Coordination
X.14 Integrated Resource Management
X.15 Data Relating to Export and Substitution of Groundwater

X.01 Declaration of Findings - The Board finds that:

A. The protection of the groundwater resource for its use within the County is of major concern to the residents of the County for the protection of their health, welfare, and safety.
B. The reliability and sustainability of the groundwater supply for all beneficial uses are of critical importance to the economic, social, and environmental well-being of the County.
C. A lack of effective groundwater management may have significant negative impacts, including, but not limited to:
    1. Lower groundwater levels leading to additional expenses from:
        a) Increased energy consumption.
        b) The need to deepen existing wells.
        c) The need to build new wells.
        d) The need to destroy non-functioning wells.
    2. Costly damage to public roads, bridges, canals, and other structures caused by land subsidence.
    3. Reduction of surface and subsurface flows leading to the potential loss of critical riparian and wetland habitat.
    4. Degradation of groundwater quality.

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D. It is essential for management purposes to adopt a monitoring program addressing groundwater levels, groundwater quality, land subsidence, and surface water flow and quality where it directly impacts or is impacted by groundwater.

X.02 Purpose - In support of the findings above, the County has determined that this groundwater management ordinance is necessary to ensure that:

A. Groundwater continues to be a reliable and sustainable resource.
B. The extraction of groundwater does not result in significant adverse economic, environmental, or social impacts.
C. Groundwater quality is protected.
D. Excessive land surface subsidence from groundwater extraction is prevented.

X.03 Declaration of Intent

A. The County intends to foster prudent groundwater management practices by establishing a policy that encourages appropriate management of the resource based on recommendations by a committee of stakeholders.
B. The County intends that its groundwater management activities occur as an open and public process that considers input from all stakeholders in the County.
C. The County intends to work cooperatively with interested local agencies to further develop and implement joint groundwater management activities.
D. The County does not intend to regulate, in any manner, the use of groundwater, except as a last resort to protect the groundwater resource.
E. The County intends to act as an enforcing agency should the local resource become threatened.
F. The County does not intend to infringe upon the rights of surface water users in the managed area.
G. The County does not intend to limit other authorized means of managing groundwater within the County.

X.04 Definitions

A. "Aquifer" means a geologic formation that stores groundwater and transmits and yields significant quantities of water to wells and springs. Significant quantity is an amount that that satisfies local needs and may range from thousands of gallons per minute to less than 5 gpm, depending on rock type and intended use.
B. "Board" means the Board of Supervisors of the County.
C. "District" means a district or municipality, located wholly or partially within the boundaries of the County, that is a purveyor of water for agricultural, domestic, or municipal use.
D. "Enforcement Agency" means the Board as the enforcement agency under this chapter.
E. "Groundwater" means all water beneath the surface of the earth below the zone of saturation, but does not include subterranean streams flowing in known and definite channels.
F. "Groundwater Basin" means an aquifer or series of aquifers with a reasonably defined lateral and vertical extent, as defined in Bulletin 118 by Department of Water Resources. "Non-basin areas" are outside defined groundwater basins and contain smaller amounts of groundwater in consolidated sediments or fractured hard rock.
G. "Groundwater Export" means the conveyance of groundwater outside of the boundaries of the County and outside of the boundaries of any district that is partially within the County.
H. "Groundwater Substitution" means the voluntary use of an available groundwater supply instead of surface water for the purposes of using the surface water outside the County and outside the boundaries of any district that is partially within the County.

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I. "Land Subsidence" means the lowering of the ground surface caused by the inelastic consolidation of clay beds in the aquifer system.
J. "Management Objective"(MO) means a condition identified for each subunit to ensure that the groundwater supply is reliable and sustainable. The MOs set acceptable conditions with respect to groundwater levels, groundwater quality, inelastic land surface subsidence, and surface water flows and quality. Compliance with the MO is tracked by a monitoring program and threshold values that are adopted for each Management Objective.
K. "Recharge" means flow to groundwater storage from precipitation, and infiltration from streams, irrigation, spreading basins, injection wells, and other sources of water.
L. "Reliability" means having an available, predictable, and usable groundwater supply at any given point in time.
M. "Stakeholder" means an individual or an entity, such as a water supplier or a county resident, with a permanent interest in the availability of the groundwater resource.
N. "Subunit" means any subdivision of a groundwater basin or non-basin area in the County created for the purposes of representation of stakeholders and the establishment of local area management objectives.
O. "Sustainable" means the groundwater resource is maintained for use by residents in the basin over a prolonged period of time.
P. "Technical Advisory Committee" means a committee of persons knowledgeable in groundwater management, hydrology, and hydrogeology established for the purpose of providing technical guidance to the Water Advisory Committee.
Q. "Threshold values" mean the limits established by the WAC for groundwater levels, groundwater quality, land surface subsidence, and surface water flow and quality that are not to be exceeded if the MOs are to be met.
R. "Water Advisory Committee" (WAC) means a multimember advisory body established for the purpose of aiding the Board in providing effective management of the groundwater resources in the County, and representing all of the subunits that are identified.
S. "Water Management Entities" means any local agency, or group of agencies, authorized to manage groundwater.

X.05 Groundwater Management Program

A. The County recognizes that effective groundwater management is key to maintaining a reliable and sustainable resource. For the purposes of establishing an effective groundwater management program, the Board shall appoint a WAC to establish MOs and make recommendations to the Board to ensure that MOs are met.
B. For purposes of establishing a WAC, the groundwater basins and non-basin areas of the County will be divided into subunits based on hydrogeologic principles and institutional boundaries. These subunits shall be established by the Board based on public input to address the groundwater management needs of the County. The WAC shall consist of members that represent each subunit. Upon establishment of the subunits, the Board shall appoint a member to represent each subunit on the WAC.
C. The WAC shall have the following responsibilities to the Board:
    1. Recommend MOs for each groundwater management subunit.
    2. Recommend a groundwater monitoring network for purposes of tracking MOs.
    3. Recommend the frequency of monitoring.
    4. Propose changes in monitoring.
    5. Ensure monitoring data receive technical review.
    6. Ensure that monitoring data are made available to the public.

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7. Recommend actions to resolve noncompliance with MOs.

D. For the purposes of providing technical advice to the WAC in carrying out its responsibilities, a technical advisory committee (TAC) shall be established. The TAC shall consist of local experts or a combination of local expertise and technical consultants from private and public organizations that are nominated by the WAC and approved by the Board. Individuals appointed to the TAC should be highly knowledgeable in groundwater management, hydrology, and hydrogeology. The TAC shall review technical data collected by monitoring programs within the County and advise the WAC.

X.06 Management Objectives

A. To ensure that the County maintains a reliable and sustainable groundwater supply, MOs for groundwater levels, groundwater quality, land subsidence, and surface water flow and quality shall be adopted for each subunit. Threshold values that are not to be exceeded shall be defined for each MO.

B. Compliance with the MOs will be determined by evaluation of data collected from groundwater level, groundwater quality, land subsidence, and surface water flow and quality monitoring networks. Evaluation of these data with respect to threshold values shall be the basis for determining compliance with the MOs.

C. Each WAC member shall recommend MOs for their subunit. The WAC shall develop a comprehensive set of recommendations for all subunits, and the Board shall adopt these MOs for the County. MOs may differ from subunit to subunit, but the established MOs shall be consistent with the overall goal of supply reliability for the County.

D. Groundwater management practices based on the established MOs for one subunit of the County shall not adversely impact adjacent subunits.

X.07 Monitoring Program Network

The WAC shall develop County-wide monitoring programs to collect representative data on groundwater levels, groundwater and surface water quality, land surface subsidence, and stream flow and quality. Each subunit shall propose its own monitoring program, and the WAC shall adopt a comprehensive monitoring program for the County. The data collected, showing current conditions and changes over time as a result of groundwater extraction, shall be evaluated by the WAC in consultation with the TAC. The WAC will recommend policies and actions to ensure that MOs for each subunit are met. The collection and evaluation of the data shall be based on scientifically sound principles, and shall incorporate appropriate quality assurance and quality control protocols.

A. Groundwater levels: The groundwater level monitoring network shall be proposed by the WAC and approved by the Board. The intent of the groundwater level monitoring network is to measure water levels in selected wells that can adequately determine representative conditions in the aquifer system for determination of compliance with the MOs. The network will include selected municipal, domestic, and irrigation wells owned by water districts, private parties, and municipal and industrial water suppliers. Where needed, dedicated monitoring wells may be installed. Participation by well owners will be voluntary.

B. Water Quality: The groundwater quality monitoring network shall be proposed by the WAC and approved by the Board. The intent of the groundwater quality monitoring network is to monitor selected wells that can adequately determine representative groundwater quality conditions in the aquifer system for identification of compliance with the MOs. The network will include selected municipal, domestic, and irrigation wells owned by water districts, private parties, and municipal

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and industrial water suppliers. Where needed, dedicated monitoring wells may be installed. Participation by well owners will be voluntary.

C. Land Subsidence: The land subsidence program and network shall be proposed by the WAC and approved by the Board. The intent of the land subsidence monitoring is to detect land subsidence for determination of compliance with the MOs. The network may include benchmarks that are surveyed for changes in elevation throughout the County, based on the judgment of the WAC of the need for such a program.

D. Surface Water Flow and Quality: The surface water flow and quality network shall be proposed by the WAC and approved by the Board. The intent of this network is to detect changes in surface water flow or surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping for evaluation of compliance with MOs.

X.08 Monitoring Frequency

The recommended frequency of collection of data for each of the parameters listed above shall be determined by the WAC. Initially, each parameter should be measured at the frequencies outlined below, unless the WAC notes upon evaluation of existing data that more frequent monitoring or additional analyses are called for.

A. Groundwater levels should be measured at least three times during the year: one measurement prior to the period of highest groundwater use, one measurement during peak groundwater use, and one measurement following the period of highest groundwater use (approximately the months of _____, _____, and _____).

B. Groundwater quality measurements of electrical conductivity, temperature, and pH should be obtained at least twice annually during the periods of highest and lowest groundwater use (approximately the months of _____ and _____). Upon evaluation of the data, the WAC may propose analyses for other constituents.

C. Selected benchmarks in the County land subsidence monitoring network should be surveyed every five years at a minimum. These surveys should be conducted following aquifer recovery and prior to the period of highest groundwater extraction (approximately the month of_____).

D. Measurement of surface water flow and quality in areas determined to directly affect groundwater levels or quality or that are affected by groundwater pumping shall be obtained at least ___ times per month as long as there are flows in the channel.

X.09 Changes in Monitoring

If evaluation of the groundwater level, groundwater quality, land subsidence, surface water flow, or surface water quality data indicates a need for more or less frequent measurements or analyses, the WAC may propose a change in the monitoring frequency. Similarly, if evaluation of the data indicates that additional monitoring sites are necessary, the WAC may propose an additional or a reduced number of sites for data collection. The Board shall adopt these changes when supported by credible evidence.

X.10 Review of Technical Data

A. The TAC shall propose and the WAC shall adopt standard methods using scientifically sound principles for review and analysis of the collected data. The TAC will meet, as needed and requested by the WAC, to evaluate the technical data and shall report their findings at appropriate meetings of the WAC. The WAC shall meet at least __ times per month during the period of maximum groundwater use (months of _____ through _____) and quarterly during the off season (months of _____ through _____), or as necessary.

B. During the period of highest groundwater use, the WAC meetings will focus on data review and analysis with respect to compliance with the current MOs. During the period of low

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groundwater use, the WAC meetings will focus on a review of compliance with MOs for the previous period of high groundwater use and consideration of the need for changes to the MOs.

X.11 Data Dissemination

The WAC, in addition to establishing methods for data collection and evaluation, shall establish methods for data storage and dissemination. The WAC shall disseminate the monitoring data and evaluation reports through public presentations and through a County-maintained groundwater Internet site. At a minimum, the WAC shall publicly present findings from the monitoring program to the Board twice annually.

X.12 Actions when MO Noncompliance is Reported

A. Action by Technical Advisory Committee. In the event that the TAC identifies an area that is not in compliance with the MOs, or if noncompliance is reported by any other means, the TAC shall report to the WAC on the regional extent and magnitude of the noncompliance. This information shall also be released to the public no later than ___ days from the time that noncompliance with MOs was identified. The TAC shall then collect all available pertinent hydrologic data, investigate possible causes for noncompliance with MOs, and recommend actions to the WAC to bring the area into compliance. These recommendations shall be made no later than ___ days after the report of noncompliance is released to the public. The TAC shall first make recommendations that focus on correcting the noncompliance through negotiations with all parties in the affected area.

B. Action by Water Advisory Committee. The WAC shall act as lead negotiator in re-establishing compliance with the MO. If negotiations with parties in the affected area do not result in timely and positive action to re-establish compliance with MOs for the basin, the WAC may recommend a plan to the Board to modify, reduce or terminate groundwater extraction in the affected area or take other necessary actions. Such a plan will be recommended to the Board only after the WAC has thoroughly reviewed the recommendations of the TAC at a public meeting. The modification, reduction, or termination of groundwater extraction in the affected area shall first be applied to wells involved in any export or substitution programs, and then to other wells if necessary. Domestic wells shall not be considered for any modification, reductions, or termination of groundwater extraction.

C. Action by Board of Supervisors. The Board of Supervisors, using its police powers, shall act as the enforcement agency for this ordinance. Any recommendation of the WAC may be appealed to the Board within __ working days.

X.13 Regional Coordination

Management decisions recommended by the WAC and adopted by the Board shall not deleteriously affect groundwater resources in any portions of groundwater basins or non-basin areas that share a common groundwater resource in adjacent counties. To accomplish this goal, the WAC shall meet and coordinate with water management entities outside the County that overlie a common groundwater basin at least twice per year once prior to the period of highest groundwater use and once following the period of highest groundwater use.

X.14 Integrated Resource Management

A. To ensure integration of planning activities within the County, the WAC shall inform County departments involved with groundwater related activities, including but not limited to Land Use or Zoning, Planning, Public Works, Utilities, and Environmental Health, of all WAC meetings and actions regarding MOs. In turn, these County departments shall take into consideration the

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adopted MOs when approving development or zoning changes or construction projects that may rely on or affect groundwater quantity or quality.

B. To the greatest extent practicable, the WAC should also integrate resource management planning with other agencies within the basin. Resource activities that could benefit from integrated planning with groundwater management include, but are not limited to:
- Groundwater management planning by other agencies—agricultural, municipal, industrial, local government
- Watershed management plans
- Urban water management plans
- Management and disposal of municipal solid waste and municipal sewage
- Drinking water source assessment and protection programs
- Public water system emergency and disaster response plans
- Surface water and groundwater conjunctive management programs
- Expansion of surface and groundwater facilities
- Water efficiency programs
- Water recycling programs
- Environmental habitat construction or restoration programs
- Water quality protection programs
- Recharge programs
- Transportation infrastructure planning

X.15 Data Relating to Export and Substitution of Groundwater

A. Districts, persons, or contractors intending to operate a groundwater export or groundwater substitution program shall submit the following data to the WAC __ working days prior to commencing the program:
1. A description of the project with the total amount of groundwater to be exchanged or substituted
2. The dates over which the project will take place.
3. A statement of the anticipated impacts of the project relative to adopted MOs.
4. A discussion of possible contingencies in the event of MO noncompliance.
5. A map showing the location of the wells to be used by the program.
6. A summary of any monitoring program proposed.
7. All required environmental documentation.

B. While the program is in operation, the following information shall be provided to the WAC at least ___ times per month:
1. All static and pumping groundwater level measurements made in the pumping well during the period of extraction for the export or substitution program.
2. The amount of groundwater extracted from each well per week.
3. Static groundwater level measurements in at least __ of the most proximal wells to the project pumping wells that can be practicably monitored.

C. All costs for providing such information to the WAC shall be borne by the project participants.

Note: Although the terms “County” and “Board” are used throughout the model ordinance for clarity, the model could be used by any local government or agency with appropriate authority or powers.

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Appendix E
SWRCB Beneficial Use Designations[1]

Agricultural Supply (AGR) – Uses of water for farming, horticulture, or ranching including, but not limited to irrigation, stock watering, or support of vegetation for ranch grazing.

Aquaculture (AQUA) – Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Cold Freshwater Habitat (COLD) – Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish, or wildlife, including invertebrates.

Estuarine Habitat (EST) – Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Freshwater Replenishment (FRSH) – Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Groundwater Recharge (GWR) – Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Hydropower Generation (POW) – Uses of water for hydropower generation.

Industrial Process Supply (PRO) – Uses of water for industrial activities that depend primarily on water quality.

Industrial Service Supply (IND) – Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well repressurization.

Inland Saline Water Habitat (SAL) – Uses of water that support inland saline water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish, or wildlife, including invertebrates.

Marine Habitat (MAR) – Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

Migration of Aquatic Organisms (MIGR) – Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

Municipal and Domestic Supply (MUN) – Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Navigation (NAV) – Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

Noncontact Water Recreation (REC-2) – Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Ocean Commercial and Sport Fishing (COMM) – Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

[1] From SWRCB 2000

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Preservation of Biological Habitats of Special Significance (BIOL) – Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation or enhancement of natural resources requires special protection.

Rare, Threatened, or Endangered Species (RARE) – Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance or plant or animal species established under State or federal law as rare, threatened or endangered.

Shellfish Harvesting (SHELL) – Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.

Spawning, Reproduction, and/or Early Development (SPWM) – Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Warm Freshwater Habitat (WARM) – Uses of water that support warmwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Water Contact Recreation (REC-1) – Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

Wildlife Habitat (WILD) – Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

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Appendix F
Federal and State MCLs and Regulation Dates for Drinking Water Contaminants

	U.S. Environmental Protection Agency		California Department of Health Services	
Contaminant	**MCL (mg/L)**	**Date[a]**	**MCL (mg/L)**	**Effective date**
Inorganics				
Aluminum	0.05 to 2[b]	1/91	1 0.2[b]	2/25/89 9/8/94
Antimony	0.006	7/92	0.006	9/8/94
Arsenic	0.05 0.01	eff: 6/24/77 2001	0.05	77
Asbestos	7 MFL[c]	1/91	7 MFL[c]	9/8/94
Barium	1 2	eff: 6/24/77 1/91	1	77
Beryllium	0.004	7/92	0.004	9/8/94
Cadmium	0.010 0.005	eff: 6/24/77 1/91	0.010 0.005	77 9/8/94
Chromium	0.05 0.1	eff: 6/24/77 1/91	0.05	77
Copper	1.3[d]	6/91	1[b] 1.3[d]	77 12/11/95
Cyanide	0.2	7/92	0.2 0.15	9/8/94 6/12/03
Fluoride	4 2[b]	4/86 4/86	2	4/98
Lead	0.05[e] 0.015[d]	eff: 6/24/77 6/91	0.05[e] 0.015[d]	771 2/11/95
Mercury	0.002	eff: 6/24/77	0.002	77
Nickel	Remanded	0.1	9/8/94	
Nitrate	(as N)10	eff: 6/24/77	(as N03) 45	77
Nitrite (as N)	1	1/91	1	9/8/94
Total Nitrate/Nitrite (as N)	10	1/91	10	9/8/94
Selenium	0.01 0.05	eff: 6/24/77 1/91	0.01 0.05	77 9/8/94
Thallium	0.002	7/92	0.002	9/8/94
Radionuclides				
Uranium	30 g/L	12/7/00	20 pCi/L	1/1/89
Combined radium-226 & 228	5 pCi/L	eff: 6/24/77	5 pCi/L	77
Gross Alpha particle activity	15 pCi/L	eff: 6/24/77	15 pCi/L	77
Gross Beta particle activity	dose of 4 millirem/yr	eff: 6/24/77	50 pCi/L[f]	77

EEC ORIGINAL PKG

Contaminant	U.S. Environmental Protection Agency MCL (mg/L)	U.S. Environmental Protection Agency Date[a]	California Department of Health Services MCL (mg/L)	California Department of Health Services Effective date
Strontium-90	8 pCi/L	eff: 6/24/77 now covered by Gross Beta	8 pCi/L[f]	77
Tritium	20,000 pCi/L	eff: 6/24/77 now covered by Gross Beta	20,000 pCi/L[f]	77
VOCs				
Benzene	0.005	6/87	0.001	2/25/89
Carbon Tetrachloride	0.005	6/87	0.0005	4/4/89
1,2-Dichlorobenzene	0.6	1/91	0.6	9/8/94
1,4-Dichlorobenzene	0.075	6/87	0.005	4/4/89
1,1-Dichloroethane	- -	- -	0.005	6/24/90
1,2-Dichloroethane	0.005	6/87	0.0005	4/4/89
1,1-Dichloroethylene	0.007	6/87	0.006	2/25/89
cis-1,2-Dichloroethylene	0.07	1/91	0.006	9/8/94
trans-1,2-Dichloroethylene	0.1	1/91	0.01	9/8/94
Dichloromethane	0.005	7/92	0.005	9/8/94
1,3-Dichloropropene	- -	- -	0.0005	2/25/89
1,2-Dichloropropane	0.005	1/91	0.005	6/24/90
Ethylbenzene	0.7	1/91	0.68 0.7 0.3	2/25/89 9/8/94 6/12/03
Methyl-tert-butyl ether (MTBE)	- -	- -	0.005[b] 0.013	1/7/99 5/17/00
Monochlorobenzene	0.1	1/91	0.03 0.07	2/25/89 9/8/94
Styrene	0.1	1/91	0.1	9/8/94
1,1,2,2-Tetrachloroethane	- -	- -	0.001	2/25/89
Tetrachloroethylene	0.005	1/91	0.005	5/89
Toluene	1	1/91	0.15	9/8/94
1,2,4 Trichorobenzene	0.07	7/92	0.07	9/8/94
1,1,1-Trichloroethane	0.200	6/87	0.200	2/25/89
1,1,2-Trichloroethane	0.005	7/92	0.032 0.005	4/4/89 9/8/94
Trichloroethylene	0.005	6/87	0.005	2/25/89
Trichlorofluoromethane	- -	- -	0.15	6/24/90
1,1,2-Trichloro-1,2,2- Trifluoroethane	- -	- -	1.2	6/24/90
Vinyl chloride	0.002	6/87	0.0005	4/4/89
Xylenes	10	1/91	1.750	2/25/89

EEC ORIGINAL PKG

Contaminant	U.S. Environmental Protection Agency MCL (mg/L)	Date[a]	California Department of Health Services MCL (mg/L)	Effective date
SVOC's				
Alachlor	0.002	1/91	0.002	9/8/94
Atrazine	0.003	1/91	0.003 0.001	4/5/89 6/12/03
Bentazon	- -	- -	0.018	4/4/89
Benzo(a) Pyrene	0.0002	7/92	0.0002	9/8/94
Carbofuran	0.04	1/91	0.018	6/24/90
Chlordane	0.002	1/91	0.0001	6/24/90
Dalapon	0.2	7/92	0.2	9/8/94
Dibromochloropropane	0.0002	1/91	0.0001 0.0002	7/26/89 5/3/91
Di(2-ethylhexyl)adipate	0.4	7/92	0.4	9/8/94
Di(2-ethylhexyl)phthalate	0.006	7/92	0.004	6/24/90
2,4-D	0.10.07	eff: 6/24/77 1/91	0.1 0.07	77 9/8/94
Dinoseb	0.007	7/92	0.007	9/8/94
Diquat	0.02	7/92	0.02	9/8/94
Endothall	0.1	7/92	0.1	9/8/94
Endrin	0.0002 0.002	eff: 6/24/77 7/92	0.0002 0.002	77 9/8/94
Ethylene Dibromide	0.00005	1/91	0.00002 0.00005	2/25/89 9/8/94
Glyphosate	0.7	7/92	0.7	6/24/90
Heptachlor	0.0004	1/91	0.00001	6/24/90
Heptachlor Epoxide	0.0002	1/91	0.00001	6/24/90
Hexachlorobenzene	0.001	7/92	0.001	9/8/94
Hexachlorocyclopentadiene	0.05	7/92	0.05	9/8/94
Lindane	0.004 0.0002	eff: 6/24/77 1/91	0.004 0.0002	77 9/8/94
Methoxychlor	0.1 0.04	eff: 6/24/77 1/91	0.1 0.04 0.03	77 9/8/94 6/12/03
Molinate	- -	- -	0.02	4/4/89
Oxamyl	0.2	7/92	0.2 0.05	9/8/94 6/12/03
Pentachlorophenol	0.001	1/91	0.001	9/8/94
Picloram	0.5	7/92	0.5	9/8/94
Polychlorinated Biphenyls	0.0005	1/91	0.0005	9/8/94
Simazine	0.004	7/92	0.010 0.004	4/4/89 9/8/94

EEC ORIGINAL PKG

Contaminant	U.S. Environmental Protection Agency MCL (mg/L)	U.S. Environmental Protection Agency Date[a]	California Department of Health Services MCL (mg/L)	California Department of Health Services Effective date
Thiobencarb	- -	- -	0.07 0.001[b]	4/4/89 4/4/89
Toxaphene	0.005 0.003	eff: 6/24/77 1/91	0.005 0.003	77 9/8/94
2,3,7,8-TCDD (Dioxin)	$3x10^{-8}$	7/92	$3x10^{-8}$	9/8/94
2,4,5-TP (Silvex)	0.01 0.05	eff: 6/24/77 1/91	0.01 0.05	77 9/8/94
Disinfection Byproducts				
Total trihalomethanes	0.10 0.080	11/29/79 eff: 11/29/83 eff: 1/1/02[g]	0.10	3/14/83
Total haloacetic acids	0.060	eff: 1/1/02[g]		
Bromate	0.010	eff: 1/1/02[g]		
Chlorite	1.0	eff: 1/1/02[g]		
Treatment Technique				
Acrylamide	TT[h]	1/91	TT[h]	9/8/94
Epichlorohydrin	TT[h]	1/91	TT[h]	9/8/94

Source: http://www.dhs.ca.gov/ps/ddwem/chemicals/MCL/EPAandDHS.pdf

a. "eff." indicates the date the MCL took effect; any other date provided indicates when EPA established (that is, published) the MCL.

b. Secondary MCL.

c. MFL = million fibers per liter, with fiber length > 10 microns.

d. Regulatory Action Level; if system exceeds, it must take certain actions such as additional monitoring, corrosion control studies and treatment, and for lead, a public education program; replaces MCL.

e. The MCL for lead was rescinded with the adoption of the regulatory action level described in footnote d.

f. MCLs are intended to ensure that exposure above 4 millirem/yr does not occur.

g. Effective for surface water systems serving more than 10,000 people; effective for all others 1/1/04.

h. TT = treatment technique, because an MCL is not feasible.

Federal and State MCLs – updated 05/23/03

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Appendix G
Development of Current Groundwater Basin/Subbasin Map

This Bulletin 118 update represents the first time that groundwater basin boundaries have been released as a digital coverage. The basin boundaries for the revised groundwater basin map were primarily defined using geologic contacts and hydrogeologic barriers. Specifically the identification of the groundwater basins was initially based on the presence and areal extent of unconsolidated alluvial sediments identified on 1:250,000 scale, geologic maps published by the California Department of Conservation, Division of Mines and Geology. The identified groundwater basin areas were then further evaluated through review of relevant geologic and hydrogeologic reports and well completion reports, and using the basin definition criteria listed in Table 8. Basin boundaries that are specified in each of the court decisions has been used for the boundaries of adjudicated basins.

Well completion reports for wells present in basin areas that were identified from the geologic map were reviewed to identify the depth to the top of the water table and the top of impermeable bedrock. If there was less than 25 feet of permeable material present or if there was no groundwater present within the permeable material, the area was eliminated from the map. The well completion reports were also reviewed to determine if water supply wells located within the delineated basin area were extracting groundwater from the permeable materials underlying the area or from the bedrock beneath the permeable material. If the wells only extracted groundwater from the bedrock, the area was eliminated from the map. This resulted in the elimination of some areas identified as basins in previous Bulletin 118 publications. If there were no wells present in basin areas identified from the geologic map and no other information on the geology underlying these areas, the areas were retained in the current version of the map. Additional hydrogeologic information might or might not verify that these areas should be retained as groundwater basins.

Groundwater basins were delineated and separated from each other by the following restrictions on groundwater flow. For more detail on the types of basins and the flow boundaries of those basins, see Table 8.

Impermeable Bedrock. Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock.

Constrictions in Permeable Materials. A lower permeability material, even with openings that are filled with more permeable stream channel materials, generally forms a basin boundary for practical purposes. While groundwater may flow through the sediment-filled gaps, the flow is restricted to those gaps.

Fault. A fault that crosses permeable materials may form a barrier to groundwater movement if movement along the fault plane has created fine material that impedes groundwater movement or juxtaposed low permeability material adjacent to an aquifer. This is usually indicated by noticeable difference in water levels in wells and/or flow patterns on either side of the fault. Not all faults act as barriers to groundwater flow.

Low Permeability Zone. Areas of clay or other fine-grained material that have significant areal or vertical extent generally form a barrier to groundwater movement within the basin but do not form basin boundaries.

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Groundwater Divide. A groundwater divide is generally considered a barrier to groundwater movement from one basin to another for practical purposes. Groundwater divides have noticeably divergent groundwater flow directions on either side of the divide with the water table sloping away from the divide. The location of the divide may change as water levels in either one of the basins change, making such a "divide" less useful. Such a boundary is often used for subbasins.

Adjudicated Basin Boundaries. The basin boundaries established by court order were used for all adjudicated basins. These court-decided boundaries affect the location of natural boundaries of adjoining basins. Some adjudicated basins are represented as subbasins in this bulletin.

Available reports on the geologic and hydrogeologic conditions in the delineated basin areas were also reviewed to determine if there was information that would further define the boundaries of the basin areas. This review resulted in changes to some of the basin boundaries identified in previous versions of Bulletin 118.

Several of the larger groundwater basins were further subdivided into groundwater subbasins in Bulletin 118-80 and additional large groundwater basins were subdivided during this 2003 revision. The subbasin boundaries were also primarily defined using geologic contacts and hydrogeologic divides where possible. If this was not possible, political or institutional boundaries were used.

The hydrogeologic information contained in the basin descriptions that supplement this update of Bulletin 118 includes only the information that was available in California Department of Water Resources (DWR) files through reference searches and through limited contact with local agencies. Local agencies may have conducted more recent studies that have generated additional information about water budgets and aquifer characteristics. Unless the agency notified DWR or provided a copy of the recent reports to DWR staff that recent information has not been included in the basin descriptions. Therefore, although Senate Bill 610 refers to groundwater basins identified as overdrafted in Bulletin 118, it would be prudent for local water suppliers to evaluate the potential for overdraft of any basin included as a part of a water supply assessment.

Persons interested in collecting groundwater information in accordance with the Water Code as amended by SB 221 and SB 610 may start with the information in Bulletin 118, but should follow up by consulting the references listed for each basin and contacting local water agencies to obtain any new information that is available. Otherwise, evaluation of available groundwater resources as mandated by SB 221 and SB 610 may not be using the most complete and recent information about water budgets and aquifer characteristics.

Groundwater basin and subbasin boundaries shown on the map included with this bulletin are based on evaluation of the best available information. In basins where many studies have been completed and the basin has been operated for a number of years, the basin response is fairly well understood and the boundaries are fairly well defined. Even in these basins, however, there are many unknowns and changes in boundaries may result as more information about the basin is collected and evaluated.

In many other basins where much less is known and understood about the basin, boundaries will probably change as a better understanding of the basin is developed. A procedure for collecting information from all the stakeholders should be developed for use statewide so that agreement on basin boundaries can be achieved.

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STATE OF CALIFORNIA

General Plan Guidelines

2017

GOVERNOR'S OFFICE OF PLANNING AND RESEARCH

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Director's Message

After a multi-year effort involving literally dozens of workshops, hundreds of meetings, and thousands of participants, I am very pleased to present the 2017 version of the General Plan Guidelines. This is the first comprehensive update since 2003, and, not surprisingly, there are many changes. In an effort to reduce time, cost, and burden, we have included hundreds of links to resources, now available by a single click. We have included an on-line mapping tool, free of charge, which allows access to state and federal and other GIS data resources. The mapping tool also allows users to download and add their own GIS layers. OPR will add additional functions to the tool in the future. We have identified changes in the law and added new sections on a number of topics including health and equity.

A great deal has changed in California since 2003, and the General Plan Guidelines reflect that. Most importantly, climate change and its implications permeate almost every aspect of the Guidelines, as it must. One thing that has not changed is the importance of the general plan itself and the unique perspective each jurisdiction brings to the process and the plan vision.

Going forward, OPR will be adding resources and links periodically, making the Guidelines more of a living document. We encourage you to help OPR identify the best resources and links as part of this effort. Most importantly, we hope that these Guidelines help improve the planning process and promote periodic general
plan updates.



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Introduction

Planning Healthy, Equitable, Resilient, and Economically Vibrant Places

"By far the greatest and most admirable form of wisdom is that needed to plan and beautify cities and human communities."

—Socrates

The general plan is more than the legal underpinning for land use decisions; it is a vision about how a community will grow, reflecting community priorities and values while shaping the future. To assist local governments in preparing general plans and the public in participating in that process, the Governor's Office of Planning and Research (OPR) periodically revises guidelines for the preparation and content of local general plans (Gov. Code § 65040.2).

This 2017 edition of the General Plan Guidelines (GPG) contains significant changes to the 2003 General Plan Guidelines. For mandatory and common optional elements of the general plan, the GPG sets out each statutory requirement in detail, provides OPR recommended policy language, and includes online links to city and county general plans that have adopted similar policies. Each chapter contains a sample selection of policies. Users can also click the links provided for more detailed policies and plans. All of the referenced policies as well as additional policies are compiled in Appendix A. For ease of use, the new GPG is text-searchable, and provides sample policy language for local governments to use or adapt. The update contains new resources and templates for cities and counties to use in considering themes, structures, and policies for their general plans, including new compendiums on infill development, renewable energy, and mitigation for conversion of agricultural land. As more resources and data sources become available, they will be added and linked to these General Plan Guidelines. The new online platform will allow OPR to add updated text, links, and information directly to the GPG, and announce any additions through the GPG listserv and on the OPR website. The GPG is a resource to help planners accomplish their respective community's priorities and vision while meeting larger state goals, increasing community collaboration, and potentially improving competitiveness for funding opportunities.

As of 2015, more than half of local jurisdictions have general plans that are over 15 years old. Often, this is because the process of adopting a general plan has become too time-consuming and costly. In order to streamline the process and reduce costs, this comprehensive update of OPR's GPG provides free online tools and resources, promotes increased use of online data, and includes templates, sample policies, and links to more information. The General Plan Mapping Tool draws data sets from multiple sources, allowing users to incorporate local, regional, and statewide data into local general plans. Local jurisdictions may pull from and modify provided policies and templates, analyze consistent data through the tool, and craft general plans at a lower cost and with less uncertainty. These new resources will increase efficiencies in the development of general plan updates for communities of all sizes throughout the state.

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NEW in the 2017 *General Plan Guidelines* suite of tools:

- Updated and expanded sections on visioning and community engagement
- New sections on healthy communities, equitable and resilient communities, economic development, and climate change
- GPG Mapping Tool, enabling free, easy access to helpful data for cities and counties
- Links to additional online tools and resources
- Recommended policies in cut and paste format, with examples of adopted policy language
- Reformatted sections on the mandatory elements, including a new section on environmental justice
- Expanded equity and environmental justice section
- Infill compendium
- Renewable energy compendium
- Model template for mitigation of agricultural land conversion

The term "element" refers to the topics that California law requires to be covered in a general plan (Gov. Code § 65302). There is no mandatory structure or maximum number of elements that a general plan must include. Once added into the general plan, each element, regardless of statutory requirement, assumes the same legal standing, and must be consistent with other elements (Gov. Code § 65300.5). The general plan is the perfect space for innovation, reflecting the unique character of each community. The format and content of general plans can vary between jurisdictions. Planners must address mandatory elements, but they have discretion to organize general plans by values (core concepts that the community

Figure 1: Examples of General Plan Layout



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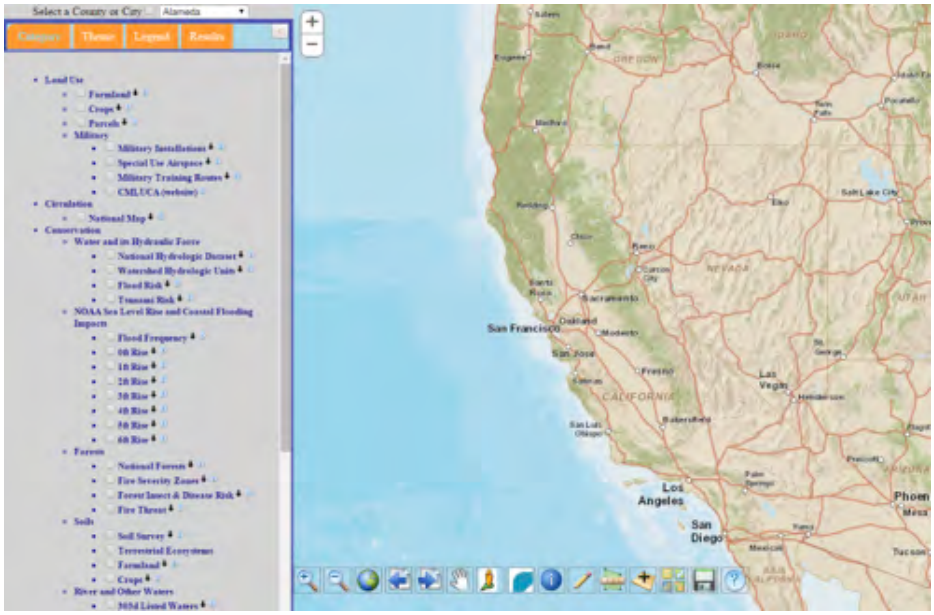
wants to enhance or uphold), themes (overarching issues identified by the community as important), challenges or goals identified through community engagement, or even by the elements themselves. Cities and counties may create new models of organizing their general plans, based on the needs and priorities identified during public engagement. Riverside County, for example, included a healthy communities element in its general plan update. The City of Fullerton structured its general plan around four focus areas, identified through community engagement, and addressed all of the elements through those focus areas. The City of Sacramento framed its general plan around sustainability and livable communities, and focused each of the required elements – as well as additional elements – around those goals. The County of Marin created a separate, easy to read summary of its 2007 countywide plan, featuring model strategies and metrics related to climate change, social equity, and other themes. OPR designed the GPG to assist every city and county in accordance with its local jurisdiction's unique vision, using whatever structure best achieves the goals of the community.

The 2017 GPG update includes a free General Plan Mapping Tool. The tool incorporates the requirements for the mandatory elements as well as themes and provides Geographic Information Systems (GIS) resources for city and county planners to use when drafting a general plan.

The tool provides access to data (varying as available from county, city, and parcel–level information) to help inform decision–making processes and enhance public participation. The mapping tool uses a platform specifically designed for general plans.

Figure 2: The General Plan Mapping Tool



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Recommendations and Sample Language

OPR has included recommendations and sample policy language to provide cities and counties with information, data, examples, and ideas to consider in their general plan. These recommendations may not fit the needs of every city and county or every circumstance. Rather, these recommendations represent a toolbox of options, allowing jurisdictions to use them as they are, modify them as appropriate within statutory requirements, or consider them as examples to inform their own policies.

According to state law,

> "Decisions involving the future growth of the state, most of which are made and will continue to be made at the local level, should be guided by an effective planning process, including the local general plan, and should proceed within the framework of officially approved statewide goals and policies directed to land use, population growth and distribution, development, open space, resource preservation and utilization, air and water quality, and other related physical, social and economic development factors." (Gov Code § 65030.1)

The following text box describes the statutory state planning priorities of the Governor's Office of Planning and Research Environmental Goals and Policy Report, as they appear in Government Code section 65041.1. The GPG aims to help achieve goals consistent with both documents by recommending practices and policies for cities and counties to incorporate locally.

STATE PLANNING PRIORITIES

California Government Code section 65041.1

The state planning priorities, which are intended to promote equity, strengthen the economy, protect the environment, and promote public health and safety in the state, including in urban, suburban, and rural communities, shall be as follows:

(a) To promote infill development and equity by rehabilitating, maintaining, and improving existing infrastructure that supports infill development and appropriate reuse and redevelopment of previously developed, underutilized land that is presently served by transit, streets, water, sewer, and other essential services, particularly in underserved areas, and to preserving cultural and historic resources.

(b) To protect environmental and agricultural resources by protecting, preserving, and enhancing the state's most valuable natural resources, including working landscapes such as farm, range, and forest lands, natural lands such as wetlands, watersheds, wildlife habitats, and other wildlands, recreation lands such as parks, trails, greenbelts, and other open space, and landscapes with locally unique features and areas identified by the state as deserving special protection.

(c) To encourage efficient development patterns by ensuring that any infrastructure associated with development, other than infill development, supports new development that does all of the following:

(1) Uses land efficiently.

(1) Is built adjacent to existing developed areas to the extent consistent with the priorities specified pursuant to subdivision (b).

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(1) Is located in an area appropriately planned for growth.

(1) Is served by adequate transportation and other essential utilities and services.

(1) Minimizes ongoing costs to taxpayers.

This GPG document is advisory. Nevertheless, courts periodically refer to the GPG to interpret planning law. For this reason, the GPG closely adheres to statute and current case law. It also relies upon commonly accepted principles of contemporary planning practice. The following words are used to indicate whether a particular subject in the GPG is mandatory, advisory, or permissive:

(a) "Must" or "shall" identifies a mandatory statutory requirement that all public agencies are required to follow.

(b) "Should" or "suggest(ed)" identifies guidance provided by OPR based on policy considerations contained in California's planning laws.

(c) "May" or "can (could)" identifies a permissive recommendation that is left fully to the discretion of the local governments involved.

OPR updated the GPG in coordination with a number of other tool, policy, and program update efforts to ensure references to external tools support the intent of the GPG. Some examples of these concurrent updates include the following:

- AB 32 Scoping Plan Update
- Cal-Adapt
- California Climate Adaptation Planning Guide
- California Coastal Commission Local Coastal Plan guidance
- California State Energy Efficiency Collaborative GHG and climate tools
- General Plan Mapping Tool
- Safeguarding California Plan
- State Hazard Mitigation Plan
- SB 244(2011), SB 743(2013), SB 379(2015), SB 1000(2016)
- California Statewide Housing Assessment
- California State Wellness Plan

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- California Strategic Growth Council
- California Water Plan
- CEQA Guidelines Update
- Cool California and the Funding Wizard
- Environmental Goals and Policy Report

The GPG also includes new sections on environmental justice, healthy communities, equity and resilience, economic development, and climate change; as well as compendiums on infill development, renewable energy, and agricultural land conservation.

How to Use These Guidelines

The General Plan Guidelines are intended to be user friendly and practical for planners, decision makers, and the general public. The GPG and the General Plan Mapping Tool can be used to frame conversations around planning, evaluate data and identify priorities, research formats and policies from similar communities, and enhance capacity for fiscally constrained departments and organizations working to update general plans. Each chapter of the GPG lays out the requirements contained in statute, connections to other requirements, additional considerations, and related data and policies to consider. Each mandatory element also includes a completeness checklist to assist communities in meeting statutory requirements. Recognizing the vast diversity of California's communities in size, demographics, geography, economics, and resources, the GPG present examples in various jurisdictions whenever possible.

Statutory Requirements

This document provides textboxes containing the statutory language that creates a legal obligation to address each of the required elements in a general plan. These textboxes can be found in the chapters corresponding to each of the elements. The information following the statutory language contains OPR's recommendations for meeting the requirement. Each statutory reference is hyperlinked to the full text of the Government Code for easy access.

Requirement Description

This section includes considerations, resources, data, and other information for developing general plan policies. Many elements are interrelated, so tables in each requirement description section note linkages between elements. This section also includes additional information through hyperlinks, which lead to examples and resources.

Recommended Data

Each section also includes recommendations for data that jurisdictions may wish to use to examine and determine specific needs and policies. Tables identify the data according to the potential intent of analysis. Where the recommended data is available, tables provide direct links to the General Plan Mapping Tool. As the GPG is reviewed and updated, additional data links will be added. Because the same data may be useful for multiple analytical purposes, some data link to multiple sections of the guidelines. The recommended data are not exhaustive but can serve as a starting point for considering the specific needs of a community and for identifying further information needed to help inform decisions related to those needs.

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Parts of a General Plan

(for more detailed descriptions and examples, see Appendix E)

Development Policy – a general plan statement that guides action, including goals and objectives, principles, policies, standards, and plan proposals.

Diagram – a graphic expression of a general plan's development policies, particularly its plan proposals, which must be consistent with the general plan text (Gov Code § 65300.5).

Goal – a general expression of community values and direction, expressed as ends (not actions).

Objective – a specified end, condition, or state that is a measurable intermediate step toward attaining a goal.

Principle – an assumption, fundamental rule, or doctrine guiding general plan policies, proposals, standards, and implementation measures.

Policy – a specific statement that guides decision–making and helps implement a general plan's vision.

Standards – a rule or measure establishing a level of quality or quantity that must be complied with or satisfied.

Plan Proposal – describes the development intended to take place in an area. Plan proposals are often expressed on the general plan diagram.

Implementation Measure – an action, procedure, program, or technique that carries out general plan policy. Each policy should have at least one corresponding implementation measure.

Recommended Policies

The government code directs OPR to provide land use policy advice. In order to do so, the GPG includes both general plan policy recommendations and links to external resources that provide policy guidance. Where possible, links are provided to the sample policies, case studies, and external reports.

Adopted state programs described in the draft Environmental Goals and Policy Report – an overview of the state's environmental goals and the key steps needed to achieve them – provide the basis for many of the policy recommendations. OPR also examined current academic publications and conducted extensive outreach to local governments, community, and advocacy groups in building policy recommendations. Cross–cutting recommendations include consideration of equity, health, and climate issues within jurisdictions,communities, and regions. With thoughtful planning based on such considerations, California will foster a future that has a strong economy, thriving built and natural environments, and a healthy, prosperous citizenry.

GPG policy recommendations focus on four key themes.

1. Climate Change: In California, climate change has been the subject of multiple Executive Orders and legislation. It is a high priority subject for any general plan update. EO B-30-15 established interim emissions reduction targets for 2030; EO S-03-05

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established long-term targets for 2020 and 2050; and EO S-13-08 established climate change adaptation and resilience as a priority. Further state goals include reduction of petroleum use by up to 50 percent by 2030, and an increase of renewable energy to 50 percent by 2030 through the Clean Energy and Pollution Reduction Act of 2016. California has set greenhouse gas (GHG) emissions reduction requirements in numerous sectors including land use and transportation planning (Assembly Bill 32, the Global Warming Solutions Act of 2006 (Nunez), hereafter referred to as AB 32; Senate Bill 375, the Sustainable Communities and Climate Protection Act of 2008 (Steinberg), hereafter referred to as SB 375; Senate Bill 743, the Transit Oriented Development Act of 2013 (Steinberg), hereafter referred to as SB 743). The AB 32 Scoping Plan includes sections on local government and the importance of local action to help achieve statewide climate goals. Additionally, the Safeguarding California Plan, Cal-Adapt, Climate Change Handbook for Regional Water Planning, and the California Climate Adaptation Planning Guide provide guidance for resilience and adaptation efforts. OPR's GPG recommendations focus on how the general plan can achieve GHG emissions reductions, increase resiliency to climate change impacts, and lead to healthier and more prosperous communities.

A general plan allows a community to envision its future growth and development







Image by Urban Advantage, Ferrell Madden Lewis

2. **Economics**: Policies related to all elements of the general plan greatly affect economic opportunity, development, and stability. Decisions regarding land use and circulation have direct and indirect fiscal implications for local economies, and, in turn, economies of urban and rural centers affect the health, climate, and equity of communities. As with all general plan topics, even if addressed in a separate section, economic development must link and integrate with other elements in order to be successful.

3. **Healthy Communities**: In 2012 the Governor issued Executive Order B-19-12 and created the Governor's Let's Get Healthy California Task Force. Chronic disease, such as obesity, diabetes, cancer, heart disease, and asthma affect quality of life and productivity. In addition, social, economic, and environmental factors where people live, work, and play affect their health and well-being. The Task Force identified

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the creation and expansion of healthy communities to be one of three major focus areas for the promotion of overall health improvement. Because planning offers one important way to improve the community's health, OPR offers recommendations for jurisdictions interested in incorporating health-supporting policies into their general plan.

4. **Equitable Opportunities**: Planning decisions affect the entire community, and the entire community must be allowed equal access to the public process (Gov Code § 11135). From determining proximity to localized noise or air pollution, to providing healthy grocery options, to creating access to employment and education opportunity, planning and policy affect everyone. Incorporating equity into all aspects of planning will ensure that residents of a city or county benefit from reduced GHG emissions, climate change adaptation policies, active transportation options, and healthy communities with access to economic opportunity for all. OPR's recommendations for equity incorporate statutory requirements for environmental justice guidance (Gov Code § 65040.12(c)) into an expanded focus on equity throughout the general plan.

Additionally, based on statewide goals, the update includes model guides and best practices related to infill development, renewable energy, and mitigation of agricultural land conversion.

Readers should note that the recommended policies are simply recommendations, intended to provide a starting point from which local governments can craft unique policies reflecting the priorities and circumstances of their communities. The GPG aims to create a suite of tools for communities to utilize in updating their general plans. By providing information, resources, and data on statutory requirements as well as non-statutory considerations relevant to planning, the GPG can help diverse community members work together towards a shared vision for their future growth.

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2

A Vision for Long-Range Planning

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

"A city is not gauged by its length and width, but by the broadness of its vision and the height of its dreams."

—Herb Caen

Why the General Plan Matters

California state law requires each city and county to adopt a general plan "for the physical development of the county or city, and any land outside its boundaries which in the planning agency's judgment bears relation to its planning" (Gov. Code § 65300). The general plan expresses the community's development goals and embodies public policy relative to the distribution of future land uses, both public and private. The California Supreme Court has described general plans as the "charter to which [zoning] ordinance[s] must conform", but the general plan extends far beyond zoning and land use (Lesher Communications, Inc. v. City of Walnut Creek (1990) 52 Cal.3d 531, 540).

According to Litman's Land Use Impact Costs of Transportation, studies show that land use decisions affect transportation, electricity, and water demand. Each planning decision affects multiple objectives beyond the immediate outcomes. General plans benefit local communities by promoting better projects, streamlined processes, integrated planning, and improved access and use of available resources.

A general plan allows a community to create a vision for its future.



Image by Urban Advantage, Ferrell Madden Lewis

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Furthermore, local policies affect building decisions, energy efficiency, and the development of infrastructure.

A local general plan should start with a shared community vision that will help set priorities throughout the planning process, and inform decision makers about community values. Creating a community vision may include the following:

- Expanded outreach to all members of the community, including public agencies and local residents
- Looking back to identify past challenges and accomplishments
- Examining current data and emerging data trends
- Considering future issues, challenges, and goals

With continued input and engagement from community members and decision makers, the processes of preparing, adopting, implementing, and maintaining the general plan serves to:

- Provide a basis for local government decision-making, including decisions on development approvals and exactions
- Provide residents with opportunities to participate in the planning and decision-making processes of their communities
- Inform residents, developers, decision makers, and other cities and counties of the ground rules that guide development within a particular community

Engaging the community in multiple ways ensures a strong general plan. For example, the City of Chula Vista held numerous community workshops to craft their vision statement, and used it to inform future goals and policies. The City of Chino engaged with the community at existing events in developing its vision statement, traveling to farmers markets, events, and local groups before meeting with city officials to craft the final statement. Chino also used the vision statement to inform the land use diagram included in their general plan, ensuring the community's values were reflected in the future growth of the city. Chapter 3 discusses community engagement in more detail.

Local General Plans and Statewide Goals

Cities and counties are critical partners in helping to achieve statewide goals. The U.S. Census Bureau projects California's population to reach 50 million residents by 2050. While the largest population will continue to be in Los Angeles County and the San Francisco Bay Area, the largest growth rates are expected to be in the Inland Empire, Sacramento Region, and San Joaquin Valley. Additionally, California's demographic diversity continues to increase, making California a minority-majority state, with residents from over sixty nations, speaking dozens of languages. Almost half of California's residents will identify as Hispanic by 2050, despite decreased immigration from Latin America. Increased immigration from Asia and the Middle East will continue to diversify communities and increase the foreign born percentage of Californians to nearly thirty percentl. The overall state economy will continue to grow, but numerous factors will affect how individuals and families benefit. Shifts in demand for labor, regional disparities, and increasing retirement rates among older residents will create differing needs throughout the state. As all Californians live longer, an increase in elderly and middle age residents will increase and shift demands on infrastructure such as housing and education, and resources including transportation and social services. Accommodating this growth equitably while

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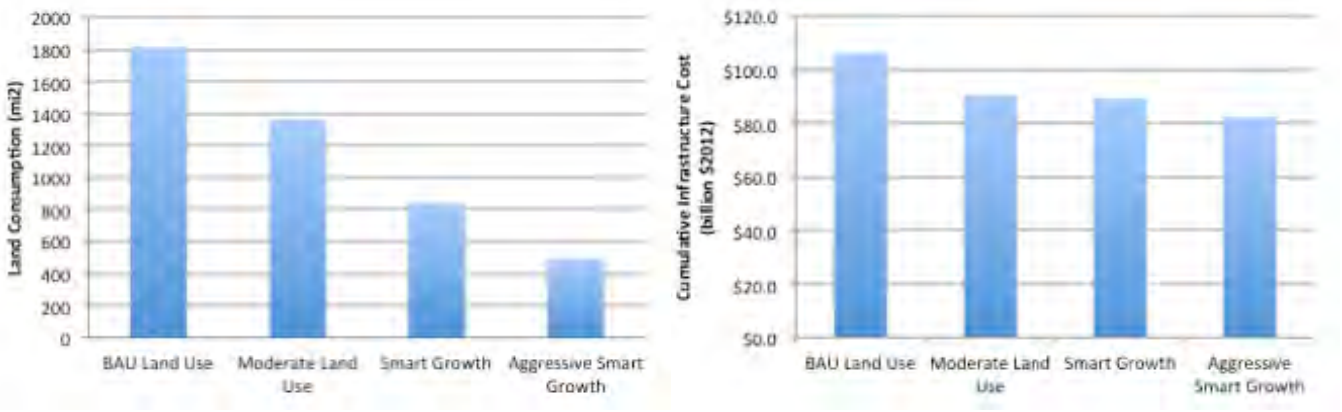
protecting the state's environment, supporting equitable development and a strong economy, and preserving the state's natural and working landscapes – all in the context of climate change – will be critical in the coming decades. Cities and counties are key partners in achieving these goals at both the state and local level.

Decisions made at the local level have a real impact on, for example, statewide greenhouse gas emissions. Local actions help determine how vulnerable the community and the state will be in the face of a changing climate and, alternatively, how resilient they can be by addressing such vulnerabilities. In many cases, the impacts of these decisions can be measured. For instance, tools like Urban Footprint can estimate health, infrastructure, services and other costs associated with various land use patterns. Measuring impacts and outcomes enables communities to weigh costs and benefits of new development and to grow in a manner consistent with community values.

> Quantifying outcomes can provide meaningful contrasts for general plan development. For example, the graphs below show the aggregate impacts of development decisions on land consumption and infrastructure costs, statewide.

Figure 3: Land Consumption and Infrastructure Costs Increase with Less Dense Development Patterns



These results come from analysis prepared by Calthorpe Associates for the state as a whole. City– and county–level analyses have yielded similar results. Current density patterns (BAU) and increasingly dense development expectations form the basis for the land use assumptions.

California's Planning Priorities

The 1978 Urban Strategy first articulated statewide planning priorities for California which were adopted in law in 2002. Briefly, the priorities are to

1. Promote infill development and rehabilitation and utilization of existing infrastructure, including water, sewer, and transportation.
2. Protect the state's natural and working lands, including agricultural land, lands of cultural and historic significance, wetlands, and wildlands.
3. Develop in an efficient manner that limits sprawl and minimizes costs to taxpayers.

These priorities are intended to inform planning and investment at all levels of government.

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2

California's Planning Priorities

The state planning priorities, which are intended to promote equity, strengthen the economy, protect the environment, and promote public health and safety in the state, including in urban, suburban, and rural communities, shall be as follows:

(a) To promote infill development and equity by rehabilitating, maintaining, and improving existing infrastructure that supports infill development and appropriate reuse and redevelopment of previously developed, underutilized land that is presently served by transit, streets, water, sewer, and other essential services, particularly in underserved areas, and to preserving cultural and historic resources.

(b) To protect environmental and agricultural resources by protecting, preserving, and enhancing the state's most valuable natural resources, including working landscapes such as farm, range, and forest lands, natural lands such as wetlands, watersheds, wildlife habitats, and other wildlands, recreation lands such as parks, trails, greenbelts, and other open space, and landscapes with locally unique features and areas identified by the state as deserving special protection.

(c) To encourage efficient development patterns by ensuring that any infrastructure associated with development, other than infill development, supports new development that does all of the following:

(1) Uses land efficiently.

(1) Is built adjacent to existing developed areas to the extent consistent with the priorities specified pursuant to subdivision (b).

(1) Is located in an area appropriately planned for growth.

(1) Is served by adequate transportation and other essential utilities and services.

(1) Minimizes ongoing costs to taxpayers

As of this update, the state is in the midst of a severe drought, continues to lose agricultural lands due to conversion, and continues to face severe air quality challenges in several regions. At the same time, since the 1970s, California has introduced a robust suite of environmental goals and policies that will help combat these issues. These policy tools have and will continue to help improve the quality of the state's environment. Most notably, the suite of policies that California has adopted to address climate change will touch on nearly every facet of the state's development.

California's Climate Change Policy and Local Communities

The effects of climate change and pollution pose great risks for Californians, including more frequent and more intense forest fires, more air pollution, deadly heat waves, a significant reduction in snowpack and state water supplies, sea level rise and erosion along California's long coastline, and billions of dollars in damage to our agricultural, tourism, recreation, and other industries. These impacts have the potential to be hugely disruptive to how local governments operate.

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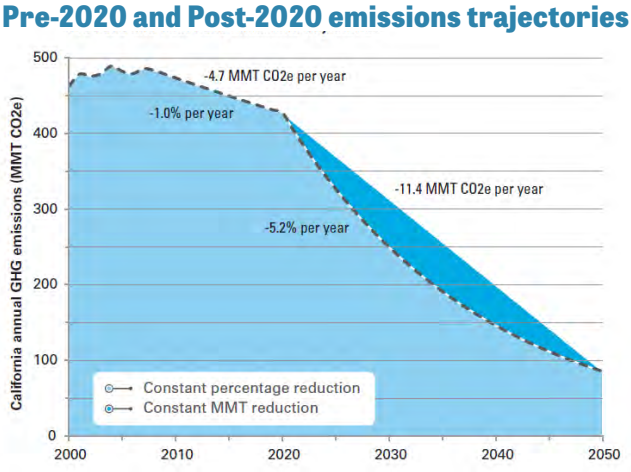
Executive Order S-03-05 established greenhouse gas (GHG) emissions reduction targets for the state. Subsequently, AB 32 (2006) established a comprehensive program to achieve quantifiable, cost–effective reductions of greenhouse gases on a scheduled basis. Additional legislation supported AB 32, including SB 375 (2008), which aligned land use and transportation with environmental goals locally through Sustainable Community Strategies (SCS), and Executive Order B-30-15, which establishes 40 % below 1990 levels by 2030 as an intermediate target towards the 2050 goals. The 2014 revised AB 32 scoping plan highlights the importance of local government in reducing emissions to achieve long–term statewide goals. In order to achieve California's 2050 emissions goal of 80% below 1990 levels, emissions must decline several times faster than the rate needed to reach the 2020 emissions limit. The 2017 revised scoping plan, per SB 32 and SB 197, is being developed to include 2030 targets and additional local guidance.

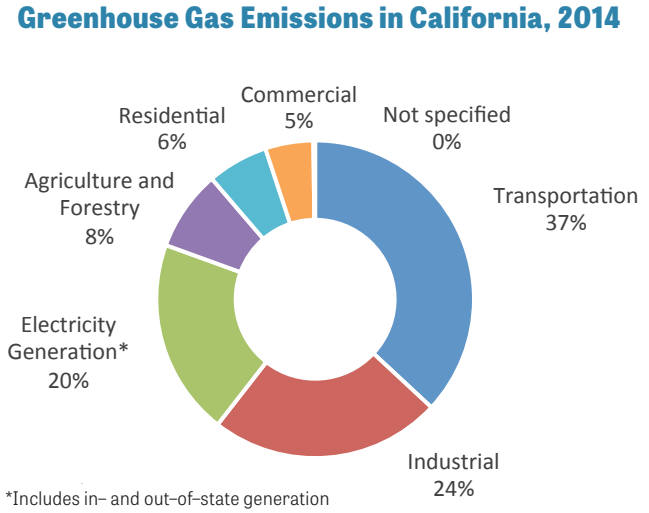
Transportation and electricity generation are the largest sources of the state's GHG emissions. State policies focus on reducing transportation emissions through cleaner fuels and promoting alternative access to destinations (e.g., walking, biking, transit, and carpooling). The state's goals for renewable energy and energy efficiency will also reduce emissions from electricity generation.

Figure 4: GHG Emissions Reductions Will Need to Occur at a Faster Rate to Achieve the State's 2050 GHG Emissions Reduction Target of 80 percent below 1990 levels, as established by EO S-3-05



Source: Data from California Air Resources Board

Figure 5: GHG Emissions in California Are Dominated by Emissions from Transportation and Electricity Generation (Data from: California Air Resources Board)



General Plan Basics

The purpose of a general plan is to guide land use planning decisions. Under state law, subdivisions, capital improvements, development agreements, and many other land use actions must be consistent with the adopted general plan. In counties and general law cities, zoning and specific plans are also required to conform to the general plan. In addition, preparing, adopting, implementing, and maintaining the general plan serves to identify the community's land use, circulation, environmental, economic, and social goals and policies as they relate to future growth and development.

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2

The City of Fresno engaged in a robust four-year process to update its general plan, which focuses on encouraging new development within the existing footprint of the city. Citing past mistakes that left some neighborhoods behind and hoping to reverse sprawl patterns, the City used Rapid Fire – the predecessor to Urban Footprint – to engage the entire community in creating their new plan for future growth.

Source: www.fresno.gov



General Plan Elements

In statute, the general plan is presented as a collection of "elements," or topic categories (Gov. Code §65302). These elements are briefly summarized below. Examples from cities and counties in the state are embedded in the GPG with links throughout the document.

- **Land Use**: designates the type, intensity, and general distribution of uses of land for housing, business, industry, open space, education, public buildings and grounds, waste disposal facilities, and other categories of public and private uses.
- **Circulation**: correlates with the land use element and identifies the general location and extent of existing and proposed major thoroughfares, transportation routes, terminals, and other local public utilities and facilities.
- **Housing**: assesses current and projected housing needs for all economic segments of the community. In addition, the housing element embodies policies for providing adequate housing and includes action programs for that purpose. By statute, the housing element must be updated every, five or eight years, according to a schedule set by the Department of Housing and Community Development (HCD).
- **Conservation**: addresses the conservation, development, and use of natural resources, including water, forests, soils, rivers, and mineral deposits.
- **Open Space**: details plans and measures for the long-range preservation and conservation of open-space lands, including open space for the preservation of natural resources, the managed production of resources, agriculture, outdoor recreation, and public health and safety.
- **Noise**: identifies and appraises noise problems within the community and forms the basis for land use distribution determinations.
- **Safety**: establishes policies and programs to protect the community from risks associated with seismic, geologic, flood, and wildfire hazards, as well as from other concerns such as drought.
- **Environmental Justice** (if completed as a stand-alone element): identifies objectives and policies to reduce pollution exposure, improve air quality, promote public facilities, improve food access, advance access to housing, and increase physical activity in identified disadvantaged communities.

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- **Air Quality**: establishes policies and programs to reduce impacts to air quality in the San Joaquin Valley Air Pollution Control District. Air quality considerations are also required for cities and counties who are required to include an environmental justice element in their general plans, and are optional elements in other areas of the state.
- **Other optional elements, identified by community**: health, equity, community development, water, climate change, and resiliency are some examples of additional elements that can be added to general plans or used to frame general plans.

The level of discussion given to each issue in the general plan depends upon local conditions and the relative local importance of that issue. When a city or county determines that an issue specified in the law is not locally relevant, the general plan may briefly discuss the reason for that decision but does not otherwise have to address that issue (Gov. Code § 65301). A jurisdiction may choose to combine elements as appropriate for local context.

A general plan may also include other topics of local interest. In addition to the mandatory elements, a city or county may adopt any other elements that relate to its physical development (Gov. Code § 65303).

Once adopted, these optional elements become an integral part of the general plan with the same force and effect as the mandatory elements. Accordingly, zoning, subdivisions, public works, specific plans, and other areas that must be consistent with the general plan must also be consistent with any optional elements. Likewise, the practice of developing stand–alone climate action, adaptation, or emissions reduction plans , if properly linked to the general plan, must also be internally consistent if used to support or augment policy, programs and implementation associated with the general plan.

Common topics that might be addressed in an additional, separate element include air quality (outside the San Joaquin Valley), climate change, capital improvements, community design, healthy communities, economic development, energy, water, and watershed planning. Depending upon the format a jurisdiction decides to use for its general plan, these topics may also be crosscutting themes, addressing required and optional elements throughout each chosen section.

An optional element may indicate how a local government will apply its existing police power or other authority to address the issues included in the optional element. For example, a historic preservation element may lay the foundation for historic district regulations or participation in the California Main Street Program, or a strategic fire prevention planning element could identify wildfire hazard areas, control new development within those areas, and provide the basis for zoning, subdivision, and brush clearance ordinances intended to minimize fire hazards.

In the statutory descriptions of the elements, a number of issues appear in more than one element. In order to minimize redundancies or internal conflicts in the general plan, combining elements or organizing the plan by issue often makes practical sense. This idea is explored further in Chapter 1.

A number of state and federal laws, such as the Infrastructure Planning: Priorities and Funding Act of 2002 the Surface Mining and Reclamation Act of 1975, the California Endangered Species Act of 1970, and others can affect the content of the general plan. These laws are discussed in detail throughout these guidelines.

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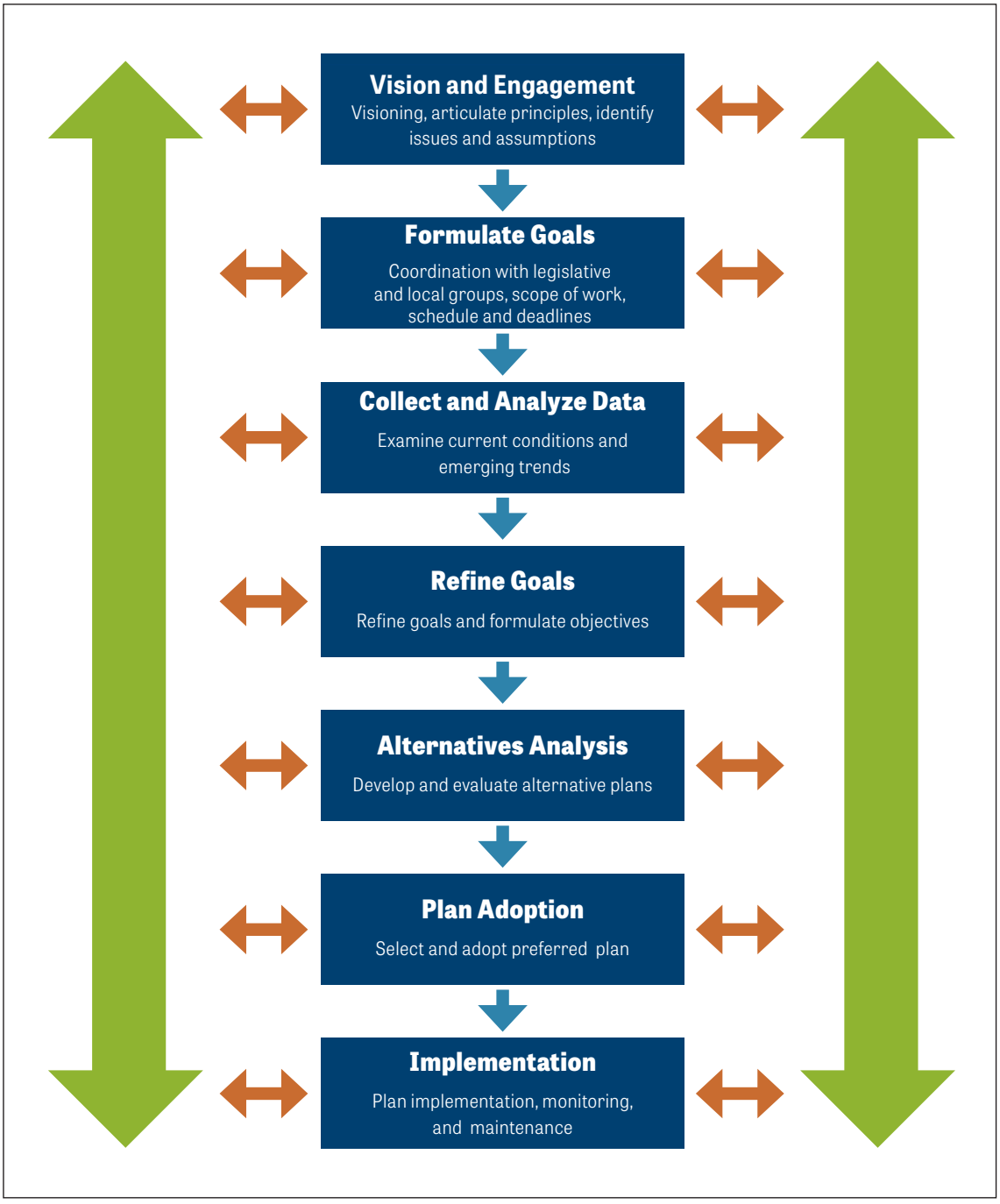
General Plan Flow Chart



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Placemaking and Urban Design

While the general plan land use map is two dimensional, placemaking takes land use policies into a three-dimensional realm by focusing on what a place will actually look like when it is built. Great districts, corridors, and sites contribute to the vitality and quality of life of a community by considering carefully the placement of buildings, the relationship of buildings to one another and to public spaces, and the design and quality of sidewalks, open spaces, and other elements of the public realm. Many communities address placemaking and urban design through an optional element such as an urban design element. However, these policies can also be incorporated into a land use element as urban form is closely related to the location of land uses and land use densities and intensities. Urban design considers the relationship between land use and the image or character of the built environment with the ultimate goal of attaining a strong sense of place. Placemaking re-envisions a community's assets, spaces, and surroundings and their relationships to each other. Using extensive public participation, placemaking attempts to create public spaces that are useful, attractive, and utilized extensively by the community, who consequently feel ownership and pride in the space.

Form based codes may be one useful tool for achieving the placemaking and urban design visions of the community. Functioning as both zoning designations and design standards, form based codes focus on creating places by examining building types, standards, sidewalks, landscaping, and other relevant issues. The form based code approach is applicable to many types of communities and can be especially meaningful in suburban contexts seeking to instill a stronger sense of place in sprawl environments and in areas focusing on infill development. Placemaking is also important to carefully plan for the public realm.

Several cities have taken varied approaches to incorporate urban design and placemaking into their general plans and land use elements.

- The City of Fullerton developed The Fullerton Vision to identify 12 distinct focus areas within which to concentrate potential change through community-led planning processes.
- The City of Sacramento's Land Use and Urban Design chapter focused on creating complete neighborhoods, distinct and memorable places, and excellence in the design of the city's form and structure through development standards and clear design direction.
- The City of Tracy used a community character element in its general plan to develop urban design principles including human-scale design, community focal points, and visual landmarks and entryways.
- The City of Brea community development element contains an urban design plan with policies for creating a sense of place and policies for creating connections. The plan also includes a Public Realm Urban Design Palette which establishes direction for city-sponsored improvements of public property, including city gateways, landscape corridors, neighborhood linkages, and public plazas.

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2

Criteria for the General Plan

General Plan criteria must include comprehensiveness, internal consistency, and long-term perspective, which are discussed below.

Comprehensiveness

Every city and county must adopt "a comprehensive, long-term general plan" (Gov. Code § 65300). The general plan must cover a local jurisdiction's entire planning area and address the broad range of issues associated with a city's or county's development. The overall general plan may also include linkages to regional plans, incorporating, where appropriate, regional policy and context.

Geographic Comprehensiveness

The plan must cover the territory within the boundaries of the adopting city or county as well as "any land outside its boundaries which in the planning agency's judgment bears relation to its planning" (Gov. Code § 65300). For cities, this means all territory within the city limits, both public and private. Counties must address all unincorporated areas.

When establishing its planning area, each city should consider using its sphere of influence as a starting point, and building off of that area based on factors such as its location in a watershed. The Local Agency Formation Commission (LAFCO) in every county adopts a sphere of influence for each city to represent "the probable physical boundaries and service area" of that city (Gov. Code § 56076). Although there is no direct requirement that the sphere of influence and the planning area match, the former provides a convenient measure of the city's region of interest.

When making its general plan, a county should consider the general plans of every city within the county itself as well as adjacent jurisdictions even if they are in a different county.

In addition, since issues are not confined to political boundaries, the law provides for planning outside of the jurisdiction's territory. Cooperative extraterritorial planning can be used to manage groundwater resources; guide appropriate development within specific geographic context (such as areas that may be affected by sea level rise as a result of climate change) and the orderly and efficient extension of services and utilities; ensure the preservation of open space, agriculture, and resource conservation lands; and establish consistent standards for development in the plans of adjoining jurisdictions.

Cities and counties should work together to delineate planning areas and may establish formal agreements for processing development proposals. As urbanization occurs and adjoining cities expand, the potential for conflict between cities competing for the same lands increases. Intercity cooperation in establishing planning areas can proactively help to avoid such disputes and avoid additional costs.

Regional Context

Viewing the local general plan in its regional context is important. Traditionally, the concept of "community" encompassed only a local entity—the city or county. With the growing interdependence of local governments, joint planning and procurement, and the increased prevalence of important issues that transcend local boundaries such as transportation, provision of energy, climate change, air quality, water supply and management, and floodplain and flood risk management, it is becoming more important to consider the regional perspective. Cities and counties should coordinate plans regionally when possible and appropriate, in

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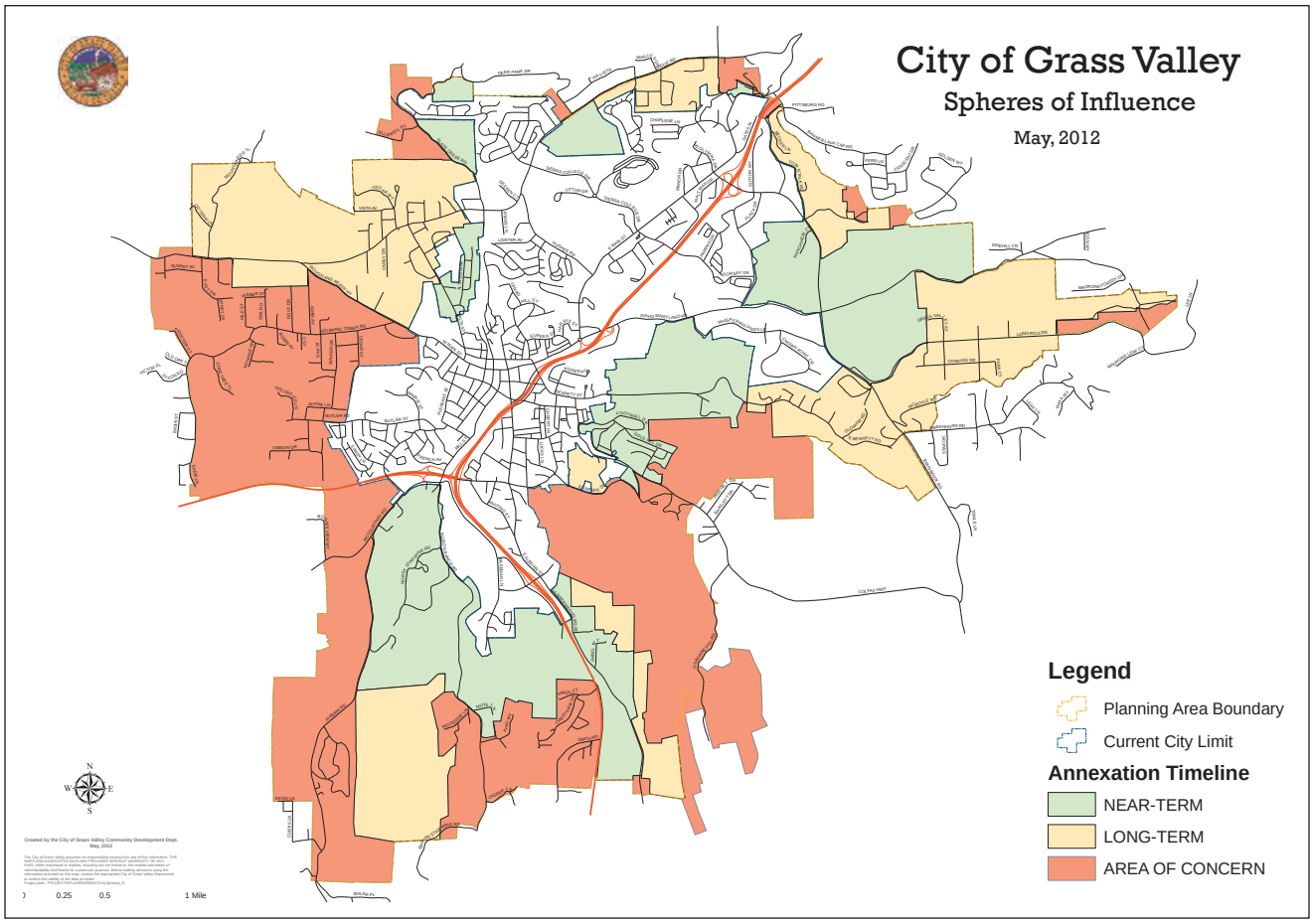
Figure 6: Map Showing Spheres of Influence for Grass Valley, CA



www.cityofgrassvalley.com/content/maps/sphere-influence-map

alignment with their sustainable community strategies, to work towards regional goals. For example, identifying risks from natural hazards and climate change may present opportunities for integrated resource management that extend across jurisdictional boundaries. Using available data –such as watershed-based floodplain management, mapped earthquake faults, or high fire-hazard areas, integrated water management plans (and new requirements for groundwater sustainability plans), sustainable community strategies, hazard mitigation plans, local coastal programs and other planning documents – will improve planning and expand opportunities. Each local planning agency should coordinate its general plan with regional planning efforts as much as possible. The general plan process allows local jurisdictions to integrate requirements with opportunities provided by multiple regional documents and initiatives.

The legislature has mandated consideration of certain regional impacts, such as regional housing needs, in the general plan. Local general plans should recognize the city or county's regional role so as to better satisfy regional needs, meet federal and state standards, and coordinate the location of public facilities. Accordingly, city planners should, like the City of Fullerton, include a

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discussion of the extent to which the general plan's policies, standards, and proposals correspond to regional plans and the plans of adjoining communities. A city or county may need to reexamine its own general plan when its neighbors make important changes to their plans.

Issue Comprehensiveness

While a general plan must address a broad range of issues, the plan should focus on those issues that are relevant to the planning area (Gov. Code§ 65301(c)). The plan must address the jurisdiction's physical development, such as general locations, appropriate mix, timing, and extent of land uses and supporting infrastructure. The broad scope of physical development issues may range from appropriate areas for building factories to open space for preserving endangered species. This may include regional issues in addition to the more localized issues described in the planning statutes.

Land use decisions not only have physical and environmental impacts, but also social and economic consequences, especially for vulnerable and disadvantaged communities. Recognizing these concerns in the general plan can help cities and counties plan for or mitigate them. Social and economic issues may be discussed within the context of the mandatory elements, such as environmental justice, housing, and land use, or in additional optional elements such as economic development or community health. Both methods are discussed in the GPG.

Internal Consistency

Internal consistency requires that no policy conflicts, either textual or diagrammatic, can exist between the components of an otherwise complete and adequate general plan such as internally referenced external documents like a climate action plan or a local energy assurance plan (Gov. Code § 65300.5). Different policies must be balanced and reconciled within the plan. The internal consistency requirement has five dimensions, described below.

Equal Status Among Elements

All elements of the general plan have equal legal status. In Sierra Club v. Board of Supervisors of Kern County (1981) 126 Cal.App.3d 698, two of Kern County's general plan elements, land use and open space, designated conflicting land uses for the same property. A provision in their general plan text reconciled this and other map inconsistencies by stating that "if in any instance there is a conflict between the land use element and the open–space element, the land use element controls." The court of appeals struck down this clause because it violated the internal consistency requirement under Government Code section 65300.5. This holding affirmed the principle that no element is legally subordinate to another; the general plan must resolve potential conflicts among its elements through clear language and policy consistency.

Consistency Between Elements

All elements of a general plan, whether mandatory or optional, must be consistent with one another. *In Concerned Citizens of Calaveras County v. Board of Supervisors* (1985) 166 Cal.App.3d 90, the county land use element contained proposals expected to result in increased population. The circulation element, however, failed to provide feasible remedies for the predicted traffic congestion that would follow. The county simply

> **"In construing the provisions of this article the Legislature intends that the general plan and elements and parts thereof comprise an integrated, internally consistent and compatible statement of policies for the adopting agency."**
>
> (Gov Code § 65300.5)

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stated that it would lobby for funds to solve the future traffic problems. The court held that this vague response was insufficient to reconcile the conflicts.

Housing element law requires local agencies to adopt housing element programs that achieve the goals and implement the policies of the housing element. The element must identify the means by which consistency will be achieved and maintained with other general plan elements, including land use (Gov. Code § 65583(c)).

A city or county may incorporate by reference all or a portion of another jurisdiction's plan, a regional plan, or its own subsidiary plan, such as a climate action plan, into its general plan. When doing so, the city or county should make sure that any materials incorporated by reference are consistent with the rest of its general plan.

Consistency Within Elements

Each element's data, analyses, goals, policies, and implementation programs must be consistent with and complement one another. Established goals, data, and analysis form the foundation for any ensuing policies. For example, if one portion of a circulation element indicates that county roads are sufficient to accommodate the projected level of traffic while another section of the same element describes a worsening traffic situation aggravated by continued subdivision activity, the element is not internally consistent (*Concerned Citizens of Calaveras County v. Board of Supervisors* (1985) 166 Cal.App.3d 90)

Area Plan Consistency

All principles, goals, objectives, policies, and plan proposals set forth in an area or community plan must be consistent with the overall general plan.

The general plan should explicitly discuss the role of area plans if they are to be used. Similarly, each area plan should discuss its specific relationship to the general plan.

Airport land use compatibility plans must also be consistent with the general plan. Where appropriate, climate action plans should also be consistent with the general plan. Climate action plans can be created concurrently with or closely following a general plan update. However, if a local agency's resources do not allow for concurrent preparation of a general plan update and the climate action plan, general plans may be amended later to integrate all or part of the climate action plan.

Text and Diagram Consistency

The general plan's text and its accompanying diagrams and maps are integral parts of the plan. They must be in agreement. For example, a conflict exists if a general plan's land use element diagram designates residential development in an area where the text describes the presence of prime agricultural land and written policies to preserve agricultural land or open space. The plan's text and diagrams must be reconciled, because "internal consistency requires that general plan diagrams of land use, circulation systems, open-space and natural resources areas reflect written policies and programs in the text for each element."

Long – Term Perspective

Since the general plan affects the welfare of current and future generations, state law requires that the plan take a long-term perspective (Gov. Code § 65300). The general plan projects conditions and needs into the future as a basis for determining objectives. It also establishes long-term policy for day-to-day decision-making based upon those objectives.

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The time frames for effective planning vary among issues. The housing element, for example, specifically involves time increments of five or eight years, according to the HCD schedule. Sewer, water, and road systems are generally designed with a 30- to 50-year lifespan. Capital improvement planning is typically based upon a five- or seven-year term. Economic trends may change rapidly in response to outside forces. Climate change is affecting local governments now, but longer term planning should anticipate the significant changes in the environmental setting associated with a changing climate as indicated by the best available science.

Differences in time frame also affect the formulation of general plan goals, objectives, policies, and implementation measures. Goals and objectives are longer term, specific policies are shorter in their outcomes, and implementation programs have the shortest span because they must quickly respond to the demands of new funding sources, the results of their own activities, and the jurisdiction's immediate needs and problems.

Most jurisdictions have selected 20 years as the horizon for the general plan. The horizon does not mark an end point but rather provides a general context in which to make shorter-term decisions. The local jurisdiction may choose a time horizon that serves its particular needs including a later horizon year time frame to address long term issues like climate change and land use. Planning is a continuous process; as such, the general plan should be reviewed regularly, regardless of its horizon, and revised as new information becomes available and as community needs and values change. With easier access to data, cities and counties have the opportunity to evaluate their general plans more often, link directly to responsible agencies, or monitor their process through data analysis or public dashboards. The City of Sacramento, for example, conducts annual reviews of their general plan as well as five-year updates to the document based on the annual assessments. These regular reviews and updates reduce the potential cost of a comprehensive rewriting of their general plan, while keeping it timely and relevant to community needs.

Considerations for General Plans

Area Plans, Community Plans, and Specific Plans

Area and community plans are part of the general plan. A specific plan is a tool for implementing the general plan but is not part of the general plan. The following paragraphs look briefly at each of these types of plans. In addition to consistency between plans, general plans must also be consistent with airport land use compatibility plans in specified regions, unless overridden by a two-thirds vote of the local government, pursuant to Public Utilities Code section 21676.

"Area plan" and "community plan" are terms for plans that focus on a particular region or community within the overall general plan area. A resolution is required to adopt an area or community plan as an amendment to the general plan, in the manner set out in Government Code section 65350. Such plans refine the policies of the general plan as they apply to a smaller geographic area and are implemented by ordinances and other discretionary actions, such as zoning. The area or community plan process also provides a forum for resolving local conflicts. Large cities and counties where there are a variety of distinct communities or regions commonly use these plans.

As discussed earlier, an area or community plan must be internally consistent with the general plan. To facilitate such consistency, the general plan should provide a policy framework for the detailed treatment of specific issues in the various

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area or community plans. Ideally, to simplify implementation, the area or community plans and the general plan should share a uniform format for land use categories, terminology, and diagrams.

Each area or community plan need not address all of the issues identified by Government Code section 65302 when the overall general plan satisfies these requirements. For example, an area or community plan need not discuss fire safety if the jurisdiction–wide plan adequately addresses the subject and the area or community plan is consistent with those policies and standards. While an area or community plan may provide greater detail regarding policies affecting development in a defined area, adopting one or a series of such plans does not substitute for regular updates to the general plan. Many of the mandatory general plan issues are most effectively addressed on a jurisdiction–wide basis that ties together the policies of the individual area or community plans.

A specific plan is a hybrid that can combine policy statements with development regulations (Gov. Code § 65450). It can be used to address the development requirements for a single project such as urban infill or a planned community. As a result, its emphasis is on concrete standards and development criteria. Its text and diagrams will address the planning of necessary infrastructure and facilities, as well as land uses and open space. In addition, it will specify those programs and regulations necessary to finance infrastructure and public works projects. A specific plan may be adopted either by resolution, like a general plan, or by ordinances such as zoning.

Specific plans must be consistent with all facets of the general plan, including the policy statements. In turn, zoning, subdivisions, and public works projects must be consistent with the specific plan (Gov. Code § 65455). Once a specific plan has been adopted, later projects may not require additional review (Cal. Code Regs., tit. 14, § 15182). The publication *A Planner's Guide to Specific Plans*, by the Governor's Office of Planning and Research (OPR), provides further information on relationships between plans.

Adoption of Another Jurisdiction's General Plan and Joint Adoption

A city or county may adopt part or all of a general plan of another public agency, or adopt a functional plan –such as a regional transportation plan, climate action plan or sustainable community strategy –prepared by a special district, regional planning agency, or some other public agency (Gov. Code § 65301(a)).

One of the benefits of this approach is that it eliminates duplication of effort in collecting data for more technical elements. A city and county may jointly prepare and separately adopt an entire general plan or individual elements within a general plan. Although joint adoption of another jurisdiction's plan or elements may be advantageous, a city or county remains solely responsible for the legal adequacy of its general plan. The other jurisdiction's plan and elements whether jointly prepared or not must be sufficiently detailed to address the concerns of the adopting agency and to provide adequate coverage of the issues required in the Government Code. A plan or element that is jointly prepared or adopted from another jurisdiction's general plan has the same legal standing as the rest of the adopting agency's general plan and internal consistency requirements continue to apply. Similarly, discretionary zoning, subdivision, and capital improvement project decisions must be consistent with the joint plan or element. One example is Government Code section 65302(g), which specifically provides that a city may adopt the county's safety element if the county's element "is sufficiently detailed and contains appropriate policies and programs for adoption by a city."

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Funding a General Plan

Updating a general plan can be a costly exercise. The cost of preparing or revising the general plan will vary tremendously with the scope of the program and the jurisdiction's circumstances. A new plan or a comprehensive revision will be much more costly than a general plan amendment. For most jurisdictions, preparing and maintaining the general plan is a general fund expense. The availability of general purpose planning grants is limited. There are, however, federal and state funds for particular planning issues, such as housing, transportation, and habitat. These planning processes can be incorporated into the general plan process in order to leverage resources.

The cost of a general plan amendment associated with a particular development is typically passed on to the developer. Some jurisdictions attempt to recoup the costs of comprehensive updates in a similar manner. In 2002, the Legislature changed state law to allow development fees to include "costs reasonably necessary to prepare and revise the plans and policies that a local agency is required to adopt before it can make any necessary findings and determinations" (Gov. Code § 66014). This change makes it clear that an update of the general plan and related planning documents may be a recoverable expense.

Potential rotating sources of funding for portions of the general plan include:

- Choice Neighborhoods Planning Grants (US HUD)
  - » Grants for planning transformation of housing and surrounding built environment
- Brownfields Area-Wide Planning Grants (US EPA)
  - » Grants to research, plan and develop implementation strategies for an area affected by one or more brownfields
- TIGER Discretionary Grants (US DOT)
  - » Grants for local communities to plan and implement transportation in relation to other goals. Some annual cycles allocate funding for planning only.

The California Air Resources Board manages the Funding Wizard, which lists current funding opportunities for a broad variety of topics related to sustainabilty and climate change.

The US EPA Smart Growth National Funding Opportunities page houses a list of additional funding opportunities.

Despite the option to adopt another jurisdiction's general plan or to jointly adopt provisions of a general plan among multiple agencies, each adopting agency must retain its sole and independent authority to make amendments to its general plan unless the government approves a joint powers agreement. In *Alameda County Land Use Association c. City of Hayward* (1995) 38 Cal.App.4th 1716, the appellate court overturned a memorandum of understanding (MOU) adopted by Alameda County and the cities of Hayward and Pleasanton to specify general plan goals and policies regarding the "Ridgelands Area." The MOU provided that any amendment to the applicable sections by one jurisdiction would not be effective unless "parallel amendments" were approved by the other two. The court held this arrangement to be an impermissible divestment of the police power, restricting the individual agencies' legislative authority to amend their general plan.

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3

Community Engagement and Outreach

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

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"Cities (and counties) have the capability of providing something for everybody, only because, and only when, they are created by everybody."

—Jane Jacobs

Introduction

Robust and inclusive community engagement is a vital component of drafting and updating a general plan. State law requires the local planning agency to provide opportunities for the involvement of the community. Such involvement should include public agencies, public utility companies, community groups, and others through hearings or other appropriate methods (Gov. Code § 65351). The law also requires that a jurisdiction make a diligent effort to include all economic groups when drafting, adopting and implementing its housing element (Gov. Code § 65583(c)(8)). For the purposes of this chapter, the term "update" will refer to adoption of new general plans as well as amendments to existing plans.

By law, cities and counties must hold at least two public hearings before adopting a general plan: one by the planning commission and another by the legislative body (either the city council or the board of supervisors) (Gov. Code §65353(a), §65355). Government Code section 65351 requires that during the preparation or amendment of a general plan, the planning agency must provide opportunities for community input through public hearings and any other means the planning agency deems appropriate. Specifically, Government Code section 65351 requires that the planning agency shall "provide opportunities for the involvement of citizens, California Native American tribes, public agencies, public utility companies, and civic, education, and other community groups." Government Code section 65357 requires that copies of the documents adopting or amending a general plan, including the diagrams and text, shall be made available to the public. The courts have found a general plan amendment invalid when it was not made available to the public (*City of Poway v. City of San Diego* (1991) 229 Cal. App. 3d 847, 861). Most planning departments, however, conduct more than the minimal number of hearings. Many jurisdictions undertake extensive outreach that exceeds the minimum statutory requirements. The spectrum of community engagement ranges from informing and consulting the public to involving, collaborating, and ultimately empowering local communities.

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A general plan update affects every aspect and member of the community. Broad participation – particularly direct or representative participation of local residents – will help achieve desired outcomes.

Many entities have recognized the ability of strong community engagement to improve local conditions, inform policy, enhance equity, and create better program outcomes. Community engagement as a process can also help strengthen community bonds. Creating the opportunity for community dialogue throughout the general plan update – while sometimes challenging – can result in a more informed plan with more public support.

As stated in Chapter 2, a general plan should start with a community's vision, but community engagement should continue throughout the process, from visioning to adoption and implementation, depending on the scope and extent of the project. A thorough update for an average-sized city typically requires at least one full year or more. The nature of the outreach process and its intended outcomes will differ in each stage of the update:

1. **Exploration**: The initial stages of outreach allow stakeholders to identify community strengths, assets, priorities for future development, and areas for improvement and, thus, to start the process of formulating a vision for the future. In addition, the exploration phase presents an opportunity to educate residents about land use planning principles prior to more extensive outreach.
2. **Collaborative Action**: After establishing a general baseline for community goals, planners should engage collaboratively with partners, considering different options for reaching the set goals and aligning policy priorities to attain the vision.
3. **Decision Making**: Exploration and collaboration should identify various policy priorities necessary for achieving the general plan vision. These priorities should then inform a framework to help identify policy options, choose among them, and assemble a draft plan.
4. **Monitoring and Evaluation**: Community engagement should continue after the plan is drafted. Updates on successful policy implementation and implementation challenges can be an opportunity to elicit feedback and help evaluate progress toward community goals.

Web-based engagement

Propel Vallejo developed a concise electronically available web document to highlight various planning options based on community input. By synthesizing all of the available information, the city created scenarios to elicit more input and inform the decision-making stage.

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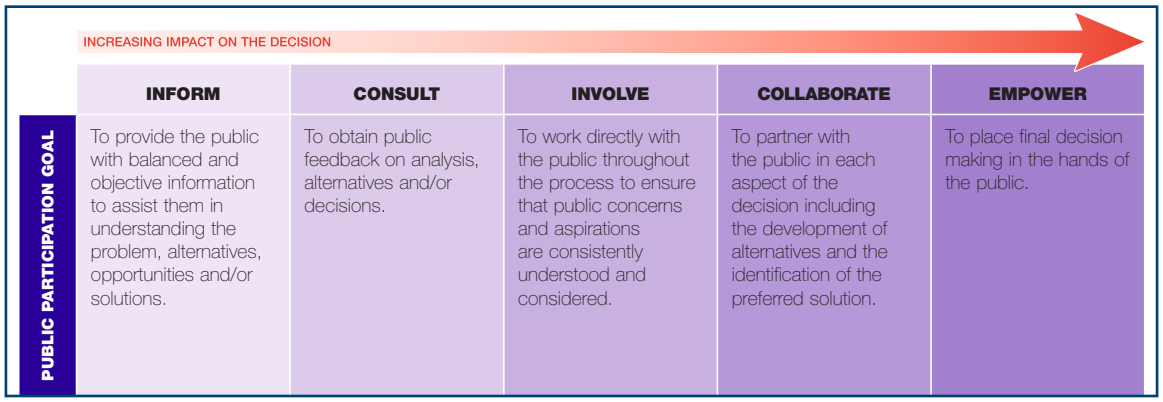
This chapter discusses various issues planning departments may consider when designing a public engagement process. It also provides tools and lists resources to inform the outreach process and ensure community involvement, input, and support for the general plan. As illustrated by Figure 7 below, statutory requirements only require limited meetings and fall into the "inform" area on the engagement spectrum. However, many jurisdictions recognize the benefits of a more involved process, and offer more extensive engagement and collaborative opportunities. Some communities have even conducted such an extensive engagement process that it moves towards "empower" in the engagement spectrum. The scenario land use planning and data informed process in the Fresno and the Vallejo plans are examples.

Figure 7: Public Engagement Spectrum



http://c.ymcdn.com/sites/www.iap2.org/resource/resmgr/foundations_course/IAP2_P2_Spectrum_FINAL.pdf

Process Design

Designing the outreach process before starting a general plan update helps ensure adequate input from various stakeholders. Unexpected events can occur during an update, including changes in elected leadership, funding, and staff. Having an outreach plan in place will help keep the process on track. In addition to any organized participation activities, the Brown Act requires that meetings of appointed advisory committees, planning commissions, and local legislative bodies be public. This section provides guidance for developing an outreach plan.

Establish an Outreach Strategy

Establishing a road map to plan public engagement efforts may help guide outreach throughout the process. Local jurisdictions vary tremendously throughout California, and engagement strategies will also vary based on local circumstances. Local communities should help define the outreach strategy most relevant to their needs. There are some issues to consider across planning for all areas, however. These include:

- Funding available for engagement activities, including translation services as needed
- Timeline for activities
- Expectation setting for stakeholders

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- Staff time, knowledge, and other expertise necessary to conduct outreach and education
- Communication tools available
- Process to ensure efforts are transparent, accessible, and fun
- Methods available to capture and record dialogue at outreach events
- Variety of meeting spaces
- Methods to continue engagement after the initial process has been completed

Some helpful tools in outreach include:

Oversight Responsibility

Assigning a staff member to oversee and be responsible for the engagement and outreach process will ensure dedicated attention to this important procedural step.

Advisory Committee or Board

Establishing a diverse advisory board or committee comprised of experts and community members can be helpful throughout the general plan update process. An advisory body can provide insight as to how to reach multiple populations, address potentially controversial issues, understand sensitive community needs, and represent a greater portion of the community. Establishment of the advisory body early in the process allows the board to inform the general outreach strategy from the beginning. An advisory board can also establish what community engagement will include for its own jurisdiction, and how community and stakeholder input is handled and communicated back to the public. Additionally, an advisory body can help build community capacity on issues such as data use and evaluation, as well as the historical context of land use planning. A manageably sized advisory body – around 10 people with an effective facilitator – should include multiple voices from the community and represent its diversity. General plan advisory board members should be drawn from the broad range of communities that exist within a jurisdiction to represent the varied interests that the public engagement process hopes to capture and to inclusively inform and enhance the general outreach strategy.

The following categories of advisory body members should be considered:

- Business leaders and/or representatives from chambers of commerce
- Representatives from the technology sector
- Local agency leaders, including water agencies, fire departments, law enforcement, parks and recreation, health officers, public works leads, and others
- Community development leaders
- Health leaders
- Representatives and advocates from various income groups, special needs populations, and neighborhoods in the jurisdiction

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- Multi-lingual representatives
- State and/or federal agency leaders, if the jurisdiction has a high proportion of public lands
- School representatives
- Faith-based community representatives
- Agriculture and food system representatives
- Environmental justice representatives
- Academics
- Local philanthropic organizations
- Individual community leaders

Survey of Overlapping Efforts

Multiple public engagement processes may be in progress simultaneously. For instance, outreach to solicit input on an application for grant funding may occur at the same time as outreach for an update of the general plan. Concurrent outreach processes can confuse participants; and this confusion poses a potential challenge for recruitment and involvement. Additionally, other public or private agencies – for example, departments of parks and recreation, hospitals, departments of public health, or non-governmental organizations – may be conducting outreach simultaneously. Increased awareness of ongoing efforts to gain input can help avoid overlapping or conflicting outreach efforts and might even allow outreach sessions to be combined.

Scale

Outreach for a county's general plan is a much larger undertaking than for a city's due to the broader catchment area. Stakeholders may also have less of a perceived stake in the process because county general planning is further removed from their local jurisdiction. Sharing how information will be incorporated into the planning process can relate the importance of participation and increase community input.

Partnership

All affected stakeholders should be represented in any public participation process. In a general plan process, this is the entire community. Partnership with various stakeholders also provides the opportunity to establish paid or unpaid volunteers to work within the community during the outreach process. Stakeholder groups in the general plan process may include:

- Community and neighborhood groups
- School districts, charter schools, and county offices of education
- County transportation commissions
- Utilities and public service providers of:
  - » Energy

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  - » Water, including water supply and wastewater. These entities involve flood/stormwater districts, regional water management groups, (groundwater sustainability agencies (GSAs), reclamation districts, etc.
  - » Telecommunications
  - » Waste
- Regional groups that can identify synergies with other regional efforts
- Affordable housing and special needs population representatives and advocates
- Non-profit and for-profit builders
- State and federal partners, as appropriate
- Educational institutions
- Industry and business
- Civic and community service organizations
- Non-governmental organizations
- Religious communities
- Existing boards and commissions, such as planning boards, departments of parks and recreation, etc.
- Other public agencies
- Topical experts:
  - » Groups working on climate change
  - » County health departments
  - » Environmental justice groups

  Tribal leaders

  Innovation or technology officers

  Local food groups

  Agricultural community members

Engaging more members of the community helps ensure a general plan that serves the needs of all residents



Source: http://www.futour.it/english/?p=48

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Tribal Consultation

When adopting or amending a General Plan, or designating open space, local governments must consult with California Native American tribes traditionally affiliated with the general plan area for the purpose of preserving or mitigating impacts to places, features, and objects described in Sections 5097.9 and 5097.993 of the Public Resources Code that are located within the city's or county's jurisdiction (Gov. Code § 65352.3, 65562.5). For more information about this consultation requirement, see the Governor's Office of Planning and Research's Supplement to the General Plan Guidelines, the Tribal Consultation Guidelines.

Cultural Considerations

Cultural differences may be present between and among professional groups as well as between and among community members. Reaching out to different professional groups and organizations not traditionally involved in planning may present additional challenges and opportunities. Understanding different interaction norms, priorities, levels of comfort with professional terminology, and expectations for project completion is essential to a productive process.

It is important to consider cultural diversity throughout the design of the community engagement process, including both overt differences, such as literacy level, socioeconomic status, and language, and more nuanced differences such as local history and cultural norms. Designing a process that is sensitive to all these considerations may help encourage broader, more equitable, and more informed participation.

To ensure equitable outreach, the following factors should be considered:

Literacy Level: It may be more difficult to reach out to Limited English Proficient (LEP) individuals, immigrant communities, or people with lower educational attainment. Planning agencies should design outreach materials and events to accommodate different literacy levels and provide background information when referring to complex concepts. Avoid the use of acronyms where possible.

Socioeconomic Status: Groups with lower socioeconomic status are often disproportionately affected by environmental hazards while facing greater barriers to participation in efforts to remediate them. These barriers may be addressed by considering factors such as location and timing of outreach, accessibility by public transportation, availability of childcare, and availability of food. Reviewing demographic information, such as the data available in the American Community Survey (ACS), can help identify the potential needs of each community.

Language: All communication should be done in the major languages spoken in the community. This includes any advertising and written background materials as well as live interpretation at key public events. Some documents, such as the draft general plan or the draft environmental impact report, may be infeasible to translate in their entirety. In such cases, the planning agency should consider translating an executive summary into the major languages spoken in the community. Interpreters should be available at meetings when it is clear that non–English speaking members of the community will be present. Many local non–profit organizations can provide minimal or low cost services for public benefit.

Age: Aging populations have specific needs that should be addressed to capture their input in the process. Considering time of day and location of events, as well as Americans with Disabilities Act (ADA) access to events and services available at the locations, will help include more elderly residents. The needs of young residents must also be considered, including outreach

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methods that benefit multiple groups such as social media and online platforms, location access and amenities, and innovative tools for discussion at events.

Local History: Certain communities may have participated in previous outreach efforts that did not result in change. Over time, either not being included or participating and/or not feeling utilized may affect future participation. Understanding the local context is helpful prior to beginning outreach. Fostering dialogue around racial inequities that have existed in the land use context can be challenging. Jurisdictions have started to engage with skilled facilitators to have conversations that advance participation and engagement opportunities. In particular, specific outreach to tribal governments should be considered.

Cultural Norms: California is rich in diversity. Each city and county across the state is comprised of different ethnic groups from around the world. From 1980-2010, the percentage of people of color, for example, increased from 33.4 percent to 59.8 percent, and is expected to increase to 73.3 percent by 2040. Some community members may not be as familiar with the democratic form of government and the ability to openly share opinions; others may be accustomed to different gender roles, or may be fearful to have conversations and dialogue recorded. It is hard to learn all of the cultural nuances for each group in the community, but working in partnership with local non-profits or other groups skilled at working across cultures can help ensure all groups are able to participate in a meaningful outreach process.

Outreach Structure

Community members and other stakeholders have many competing interests and limited time. Allowing different levels and types of involvement in the process can help foster participation. For example, going to places where people already gather—a community health center, a street fair, a cultural event, a public event at a local religious or community center, or a community event at a local school—may allow attendees to give input without a large time commitment. This is an especially helpful mode of outreach when looking for feedback on specific topics, such as health, equity, and environmental justice. Meeting stakeholders in locations they are familiar and comfortable with can also help to bridge cultural and trust gaps. Other more time-intensive activities, such as focus groups, charrettes, and workshops, can be made available for stakeholders who are interested in providing more in-depth input. The structure of outreach is also important for transparency and continuing communication throughout the process of a plan update. Ongoing information sharing can help maintain community relationships and build trust in the process, especially if culturally appropriate communication methods are used. Web-based communications, for example, may exclude stakeholder groups without regular access to the Internet, and should be supplemented by other methods for greater reach across groups.

Data

Data and data visualizations can be powerful tools to catalyze community engagement. Some local jurisdictions have used maps with geospatial data and charts to examine transit routes, map community assets and risks, or share health outcome information to allow community members to understand planning in a tangible way. Data presentations should be tailored to their specific audience. For instance, some members might want specific details, including how the data are generated and collected. Other stakeholder groups may only be interested in general associations and how the data fit into the process. Missing data should be considered alongside existing data. Including funds in the budget to collect data as the general plan process proceeds will help address identified gaps in data availability.

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There are also methods to allow community members to collect local data themselves. Tools such as walk audits, surveys of building types, and community photos help communities envision improvement while increasing potential participation. Considering how these data are valued – versus other data sets and sources such as traditional data, including how much weight they will carry in the process and how public contributors will be incorporated – is important to help ensure improved community data and input.

On the Horizon

As technology has advanced in the private sector, people have become accustomed to using the Internet and their personal cell phones to locate services, buy products, fund projects through crowdsourcing, and share their lives on social media. This constant and immediate interaction is changing the cultural norms for level of involvement with business, other community members, and, ultimately, with government agencies. Groups such as Code for America build open source technology to improve access to government services. Some places are starting to allow citizens to use personal cell phones to do surveys of local conditions, tweet responses to proposed policy options, or even provide their commentary online for local city council meetings rather than participate in person. As more local jurisdictions create positions for innovation officers and facilitate new ways of interacting with local government, planning departments will likely have new opportunities for engagement. However, jurisdictions should not ignore age and cultural differences in the rate of adoption of new technology as potential methods of engagement increase. As with any strategy, balancing alternative methods and using various tools to engage diverse perspectives will help increase input and prevent unintentional exclusion of community members.

Technology continues to create new methods of engaging the community in analysis and decision making



Source: https://www.pexels.com/search/analytics/

Partnering for increased engagement in Salinas

In fall 2013, the City of Salinas initiated an Economic Development Element (EDE) planning process. The City's initial goal was to position Salinas for outside investment to become the agricultural technology capital. However, when the City asked local community based organizations (CBOs) about their economic development priorities, multiple new topics emerged including training for transitioning agricultural workers; reducing poverty; support for local entrepreneurs and small businesses; more childcare facilities; education and youth development; and tracking the city's economic indicators by neighborhood, race/ethnicity, and income group.

The CBOs also wanted improved community engagement for the EDE process. Early activities required a technical understanding which intimidated numerous residents (and CBOs) into not participating. While 75% of Salinas residents identify as Latino and 66% of residents speak Spanish at home, the workshop presentations and materials were all in English with limited Spanish interpretation assistance. The collaborative Building Healthy Communities

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– East Salinas (BHC), identified this need and entered an MOU with the City to provide additional engagement opportunities tailored to the Latino residents in East Salinas (93% Latino).

This supplemental effort consisted of a pop-up workshop, a community workshop, and house meetings to learn about East Salinas residents' challenges with employment, education, shopping, and businesses. Additionally, BHC convened bi-weekly meetings with coalition members so they could collaboratively provide support and feedback to the City on engagement and policy proposals.

The BHC-led pop-up workshop's materials and hosts were bilingual and activities included a vision photo booth, goal prioritization dot exercise, and posters that asked people for ideas about "Small Businesses, Entrepreneurship and Innovation" and "Youth Development." The activities did not require any prior knowledge of the planning process or of economic development policy. A few months later, BHC and the Monterey County Health Department co-hosted a community workshop in East Salinas, held in Spanish with English translation. Activities framed EDE topics at an individual or household level making the discussion accessible to all attendees. Community leaders also organized, facilitated, and summarized small house meetings in Spanish to hear from many undocumented and mono-lingual Spanish-speaking families. From these activities, the resident's and business owners and workers articulated their dreams for their families and Salinas youth.

BHC's involvement in the process shifted the EDE's framework, promoted inclusion of policies with a health and equity framework, and created an entire quality of life section in the element. Evaluation metrics were modified to show breakdowns by race and ethnicity and include health and quality of life indicators. This process demonstrated that East Salinas residents have valuable contributions when culturally-appropriate community engagement opportunities are available. The City now sees BHC and other local CBOs as partners and allies. City of Salinas Planning RFPs now include requirements for processes to include fully bi-lingual and collaborative planning processes.

Source: Beth Altshuler, Raimi + Associates; Building Healthy Communities — East Salinas; and City of Salinas

Engagement Tools

There are a wide variety of engagement tools that can be used to inform and engage the community in a public participation process. Tools should be chosen based on the needs, strengths, and resources of the community. Using multiple techniques can help to reach a wider range of community residents. Community members who help develop the general plan may become champions throughout the process, helping carry the plan through adoption and implementation. Below are examples of different tools that may be employed.

Meetings, Workshops, and Events

Well-timed meetings help solicit input and keep participants informed. Ensuring that meetings and outreach activities are held at a variety of times and locations—after work hours, on weekends, or at facilities that are easily accessible via public transit—helps increase potential participation. Meeting types can vary depending on a variety of factors, including the meeting's purpose or its participants. In addition to regular meeting structures, project leads can use innovative methods such as story telling, games, or

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white board activities to capture input. Meeting types include, but are not limited to:

- Public hearings
- Town hall meetings
- Open houses
- Events in non-traditional places, such as farmers' markets, churches, health fairs, school events, and community fairs
- Panel discussions
- Neighborhood meetings
- Meetings of civic organizations, such as chambers of commerce
- Focus groups
- Small in-home meetings

Activities

Activities are a helpful tool to expand thinking and demonstrate new opportunities and possibilities. For example, conducting a "walk audit," where local residents physically walk around as a group and collect standardized information about the condition of the built environment, could highlight infrastructure and safety needs. Activities can also provide group-learning opportunities and build relationships between community members and planning and consulting staff.

Tours

Tours to other cities and counties can show decision-makers and participants examples from other communities and help them visualize ideas for their own community. Tours within an agency's own jurisdiction are also a good way to experience parts of the city or district with which participants may be less familiar. Organized tours of recent or proposed projects within the community may also provide a good basis of discussion for decision makers and participants.

Open Houses

Open houses can allow community members to view plan proposals, data, and maps in a casual environment that allows people to come and go as their schedules allow. Open houses can be held at a church, school, community center, local business, or other location easily accessible to the public. Planners and visitors should be able to talk informally about the planning process, with translators present as necessary. Open houses can be combined with other tools, such as written or visual surveys.

Community Image Surveys and Photo Voice

Photos can be a powerful engagement tool to change the built environment. Various methods have been used with photos. Community Image Surveys are a visual preference method that are scored and used to assess preferences. Photovoice is a participatory method where users can capture elements about the environment and use them as a starting point for a discussion about their community.

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Design Charrettes

Design charrettes are interactive, visual, and time-intensive events where the public can participate with interdisciplinary teams of planners, architects, engineers, and artists, as well as each other. While charrettes are often used for specific plans and individual projects, they can also help community members visualize what they want their community to look like. These preferences can then be translated into general plan goals and specifications.

Web Based Meeting and Engagement Tools

Webinars, online conferences, and Internet collaboration tools allow for easy, convenient engagement with the public. People with busy schedules, families, or limited mobility may find participation simpler via web-based tools where they can enter questions or comments based on their own availability. Web-based tools range from simple online webinars or meetings to open forums, documents with commenting capability, and collaborative images for visioning. While some community members may not have access or interest in using online tools, including them in an engagement strategy may increase participation.

Mailings – email and regular mail

Mailings can be used to advertise process, request input, or share information. Per Government Code sections 65091 and 65092, some notices must be mailed in prescribed ways, but in all other situations the types of mailing used should be based on the desired input goals. Mass surveys or opinion mailings work well to broaden the range of participants in the process and can also share information about process scope, timelines, website links, data availability and other issues. Newsletters work to keep the public updated on the process as well. Some communities utilize existing mailing services, such as utility bills, to reduce costs.

Surveys

Surveys are most often used in the beginning of a general plan process to help identify community issues and concerns and to identify residents' opinions about the strengths and weaknesses of their community. A survey can help identify issues to be addressed by the general plan and areas where residents would like more information. A good survey includes the public early in the process, broadens the range of participants by including residents who do not come to meetings, and publicizes the general plan process. A statistically valid survey of local opinion, while more difficult to conduct, can be persuasive to decision makers and the public. Including demographic questions in a survey will help identify any inequities in response rates and detect important differences in opinions among groups.

There are a number of methods available to improve access and equity in surveys. Pilot testing the survey instrument with an advisory group or with a diverse group of pilot subjects may improve the form. The survey should be piloted in every language in which it will be offered to ensure that translations are conveying the intended information. While this will add time to the process, it may ultimately yield more accurate results and improve public perception of the data. Door-to-door surveys may also be an effective outreach method and can yield a higher response rate than traditional mail surveys.

Additionally, soliciting feedback on data interpretation may be useful before finalizing analyses. Because different interests may interpret the same data in multiple ways, providing an opportunity for discussion, feedback, and suggestions on how to analyze results may provide a stronger sense of transparency and trust in the process.

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Beyond outreach

Conducting outreach with communities before and during the general plan update is key to having a more informed plan. Capturing input along the way is important for presentations back to city councils and county boards of supervisors to show how the plan is informed by community input. Beyond initial outreach, it is also important to have a mechanism in place to communicate with stakeholders who were involved during the update process, so they are aware of how their input was incorporated into the plan. Mechanisms to keep track of progress after the plan has been adopted have been well received in communities.

Jurisdictions have used different mechanisms to do this work. Some jurisdictions have assigned the various components of the general plan to different departments, allowing stakeholders to follow progress based on goals that align with the adpoted goals of existing agencies.

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Required Elements

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

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"A city (or county) is not an accident but the result of coherent visions and aims."

—Leon Krier, ***The Architecture of Community***

Quick Links to Individual Elements

Land Use | **Conservation** | **Noise** | **Environmental Justice**

Circulation | **Open Space** | **Safety** | **Air Quality**

Housing

Introduction

All statutory references are to the California Government Code unless otherwise noted.

While a general plan will contain the community vision for future growth, California law also requires each plan to address the mandated elements listed in Government Code section 65302. The mandatory elements for all jurisdictions are land use, circulation, housing, conservation, open space, noise, and safety. Cities and counties in the San Joaquin Air Pollution Control District must also address air quality in their general plans. Cities and counties that have identified disadvantaged communities must also address environmental justice in their general plans, including air quality. The purpose of the following sections is to outline the content of each element as required by statute.

Relationships Among Elements and Issues

This chapter presents each of the mandatory elements separately. There is no requirement that a general plan be organized into separate elements, however, and planners should consider local context in general plan preparation. A jurisdiction may organize its

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general plan in any format, including consolidated elements, so long as all of the relevant statutory issues are addressed (Gov. Code § 65301; Kings County Farm Bureau v. City of Hanford (1990) 221 Cal.App.3d 692). The elements and issues should form an integrated, internally consistent plan, and inconsistencies cannot be remedied by a statement giving one element precedence over the others (Gov. Code § 65300.5; Sierra Club v. Board of Supervisors of Kern County (1981) 126 Cal.App.3d 698). A concise general plan can avoid repetitive discussions of topics by consolidating the statutory requirements into a few functional elements. When revising a single element, local agencies should examine and, if necessary, revise the other elements, including optional elements, to avoid internal inconsistencies. The statutory elements call for interrelated content. For example, consideration given in the conservation element to the vegetation that supports an endangered wildlife species also involves analyzing topography, weather, fire hazards, availability of water, and density of development—issues which arise in other elements as well. The table on the following page illustrates the potential relationships among the mandatory elements and the issues addressed in a general plan. Not every general plan will address these issues to the same extent or in the same manner. Cities and counties should design their general plan format to suit the topographic, geologic, climatologic, political, socioeconomic, cultural, and historical diversity of their community. Each section in this GPG document will also highlight the relationships between the elements.

Topics, Elements	Land Use	Circulation	Housing	Conservation	Open Space	Noise	Safety	Environmental Justice
Agriculture	IN STATUTE	-	IN STATUTE	RELATED	IN STATUTE	-	RELATED	RELATED
Air Quality	RELATED	RELATED	RELATED	-	RELATED	-	RELATED	IN STATUTE
Airports	RELATED	IN STATUTE	RELATED	-	RELATED	IN STATUTE	RELATED	RELATED
Bicycle and Pedestrian Routes	RELATED	IN STATUTE	RELATED	-	-	-	RELATED	RELATED
Climate Change (Adaptation)	RELATED	RELATED	RELATED	RELATED	RELATED	-	RELATED	RELATED
Climate Change (GHG Emissions)	RELATED	RELATED	RELATED	RELATED	RELATED	-	RELATED	RELATED
Density	IN STATUTE	RELATED	IN STATUTE	-	-	-	RELATED	RELATED
Education	IN STATUTE	RELATED	RELATED	-	-	-	RELATED	RELATED
Social Equity	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED
Environmental Justice	RELATED	RELATED	IN STATUTE	-	-	-	RELATED	IN STATUTE
Fire	RELATED	-	IN STATUTE	-	IN STATUTE	-	IN STATUTE	RELATED
Fisheries	RELATED	-	-	IN STATUTE	IN STATUTE	RELATED	RELATED	RELATED
Flooding	IN STATUTE	RELATED	IN STATUTE	IN STATUTE	-	-	IN STATUTE	RELATED
Food Access	RELATED	RELATED	RELATED	-	-	-	RELATED	IN STATUTE
Forests/Timber	IN STATUTE	RELATED	-	IN STATUTE	IN STATUTE	-	RELATED	RELATED
Health	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	IN STATUTE
Housing	IN STATUTE	RELATED	IN STATUTE	RELATED	RELATED	RELATED	RELATED	IN STATUTE
Industrial Uses	IN STATUTE	RELATED	RELATED	-	-	IN STATUTE	RELATED	IN STATUTE
Land Reclamation	-	-	-	IN STATUTE	-	-	RELATED	RELATED
Land Use	IN STATUTE	IN STATUTE	IN STATUTE	IN STATUTE	RELATED	IN STATUTE	IN STATUTE	RELATED

■ Identified in statute ■ Closely related to statutory requirements

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Topics, Elements	Land Use	Circulation	Housing	Conservation	Open Space	Noise	Safety	Environmental Justice
Military Compatibility	IN STATUTE	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED
Minerals	RELATED	RELATED	-	IN STATUTE	IN STATUTE	-	RELATED	RELATED
Noise Contours	RELATED	IN STATUTE	RELATED	-	-	IN STATUTE	-	RELATED
Public Buildings	IN STATUTE	RELATED	RELATED	RELATED	RELATED	RELATED	IN STATUTE	RELATED
Railways and Yards	RELATED	IN STATUTE	RELATED	-	-	IN STATUTE	RELATED	RELATED
Recreation	IN STATUTE	RELATED	-	RELATED	IN STATUTE	-	RELATED	IN STATUTE
Scenic Resources	IN STATUTE	RELATED	RELATED	RELATED	IN STATUTE	RELATED	-	RELATED
School Siting	IN STATUTE	RELATED	RELATED	-	RELATED	RELATED	IN STATUTE	RELATED
Seismic Hazards	RELATED	RELATED	RELATED	RELATED	IN STATUTE	-	IN STATUTE	RELATED
Soil Conservation	RELATED	RELATED	RELATED	IN STATUTE	IN STATUTE	-	-	RELATED
Soil Instability	RELATED	RELATED	RELATED	-	-	-	IN STATUTE	RELATED
Transportation Routes	RELATED	IN STATUTE	IN STATUTE	RELATED	IN STATUTE	IN STATUTE	IN STATUTE	RELATED
Transportation Terminals	RELATED	IN STATUTE		IN STATUTE	-	RELATED	RELATED	RELATED
Utilities/ Easements	RELATED	IN STATUTE	RELATED	RELATED	IN STATUTE	RELATED	RELATED	RELATED
Waste Facilities	IN STATUTE	RELATED	IN STATUTE	-	-	RELATED	RELATED	RELATED
Water Quality	RELATED	-	-	IN STATUTE	IN STATUTE	-	RELATED	RELATED
Water Supply	RELATED	-	IN STATUTE	IN STATUTE	IN STATUTE	-	IN STATUTE	RELATED
Watersheds	RELATED	-	RELATED	IN STATUTE	IN STATUTE	-	RELATED	-
Waterways/Water Bodies	RELATED	-	RELATED	IN STATUTE	IN STATUTE	RELATED	RELATED	-
Wildlife	RELATED	RELATED	RELATED	IN STATUTE	IN STATUTE	-	-	-

■ Identified in statute ■ Closely related to statutory requirements

Regardless of which format a general plan takes, the content must form an integrated, internally consistent plan (*Sierra Club v. Board of Supervisors of Kern County* (1981) 126 Cal.App.3d 698).

Mandatory Element Format

The Government Code requires OPR to "develop and adopt guidelines for the preparation of and the content of the mandatory elements required in city and county general plans" (Gov. Code § 65040.2). According to the Government Code, the guidelines shall be "advisory to each city and county in order to provide assistance in preparing and maintaining their respective general plans" (Gov. Code § 65040.2(c)).

These Guidelines present the statutory elements in the order that they appear in Government Code section 65302. This order should not be construed as a ranking of importance or the order in which a jurisdiction should prepare elements. Elements can be prepared in any order or combined, as discussed in.

For a glossary of terms and a description of the parts of a general plan, see Appendix E.

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4

Land Use Element

Introduction

The most fundamental decisions in planning begin with land use: what to put where. Land use planning envisions the future of a city or county and interacts with all other elements of planning. At its best, the land use element will reflect the community's vision; promote thoughtful, equitable, and accessible distribution of different land uses, including residential, commercial, industrial, agricultural, and open space; and align well with other general plan elements. Planners can also use the land use element as a tool to improve public health, reduce infrastructure costs, enhance local economies, and address long-term environmental issues such as climate change and water resources.

The land use element can also help resolve conflicts and identify trade-offs in land use decisions. For example, increasing density may result in a higher population, but it can also help enhance water supply reliability, reduce long-term costs of infrastructure maintenance, improve water use efficiency, land conservation, housing and transit options, and equity. Designating "least-conflict" areas for solar development may increase energy independence and generate local economic benefits while also preserving valuable agricultural lands. Pursuing urban infill projects may require higher intensity development directed at a limited number of parcels varying in suitability, but infill may also allow for more accessible transit and walkability thus reducing vehicle miles traveled and subsequent greenhouse gas emissions. Identifying and resolving such issues in the land use element can result in development patterns that are predictable, coherent, and reflect community values.

Gov. Code § 65302 (a) A land use element that designates the proposed general distribution and general location and extent of the uses of the land for housing, business, industry, open space, including agriculture, natural resources, recreation, and enjoyment of scenic beauty, education, public buildings and grounds, solid and liquid waste disposal facilities, greenways as defined in Section 816.52 of the Civil Code and other categories of public and private uses of land. The location and designation of the extent of the uses of the land for public and private uses shall consider the identification of land and natural resources pursuant to paragraph (3) of subdivision (d). The land use element shall include a statement of the standards of population density and building intensity recommended for the various districts and other territory covered by the plan. The land use element shall identify and annually review those areas covered by the plan that are subject to flooding identified by flood plain mapping prepared by the Federal Emergency Management Agency (FEMA) or the Department of Water Resources. The land use element shall also do both of the following:

(1) Designate in a land use category that provides for timber production those parcels of real property zoned for timberland production pursuant to the California Timberland Productivity Act of 1982 (Chapter 6.7 (commencing with Section 51100) of Part 1 of Division 1 of Title 5).

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(2) Consider the impact of new growth on military readiness activities carried out on military bases, installations, and operating and training areas, when proposing zoning ordinances or designating land uses covered by the general plan for land, or other territory adjacent to military facilities, or underlying designated military aviation routes and airspace.

(A) In determining the impact of new growth on military readiness activities, information provided by military facilities shall be considered. Cities and counties shall address military impacts based on information from the military and other sources.

(B) The following definitions govern this paragraph:

(i) "Military readiness activities" mean all of the following:

(I) Training, support, and operations that prepare the men and women of the military for combat.

(II) Operation, maintenance, and security of any military installation.

(III) Testing of military equipment, vehicles, weapons, and sensors for proper operation or suitability for combat use.

(ii)"Military installation" means a base, camp, post, station, yard, center, homeport facility for any ship, or other activity under the jurisdiction of the United States Department of Defense as defined in paragraph (1) of subsection (g) of Section 2687 of Title 10 of the United States Code.

In this way, the land use element functions as a guide to planners, the general public, and decision makers. Its objectives, policies, and programs relate directly to the other elements. In practice, the land use element is often the most visible and frequently used element in a general plan.

CORRELATIONS AMONG ELEMENTS

	Circulation	Housing	Conservation	Open Space	Noise	Safety	EJ
Land Use	IN STATUTE	IN STATUTE	IN STATUTE	RELATED	IN STATUTE	IN STATUTE	RELATED

■ Identified in statute ■ Closely related to statutory requirements

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Completeness Checklist

Local agency staff can use the following checklist to help ensure that the land use element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required in Government Code section 65302(a). Conservation elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied.

California Government Code Section	Brief Description of Requirement
§ 65302(a)	General distribution, location, and extent of:
§ 65302(a)	Housing Density and intensity Potential for flooding impacts.
§ 65302(a)	Business Density and intensity Potential for flood?
§ 65302(a)	Industry Density and intensity Potential for flood?
§ 65302(a)	Open space, including agriculture, natural resources, recreation, and scenic resources Potential for flood?
§ 65302(a)	Education Density and intensity Potential for flood?
§ 65302(a)	Public facilities Density and intensity Potential for flood?
§ 65302(a)	Solid and liquid waste disposal Density and intensity Potential for flood?
§ 65302(a)(1)	Timberland Production Intensity Potential for flood?
§ 65302(a)	Other Density and intensity Potential for flood?
§ 65302(a)	Greenways, as defined in Civil Code Section 816.52
§ 65302(a)	Identify areas subject to flood plain mapping Annual review
§ 65302(a)(2)	Impact on military land use compatibility and readiness
§ 65302(b)(1)	Correlation with the circulation element

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Required Contents

Government Code section 65302(a) describes the required content of a land use element. Specifically, the land use element must designate the proposed general distribution, general location, and extent of land uses for

- Housing, business, and industry
- Open space, including agricultural land, watersheds, natural resources, and recreation
- Recreation facilities and opportunities
- Educational facilities
- Public buildings and grounds
- Future solid and liquid waste facilities
- Greenways
- Timberland Preserve Zone lands
- Areas subject to flooding, identified by either flood plain mapping prepared by the Federal Emergency Management Agency (FEMA) or the Department of Water Resources or mapped flood areas adopted by the local community on Flood Insurance Rate Maps
- Military land use compatibility and impacts to military readiness
- Other categories of public and private uses of land, such as marine protected areas

The land use element should contain a sufficient number of land use categories to conveniently classify the various uses identified by the plan. Land use categories should be descriptive enough to distinguish between allowable levels of intensity and allowable uses. The element should include categories reflecting existing land uses as well as projected development. Additionally, the land use element must include "a statement of the standards of population density and building intensity recommended for the various districts and other territory covered by the plan" (*Camp v. County of Mendocino Board of Supervisors* (1981) 123 Cal. App.3d 334). There need not be an equal number of land use designations and zoning classifications. In many cases, there may be more than one zone that would be consistent with each land use designation.

The land use element must accommodate specific land uses identified in the conservation element pursuant to Government Code section 65302(g)(d)(3). The land use plan must identify waterways used in flood management and could also identify groundwater recharge areas.

The land use element must also consider the impact of new development on military readiness activities carried out on military bases, installations, and in operating and training areas. Planners must take such impacts into account when proposing zoning ordinances or designating land uses covered by the general plan for land that is either adjacent to military facilities or underlying designated military aviation routes and airspace (Gov. Code § 65302(a)(2)). For a GIS map of military aviation routes and airspace by

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local government boundary, see the California Military Land Use Compatibility Analyst. For more information on community and military compatibility planning, see the supplement to the general plan guidelines.

The land use element must also be consistent with airport land use compatibility plans where applicable (Gov. Code § 65302.3). For more information on airport land use compatibility and requirements, see the California Airport Land Use Planning Handbook.

The land use element must reflect the specific contents from other elements. For example, the land use element must account for "rivers, creeks, streams, flood corridors, riparian habitats, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management," as identified in the conservation element (Gov. Code § 65302(d)(3)). The law also requires the land use element to correlate with the circulation element (Gov. Code § 65302(b)); and to use the noise element (Gov. Code § 65302(f)) as a guide for establishing a pattern of land use that minimizes the exposure of community residents to excessive noise. For more detailed discussions of those requirements, see the circulation, conservation, and noise elements.

As explained later in this chapter, in some circumstances the land use element must also identify disadvantaged communities and plan for infrastructure in those communities.

Density and Intensity

California's population continues to grow, and the general plan presents a platform to prepare for future needs. Jurisdictions must plan to accommodate the share of the regional housing need that is allocated to them by their Council of Governments (Gov. Code § 65584 (b)). In doing so, planners should consider several factors in their forecasts and build-out scenarios, including population growth and trends, community and regional demographics, the local mix of jobs and housing, economic trends, and infrastructure needs. The Demographic Research Unit within the California Department of Finance (DOF) prepares annual population estimates for the state and for individual counties and cities. This unit also produces information on housing units, vacancies, average household size, components of population change, and special populations. More broadly, the Department of Finance forecasts both population and public school enrollment for the state and for each county for 50 years into the future. DOF data are used to comply with various state codes, including the Regional Housing Needs Assessment (RHNA) process, and for research and planning purposes by federal, state, and local agencies, the academic community, and the private sector.

"Population density" refers to the "numbers of people in a given area and not to dwelling units per acre, unless the basis for correlation between the measure of dwelling units per acre and numbers of people is set forth explicitly in the plan" (*Twain Harte Homeowners Association v. County of Tuolumne* (1982) 138 Cal.App.3d 664). Quantifiable standards of population density must be provided for each of the land use categories contained in the plan. Population density standards need not be restricted solely to land use designations with residential development potential. As the court stated in Twain Harte, "it would not be unreasonable to interpret the term 'population density' as relating not only to residential density, but also to uses of nonresidential land categories and as requiring an analysis of use patterns for all categories . . . it appears sensible to allow local governments to determine whether the statement of population standards is to be tied to residency or, more ambitiously, to the daily usage [sic] estimates for each land classification." Although applied differently from one jurisdiction to another, residential population density can best be expressed as the relationship between two factors: the number of dwellings per acre and the number of residents per dwelling.

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Camp v. Mendocino County Board of Supervisors (1981) 123 Cal.App.3d 334 also held that, in addition to assigning different uses to different areas, an adequate general plan must also contain standards for building intensity.

Considerations for defining building intensity can include, but are not limited to:

- Intensity should be defined for each of the various land use categories in the plan.
- General use captions such as "neighborhood commercial" and "service industrial" may be insufficient measures of intensity by themselves.
- Building intensity is not synonymous with population density.

Intensity will be dependent upon the local plan's context and may be based upon a combination of quantifiable variables:

- Many jurisdictions prescribe minimum and maximum numbers of dwelling units per acre as a useful residential standard.
- Floor Area Ratio (FAR), which represents the ratio of the area of a building's floor to that of its total site, is a common measure of commercial and industrial intensity.
- A dual standard of maximum lot coverage and maximum building height may be suitable for agricultural and open-space areas, as well as recreational areas with development limits.
- Lot size has been widely used for agricultural and open-space designations, but it may be an inadequate standard for building intensity.

Coordinating land use and transportation can revitalize underused spaces





Image by Urban Advantage, Community Design + Architecture

Intensity standards can also include provisions for flexibility, such as density bonuses, cluster zoning, and planned unit developments. Standards for permitted uses and building types qualitatively determine the uses that will be allowable in each land use designation.

Many communities have chosen to incorporate form-based codes into their plans, regulating building and infrastructure forms in addition to—or in place of—uses. Form-based codes focus on the community's vision for the physical characteristics of a community, in addition to the statutory requirements presented in law. Government Code section 65302.4 permits form-based codes in general plans, stating that "[t]he text and diagrams in the land

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use element that address the location and extent of land uses, and the zoning ordinances that implement these provisions, may also express community intentions regarding urban form and design. These expressions may differentiate neighborhoods, districts, and corridors, provide for a mixture of land uses and housing types within each, and provide specific measures for regulating relationships between buildings, and between buildings and outdoor public areas, including streets." This tool achieves certainty over the physical outcome of land use and development decisions while enhancing flexibility to create more infill or infrastructure as needed. Cities in California that have used form-based codes, such as Ventura, Benicia, and Petaluma, provide examples of this practice.

As defined by the National Center, development capacity analysis, sometimes called 'build-out analysis' represents "an estimate of the total amount of development that may be built in an area under a certain set of assumptions, including applicable land use laws and policies (e.g., zoning), environmental constraints, etc." Calculating the acreage within each land use category and multiplying that number by the applicable density and intensity factor estimate theoretical development capacity. Realistic development capacity involves analysis of growth forecasts and other factors, including inhibitions to development. The referenced report by the National Center for Smart Growth Research and Education, Maryland Department of Planning, and Lincoln Institute of Land Policy recommends a five-step process for capacity analysis based on best practices from Oregon, Maryland, and Washington:

i. "Identify vacant land and those lands that cannot be developed due to environmental constraints.

ii. Subtract land needed for urban public services.

iii. Add land that can be redeveloped or developed at greater intensity through infill.

iv. Identify land with public services.

v. Estimate development capacity."

An analysis should include a discussion of the realistic capacity of lands by zoning district, as related to housing and other development. Specifically, the element should demonstrate the ability to achieve the densities assumed in the land inventory either through a discussion of past development trends by zoning district or through city regulations, policies or programs requiring the assumed densities. Assumed densities should not include density bonuses. In communities with limited vacant land, the land inventory should identify and analyze sites with redevelopment potential for new and more intensive residential development. In such cases, the land inventory should describe the acreage, zoning and development standards, existing uses and ripeness for redevelopment, realistic development capacity, the general character and size of sites judged suitable for residential development, market trends, and any policies or incentives to facilitate their development. The inventory should estimate the realistic development capacity based on an analysis of these factors. Such sites may be made available by implementing programs applicable to redevelopment, including recycling, infill, re-designation, and rezoning of nonresidential sites for appropriate residential use.

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4

Statutory Requirements

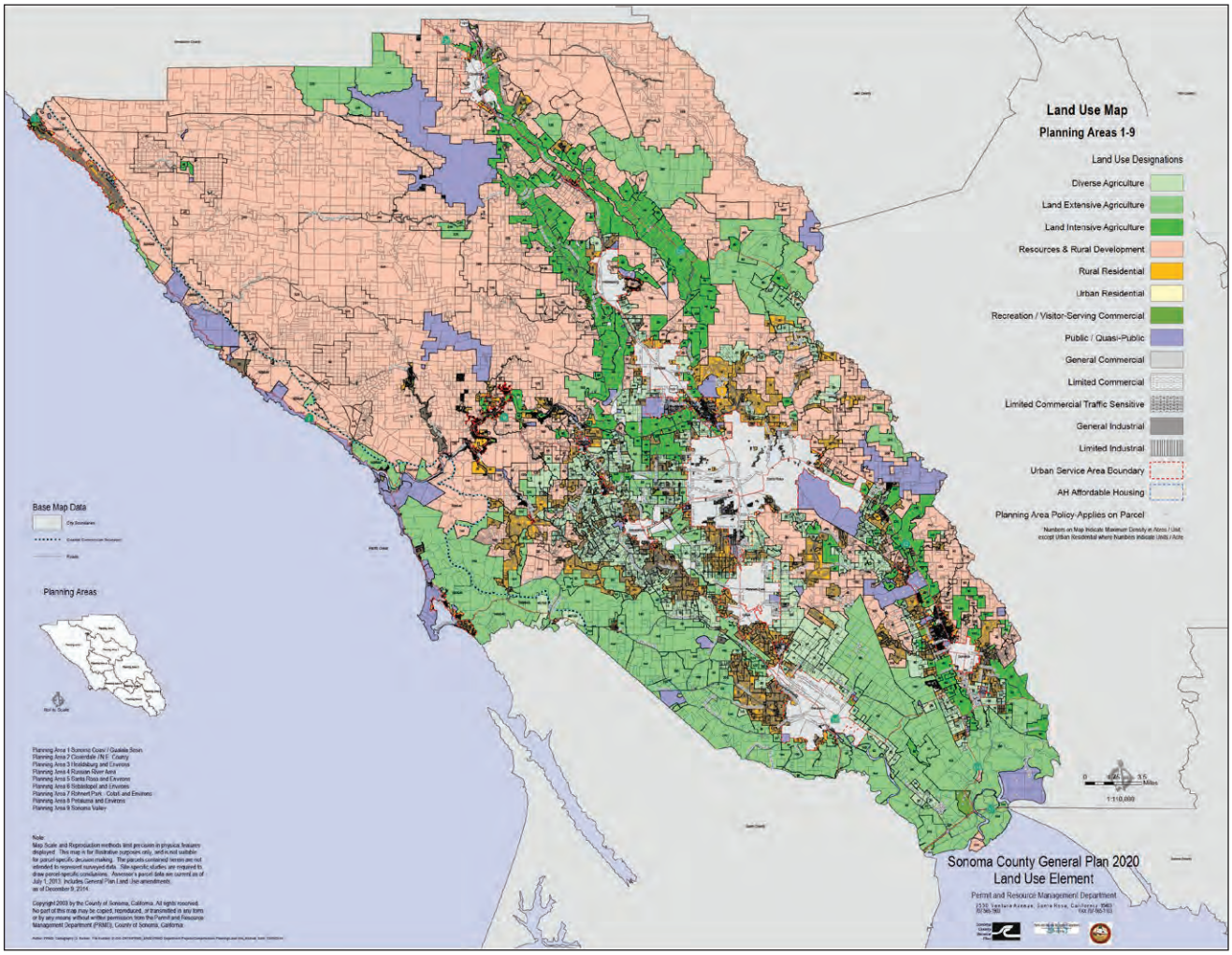
This section offers a general guide to the contents of the land use element. Note that while the focus is on the minimum requirements for an adequate land use element, an effective general plan will also focus on the issues of greatest relevance to the community.

Diagram

Requirement Description:

The land use element must designate the proposed general distribution, location, and extent of land uses, and shall include a diagram or diagrams (Gov. Code §§ 65302-65302(a)). For examples of such diagrams, see figures 6-8.

Figure 8: Land Use Map for Sonoma County



Source: http://www.sonoma-county.org/prmd/gp2020/fig-lu1.pdf

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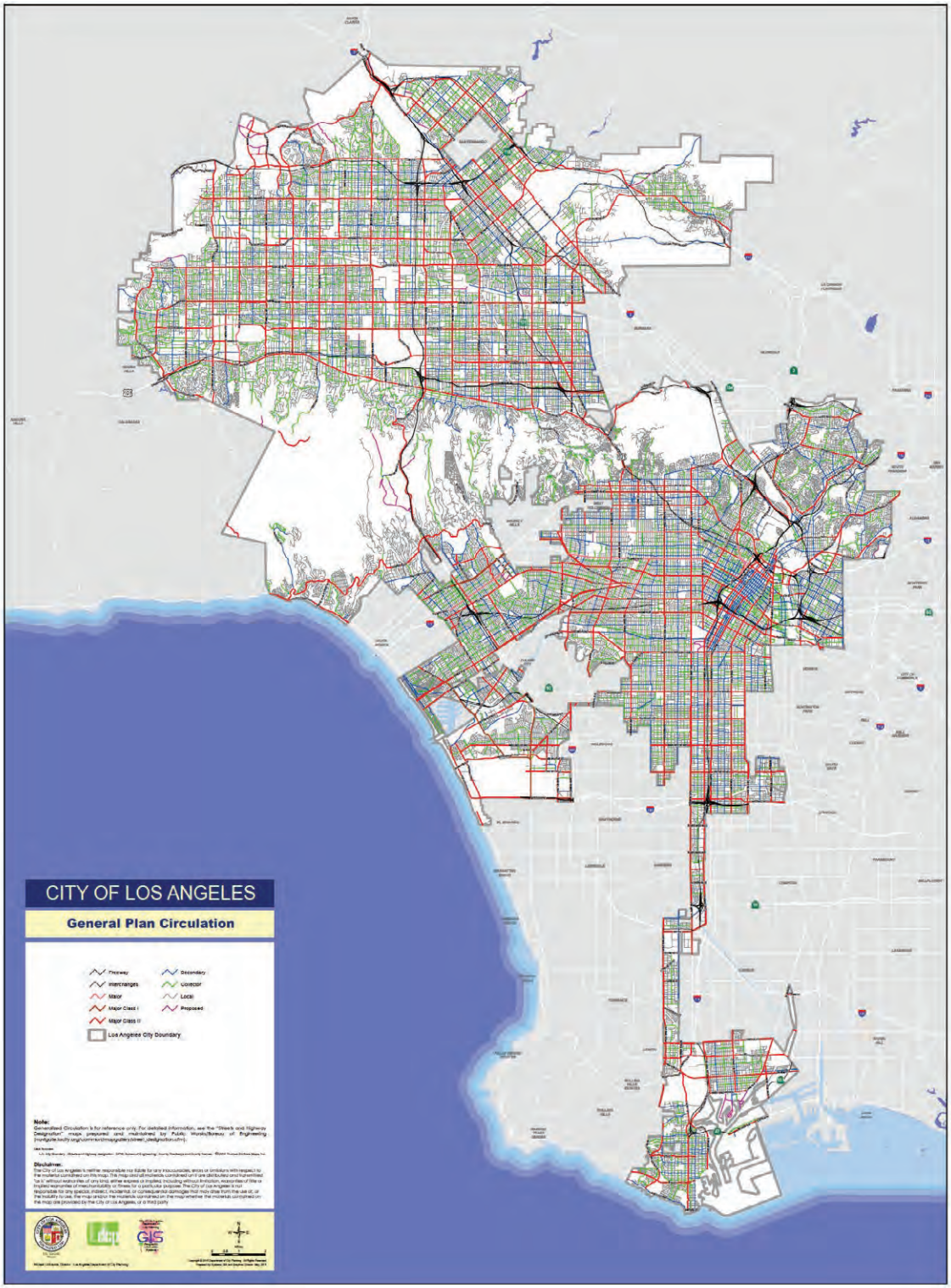
Figure 9: City of Los Angeles Circulation Map



Source: http://planning.lacity.org/mapgallery/Image/Citywide/GenCirculation.pdf

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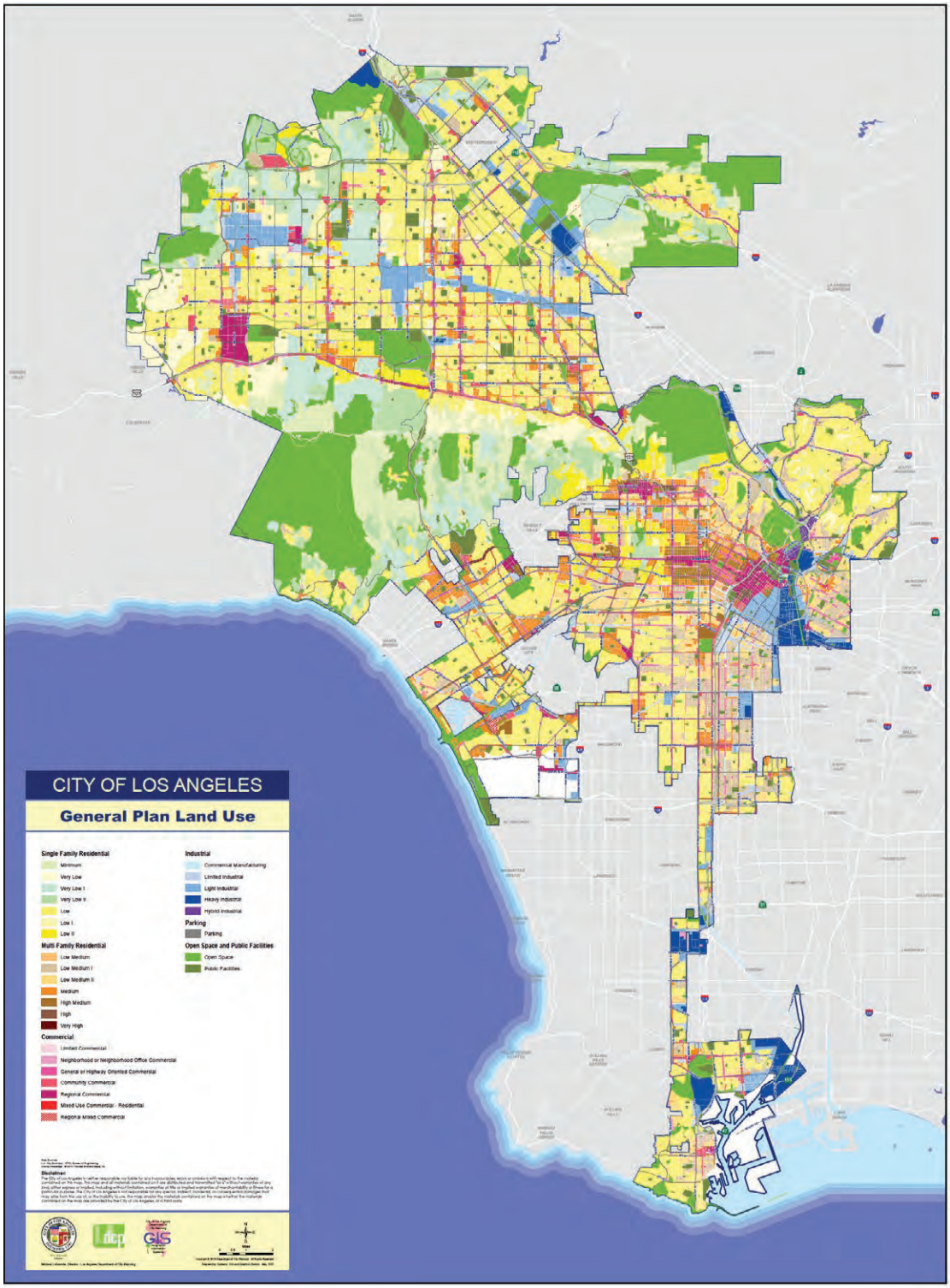
Figure 10: City of Los Angeles Land Use Map



Source: planning.lacity.org

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Many types of development policies lend themselves well to graphic treatment, such as the distribution of land uses, urban design, infrastructure, and geologic and other natural hazards. A diagram must be consistent with the general plan text and should have the same long-term planning perspective as the rest of the general plan. The text and diagrams in the land use element that address the location and extent of land uses, and the zoning ordinances that implement these provisions, may also express community intentions regarding urban form and design. Such diagrams and text may differentiate neighborhoods, districts, and corridors; provide for a mixture of land uses and housing types; and provide specific measures for regulating relationships between buildings as well as between buildings and outdoor public areas (Gov. Code § 65302.4). Jurisdictions may adopt traditional land use typologies, such as mixed use or residential, that are based on urban form and design—for example, Sacramento has created categories for "transit centers" and "new growth areas"—or they may use a combination of typologies. Caltrans' Smart Mobility Framework suggests seven place type categories with sub-categories to fit local context and relates community design to circulation and access through efficiency factors. Some communities have adopted similar place types, modified for local context.

The Attorney General has observed that "...when the Legislature has used the term 'map,' it has required preciseness, exact location, and detailed boundaries but no such precision is required of a general plan diagram." As a general rule, a diagram or diagrams, along with the general plan's text, should be detailed enough so that all users of the plan can reach the same conclusion on the appropriate use of any parcel of land at any particular phase in the physical development of a city or a county. Decision makers should also be able to use a general plan and its diagram(s) to make day-to-day land use and infrastructure decisions that are consistent with the future physical development scheme of a city or a county. Given the long-term nature of a general plan, however, its diagram(s) and text should be general enough to allow a degree of flexibility in decision-making as times change. For example, a general plan may recognize the need for and desirability of a community park in a proposed residential area without immediately designating its precise location. Accordingly, the plan should have a generalized diagram along with policies stating that selection of the park site and appropriate zoning will take place when subdivision of the area is approved.

Many communities use a map as the general plan diagram. The land use element should focus on the future growth and physical development of the community in accordance with the land use map while ensuring the provision of adequate infrastructure and services to existing communities. Maps are useful for designating land use categories, as well as building densities, FAR, and other development goals. The maps in figures 6-8 demonstrate some of these varying uses. Observing proposed land uses side by side on a map will help decision makers and the public understand the relationships between them. It may also be helpful to include other elements, such as circulation and infrastructure, in the land use map when possible. Including known assets such as roads, transit routes, job centers, and service centers can help inform decisions about future land uses and needs. For example, the City of San Diego created numerous maps in which community features such as wastewater facilities and bikeways are overlaid onto more traditional depictions of land use and the street system, while the City of Emeryville used mapping to designate density and intensity in each land use category. The GPG Mapping Tool can help communities layer data to identify areas of need and opportunity as well as potential locations for specific types of land use.

Categories used in the land use element should align with the goals of the general plan. For example, a jurisdiction wanting to promote infill development and compact growth may consider setting minimum density standards along with traditional maximums.

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In some instances, land use policies provide the basis for requiring exactions and development fees of new projects (for example, parks and recreational facilities under the Quimby Act of 1975 (Gov. Code § 66477). The distribution of land use categories that are reflected in the plan diagram must conform to the plan's policies. Law does not require existing development to fully adhere to all of the development policies set forth by the plan; however, new and future development must be in uniform compliance.

The land use element requirements provide an opportunity to determine the future of a community. By ensuring thoughtful, equitable, and accessible distribution of different densities, intensities, and land uses and by aligning with other general plan elements, the land use element can address long term environmental issues such as climate change, enhance local economies, reduce infrastructure costs, facilitate healthy lifestyles, improve air quality, increase transportation choices, create community resilience, also address emerging developments in technology, such as connected and autonomous vehicles, and resulting changes in land use, and promote quality housing for all residents of the community.

Housing, Business, and Industry

Requirement Description:

A land use element must designate the general distribution, location and allowable intensity of use for housing, business, and industry. To do so, a jurisdiction should

- Examine population data, including regional and local population and growth forecasts.
- Identify demographic trends (age, income, persons per household, vehicle ownership rates, etc.).
- Inventory existing residential, commercial, and industrial land use in the planning area.
- Identify key community assets (i.e., a thriving downtown, waterfronts, or open spaces, particularly those identified in the open space and conservation elements) that should be enhanced or preserved.
- Identify geographic, fiscal, and institutional limitations that may affect the location and type of future growth, such as infrastructure capacity (water and energy service, sewage treatment, storm drainage adequacy, fiber optics, etc.) and environmental concerns (flooding, fire hazard, noise, etc.).
- Consider functional and physical differentiation of land uses – neighborhoods, districts, corridors, employment centers, etc.
- Analyze existing urban form – blocks, connectivity, building footprints, relationship to street frontages, parking allocations, etc.
- Analyze properties subject to land use development—vacant, underdeveloped, transit-oriented, etc.—and include a discussion of the methodology used to identify such properties.
- Determine project needs for specific land use considerations, including watershed and groundwater recharge; residential, commercial, and industrial development based upon estimates of future population; anticipated changes in environmental conditions such as those resulting from climate change; and economic conditions.

Additionally, the land use element should consider the appropriate methodology for identifying land use designations aligned with general plan goals. For example, it may designate residential and commercial growth in a series of connected areas or along existing

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transit routes so as to encourage compact development and promote access for various populations, or it may require buffer zones surrounding industrial land and hazardous materials sites.

The general plan tends to be more about long-range planning and looking forward. However, considering current conditions and past planning decisions is important to ensure that the land use element does not perpetuate or exacerbate existing problems. Data and tools such as the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment has developed Cal EnviroScreen as a screening methodology that identifies California communities that are disproportionately burdened by pollution. In the context of planning for future growth, such data may inform future decisions about whether certain locations are appropriate for additional commercial and industrial facilities. It is good planning for all jurisdictions to address this. Certain jurisdictions subjected to SB 1000 will now be required to address environmental justice issues. (See EJ section and Chapter 5 for more information on equity and environmental justice).

Land use decisions can have other significant impacts on health. Increases in density, development intensity, and a mix of land uses can promote physical activity and the use of active transportation and transit. The use of flexible and context sensitive urban design strategies can promote walkable and bikeable environments, which has been shown to be beneficial for health.

SAMPLE OF OPR RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of analysis	Recommended Data
Identify locations in need of particular community assets.	Population density (US Census).
Identify potential gaps in services.	Types of businesses geographically.
Support mixed-use communities and vibrant places supportive of recreation, retail, and housing.	Diversity of functional zoning.

Open Space, Including Agricultural Land, Natural Resources, and Recreation

Requirement Description:

A land use element must provide for the general location and distribution of land uses for "open space, including agriculture, natural resources, recreation, and enjoyment of scenic beauty" (Gov. Code § 65302(a)). Determining policies and locations for open space in the land use element may help create a foundation to build detailed policies in the conservation and open space element, or connect to themes such as economic development, climate change, equity, or healthy communities for general plans not organized by elements.

The land use diagram should designate and correspond to the inventory of existing open space and identify public land for future open space, as detailed in the open space element. This may include designation of parks, greenways, forests, community gardens, public beaches, fishing piers, access points to marine protected areas, and other open space categories identified by the community. Promoting equitable access to parks, open space, and recreational assets, will afford all communities the opportunity to be physically active.

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Statewide policies favor preservation of open space.

(a) "That the preservation of open-space land ... is necessary not only for the maintenance of the economy of the state, but also for the assurance of the continued availability of land for the production of food and fiber, for the enjoyment of scenic beauty, for recreation and for the use of natural resources.

(b) That discouraging premature and unnecessary conversion of open-space land to urban uses is a matter of public interest and will be of benefit to urban dwellers because it will discourage noncontiguous development patterns which unnecessarily increase the costs of community services to community residents" (Gov. Code § 65561).

For cities and counties with agricultural lands, consideration of those lands specifically in a broader land use context may help identify better policies to achieve their general plan goals. In addition to their value as an economic driver, agricultural lands can help cities and counties preserve open space lands' aesthetic qualities, maintain physical separation between urban areas, and preserve biological resources. However, some of the most valuable agricultural lands are located closest to growing cities and are thus at highest risk for conversion. Without appropriate land use planning and policies that encourage conservation, many of these spaces may be permanently lost. Tax incentives for converting vacant space into urban agricultural zones provide potential tools for cities with smaller plots of useable land.

The land use element policies and maps must be consistent with the conservation and open space element, both of which contain more specific requirements.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identify proportion of the population, especially vulnerable or disadvantaged communities, within X miles of recreational open space and with ready access to it (e.g. transit).	Census tract data with geo-mapping overlay of recreational open space overlaid with mass transit routes.
Identify areas important to water supply or water quality to ensure protection.	Water supply source areas, infiltration areas, areas above groundwater supplies, wetlands, natural filtration basins, and priority recharge zones.

Educational Facilities

Requirement Description:

The land use element must plan for the use of land for "education" (Gov. Code § 65302(a)). Educational facilities may include district-run facilities, but also charter schools, private schools, parochial schools, preschools, closed and surplus school properties, career colleges, higher education satellite campuses, home school centers, independent study centers, adult education and regional occupational programs. Local governments and school districts have separate but related statutory requirements and authority, as explained in the list below, and coordination is mutually beneficial. Land use may affect school functions—for example, by facilitating safe routes to schools. Similarly, the placement of schools within a community may influence circulation patterns and housing decisions. School siting should consider regional growth characteristics as well as changes in demographics and density as state

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and local laws change to prioritize more resource efficient development patterns, including agricultural farmland preservation. Additionally, school districts and communities should consider climate related risks, such as flooding, fire, and other hazards, when planning new facilities. Ensuring that school districts participate in the planning process through outreach, engagement, and coordination where possible can benefit the community, reduce potential future issues, and facilitate alignment between city, county, and district goals.

California Code of Regulations, Title 5, §14001. Minimum Standards:
Educational facilities planned by school districts shall be:

(a) Evolved from a statement of educational program requirements which reflects the school district's educational goals and objectives.

(b) Master-planned to provide for maximum site enrollment.

(c) Located on a site which meets California Department of Education standards as specified in Section 14010.

(d) Designed for the environmental comfort and work efficiency of the occupants.

(e) Designed to require a practical minimum of maintenance.

(f) Designed to meet federal, state, and local statuary requirements for structure, fire, and public safety.

(g) Designed and engineered with flexibility to accommodate future needs

School districts are required to comply with city/county zoning ordinances if the city/county has an adopted general plan and the ordinances make provisions for the location of public schools. Nevertheless, a school district governing board that has complied with notification requirements may, by a two-thirds vote, "render a city or county zoning ordinance inapplicable to a proposed use of property by the school district" for classroom facilities (Gov. Code § 53094) pursuant to Attorney General Opinion No. 99-401, "even though such use would not be in conformity with the general plan" (82 Ops.Cal.Atty.Gen. 135). There are certain exceptions to the ability of a school district to render zoning inapplicable (Gov. Code § 53094), such as property within a farmland security zone or property covered by regional plans, such as those adopted by the Coastal Commission or Tahoe Regional Planning agency. School districts must also comply with city and county ordinances regulating improvements in drainage, roads, and on-site grading plans (Gov. Code § 53097). Additionally, charter schools may have separate rules and requirements, including exemption from certain laws governing school districts (Ed. Code § 47610). Early coordination between school districts and planners can help improve outcomes for all. The National Safe Routes to School Partnership outlines numerous best practices for school siting, as well as case studies on communities around the nation. Although cities and counties control land use approvals, and school siting is controlled by local school districts, consultation between those entities is required at several points in the planning process. Before adopting a general plan, a local government must solicit input from affected school districts (Gov. Code § 65352(a)(2)). The Local Agency Formation Commission (LAFCO) should also be consulted early in the process of school site consideration.

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- Before completing any long-range plans that contemplate school site acquisition, a school district must notify local government planning agencies and must participate in a meeting if requested (Gov. Code § 65352.2(b)).
- Before the acquisition of property for facilities, school districts must consult with the planning agency of local governments (Gov. Code § 65402(c)).
- Before obtaining the title to land for a proposed school site or adjacent to a present school site, the governing board of each school district shall give written notice to the planning commission with jurisdiction. The planning commission shall then investigate the proposed site (Pub. Resources Code § 21151.2).
- "The governing board of any school district shall meet with appropriate local government recreation and park authorities to review all possible methods of coordinating planning, design, and construction of new school facilities and school sites or major additions" (Ed. Code § 35275).
- Prior to acquiring a school site that is designated in a local general plan for agricultural uses, a school district must consult with the local government (Ed. Code § 17215.5(a)). If the proposed school site is within an agricultural preserve, additional notification to the California Department of Conservation is required (Gov. Code § 51291(b)).
- Additional notification to the local airport land use commission may also be required (Pub. Utilities Code § 21676).

Consultation between local governments and school districts at these various points in the planning process may resolve conflicts before they arise, creating a more efficient process. Useful consultation topics may include

- District school facilities' master plans and the acreage necessary to build a school, as well as other location factors.
- The ability of potential school sites to be accessed by parents and students on foot, or by public transit.
- The potential impacts that agricultural operations, industry, waste facilities, or other polluting land uses may have on schools.
- The potential for joint use of parks or co-location with other facilities, given the tendency for schools to function as hubs for the community during school and non-school hours

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Proximity of schools to housing and transportation.	School locations, including private and charter schools, residential areas, transit maps, bike and pedestrian routes.
Potential joint use programs between schools and communities.	Community assets and needs, school facilities and hours.
Density of fast food outlets within ½ mile of schools (most relevant for high schools with open campuses).	City/county permit records.
Proximity of schools to safe active transportation options to/from home/school.	Circulation element (sidewalks, bike paths; school catchment areas), motor vehicle related pedestrian and bicycle crash rates.
Health impacts of location.	Youth obesity prevalence.

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Public Buildings and Grounds

Requirement Description:

The land use element must plan for the use of land for "public buildings and grounds" (Gov. Code § 65302(a)). Such "public buildings and grounds" may include community centers, libraries, and clinics. New or enhanced public facilities can catalyze other planned development as well as redevelopment of existing areas. Additionally, thoughtful distribution of public buildings can help ensure equitable access to public resources and services throughout the community. Consideration should be given to housing and transportation access surrounding proposed public buildings, as well as preservation of access to existing buildings and grounds. Depicting planned future public facilities in the general plan diagram or using symbols to identify possible future use may help align these uses with other community assets and needs.

An inventory of public buildings and grounds will help assess the distribution of public facilities across the community and identify underserved areas. The land use element should also assess the need for additional facilities based upon existing need for enhanced services and projected increases in land use intensity and population. An inventory of public and private historical landmarks (Pub. Resources Code § 5024) and existing public surplus land should also be included.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Equitable distribution of public facilities. Increased opportunity for community access to public facilities.	Community asset maps.
Access to public facilities.	Transit maps and timetables; population and demographics.
Density of fast food outlets within ½ mile of schools (most relevant for high schools with open campuses).	City/county permit records.
Opportunities for shared use of public buildings by communities, e.g., meeting spaces, auditoriums, etc.	Inventory of publicly owned facilities, including size, location, resources, and access.

Solid and Liquid Disposal Facilities

Requirement Description:

The land use element must plan for the use of land for "solid and liquid waste disposal facilities" (Gov. Code § 65302(a)). Plans should include an inventory of existing solid and liquid waste disposal, recycling, anaerobic digestion, remanufacturing and composting facilities to aid compliance with the Countywide Integrated Waste Management Plan and other associated laws as noted below. Waste reduction and recycling is an essential element of a sustainable community. In addition to conserving resources and protecting the environment, reducing waste and remanufacturing products using recycled materials benefits local communities by reducing greenhouse gas emissions, creating jobs, addressing food insecurity, and has many other benefits. Based upon projected land uses and population growth as well as potential opportunities to reduce waste streams, the land use element should consider the infrastructure that is needed to recover edible food waste and facilitate its delivery to food banks and other appropriate entities. The element should also consider the potential need for additional recycling, anaerobic digestion, composting and remanufacturing facilities. For example, recycling organic materials through composting, mulching, and anaerobic digestion – pursuant to SB 1383,

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the Short Lived Climate Pollutants Act of 2016, the Solid Waste: Diversion Act of 2011, the Solid Waste: Organic Waste Act of 2014 (SWOWA), the AB 32 Scoping Plan, and local requirements – can produce renewable energy and fuel and reduce GHG emissions. As jurisdictions establish organic material recycling programs, the general plan should consider the infrastructure that is needed to support increased diversion of organics from landfills, including the location of new facilities, the possibility of upgrading existing facilities to accommodate organic material specifically, (i.e., co-locating composting and digestion facilities at existing facilities such as transfer stations, material recovery facilities, and landfills), or the creation of new curbside collection requirements for food scraps with yard waste. The land use element should also include a transparent and proactive process to involve potentially impacted or disadvantaged communities in the early stages of facility planning and permitting processes. These issues may also be addressed in the county climate action plan. If relevant, cities and counties should consult with special districts and utilities providers to ensure the proposed land use plan is supported by adequate facilities.

In October of 2015, Governor Brown signed AB 876 (McCarty) to address longer-term planning for organics infrastructure by requiring counties and regional agencies to report the following information to CalRecycle commencing on August 1, 2017:

(1) An estimate of the amount of organic waste in cubic yards that will be disposed by the county or region over a 15-year period.

(2) An estimate of the additional organic waste recycling facility capacity in cubic yards that will be needed to process the amount of organic waste identified.

(3) Areas identified by the county or regional agency as locations for new or expanded organic waste recycling facilities capable of safely meeting the additional organic waste recycling facility capacity need identified.

Addressing the facilities that may need to be expanded or sited to process the organic materials in 15 years will require each county or regional agency to assess its unique situation, including existing facilities and their ability to process the material, and any new or expanded facilities that can be identified.

In addition, the general plan should consider the potential impacts of solid and liquid waste facilities, waste-to-energy plants, and similar facilities on surrounding land uses and access routes as identified in the circulation element. Generally, schools, hospitals, residences, and other potentially sensitive buildings should not be located where nearby facilities could have adverse health impacts. When designating new areas in the land use plan for waste facilities, the city or county should carefully consider whether surrounding areas are already burdened by existing sources of pollutants.

The publication, Model Goals, Policies, Zoning, and Development Standards for Composting and Remanufacturing Facilities, is intended to educate and inform local policy-makers and planners about land use planning approaches and zoning tools to encourage the economically beneficial use of recyclable materials generated in California. It identifies options and model language for general plan goals and policies, as well as zoning ordinance standards related to anaerobic digestion, composting, and remanufacturing facilities using recycled materials. These examples provide a starting point that can be modified to fit individual city or county circumstances.

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Planning for Organic Waste Diversion

California has an ambitious goal of 75 percent recycling, composting, or source reduction of solid waste by 2020. Achieving that goal will require the recycling, composting, or source reduction of an additional 23.5 million tons of recyclables annually, a significant portion of which is organic material. To redirect that much organic material by 2020 will require major efforts on many fronts, including the expansion or siting of many facilities to accommodate higher recycling volumes, stronger markets for recycled materials, ideally within underserved regions of the state, that are sustainable and responsive to local needs and opportunities.

In September 2016, Governor Brown signed SB 1383 (Lara, Chapter 395, Statutes of 2016), establishing methane emissions reduction targets in a statewide effort to reduce emissions of short-lived climate pollutants (SLCP) in various sectors of California's economy. Actions to reduce short-lived climate pollutants are essential to address the many impacts of climate change on human health, especially in California's most at-risk communities, and on the environment. SB 1383 establishes targets to achieve a 50 percent reduction in the level of the statewide disposal of organic waste from the 2014 level by 2020 and a 75 percent reduction by 2025. The law also establishes an additional target that not less than 20 percent of currently disposed edible food is recovered for human consumption by 2025. Additional information on the organic waste recycling requirements can be found at CalRecycle's SLCP Webpage.

SB 1383 builds upon California's leading commitments to reduce greenhouse gas emissions and air pollution statewide. Governor Brown identified reductions of short-lived climate pollutant emissions, including methane emissions, as one of five key climate change strategy pillars necessary to meet California's target to reduce greenhouse gas emissions 40 percent below 1990 levels by 2030 as established in SB 32 (Pavley, Chapter 249, Statutes of 2016). SB 1383 will further support California's efforts to achieve other policies, such as increased commercial recycling as mandated by the Solid Waste: Organic Waste Act of 2014, hereafter referred to as SWOWA, and greater recycling by the general public.

To achieve these goals and targets, local agencies are turning to innovative technologies like anaerobic digestion to convert waste into energy and to reduce greenhouse gas emissions that contribute to climate change. Local anaerobic digestion projects provide a number of benefits including landfill disposal cost savings, the ability to meet greenhouse gas reduction and state waste diversion goals, and increased community pride and recognition for their role as an environmental leader. Anaerobic digestion facilities have the option of producing electricity or natural gas with heat as a co-product. Electricity can be used to power the facility itself or can be exported to the electrical grid. Natural gas can be used to fuel natural gas vehicles, including solid waste and recycling trucks, delivery trucks, passenger vehicles, and buses. Either energy choice will generate a revenue stream which can help offset the costs of the facility.

The Sacramento BioDigester started in 2012 with the capacity to process 10,000 tons of food waste per year, and its capacity expanded to four times that amount in early 2015. The 40,000 ton input capacity includes food waste from area restaurants, food processors, hospitals, the international airport, elementary schools, and supermarkets. The 730,000 gallons of biofuel produced annually are used at an onsite fueling station to fuel all of the natural gas trucks of the local trash and recycling collection fleet (24 of 55 trucks) as well as a portion of the city's and county's waste fleets, security cars, California State University, six Sacramento commuter buses, and two local

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catering companies. The BioDigester also has an exclusive contract to provide natural gas to Sacramento School District's 6-12 buses and is the backup provider for Elk Grove's 6-12 buses. The waste gas that is not clean enough to use for transportation fuel is used to produce one million kilowatts of electricity which powers both the facility and the fueling station. The digestate is used to produce eight million gallons of organic soils and fertilizers for Sacramento area farms.

Alameda County adopted its Community Climate Action Plan in February of 2014. It builds off the county's already exemplary waste management programs by establishing a target of diverting 90 percent of all waste from landfills by 2030 with an interim goal of 82.5 percent by 2020. To achieve this, the county has outlined measures and strategies that include mandatory household and commercial food waste recycling and a corresponding outreach and education program. The Alameda County Waste Management Authority Board, also known as StopWaste.Org, is a joint powers authority. Its members include the county, the fourteen cities in the county, and two special districts that provide solid waste and recycling services. Its education activities aim to encourage businesses to recycle and include technical assistance for waste prevention and recycling, targeted outreach and assistance to large businesses, online resources for smaller businesses, grants for businesses, and a high profile recognition program for businesses that recycle.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Safety and health concerns for vulnerable populations.	Locations of schools and hospitals as well as populations of children and elderly facilities or communities.
Vehicle miles traveled (VMT) effects of waste facility location.	Distances and frequency of truck travel between residential and commercial centers and facilities; local sustainable communities strategies (SCS).
15 years capacity needed for organics recycling.	Capacity needed and available/planned infrastructure.

Greenways

Requirement Description:

A land use element must designate the proposed general distribution, location, and extent of uses of land for greenways, defined by Civil Code 816.52(b) as "a pedestrian and bicycle, nonmotorized vehicle transportation, and recreational travel corridor that meets the following requirements:

(1) Includes landscaping that improves rivers and streams, provides flood protection benefits, and incorporates the significance and value of natural, historical, and cultural resources, as documented in the local agency's applicable planning document, including, but not limited to, a master plan, a general plan, or a specific plan.

(2) Is separated and protected from shared roadways, is adjacent to an urban waterway, and incorporates both ease of access to nearby communities and an array of amenities within an urbanized area and services for the users of the corridor and nearby communities.

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(3) Is located on public lands or private lands, or a combination of public and private lands, where public access to those lands for greenway purposes has been legally authorized by, or legally obtained from, the fee owner of the land and, if applicable, the operator of any facility or improvement located on the land, through leases, easements, or other agreements entered into by the fee owner and the operator of any affected facility or improvement on the land.

(4) Reflects design standards regarding appropriate widths, clearances, setbacks from obstructions, and centerlines protecting directional travel, and other considerations, as appropriate, that are applicable for each affected local agency, as documented in the local agency's applicable planning document, including, but not limited to, a master plan, general plan, or specific plan, and that are consistent with plans and facilities for controlling the floodwater of rivers and their tributaries, as applicable.

(5) May incorporate appropriate lighting, public amenities within an urbanized area, art, and other features that are consistent with a local agency's planning document, including, but not limited to, a general plan, master plan, or specific plan."

Planning for greenways should coordinate closely with the circulation, conservation, and open space elements, and consider implications on community health, economic development, environmental justice, and social equity.

Identify and Annually Review Areas Subject to Flooding

Requirement Description:

In addition to the requirement to designate specific land uses, the land use element must "identify and annually review those areas covered by the plan that are subject to flooding identified by flood plain mapping prepared by the Federal Emergency Management Agency (FEMA) or the Department of Water Resources" (Gov. Code § 65302(a)).

When fully informed by applicable flood information and assessments of climate change impacts and management practices, careful land use planning can effectively reduce vulnerability to potential flood damage in cities and counties. Such careful planning can include non-structural flood protection measures, low impact development, and improved stormwater management practices. Federal, state, and local agencies may construct and operate flood protection facilities to reduce flood risks, but some amount of risk will remain for those residing in floodplains. Therefore, increasing awareness can help ensure Californians recognize the potential threat and are better prepared to respond to flood emergencies.

The Land Use: Water Supply Act of 2007 (AB 162, Wolk) requires additional consideration of flood risk in local land use planning throughout California and named the Department of Water Resources (DWR) as a source for floodplain information and technical data for local governments. The Sustainable Groundwater Management Act of 2014, hereinafter referred to as SGMA, considers the connections between groundwater management, land use, and flood management and allows local agencies to customize plans to their regional needs.

DWR published two reports—Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities and Guidance on General Plan Amendments for Addressing Flood Risk—to provide assistance and recommendations for local government compliance with 2007 flood legislation. DWR also created a sustainable groundwater management toolbox to assist with SGMA.

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Local jurisdictions must assess floodplain mapping, groundwater recharge, and stormwater management information and determine any needed changes in the general plan. If new data comes to light, then the existing general plan's background information, maps, goals, policies, and implementation measures may need updating. As flood risk may change over time, cities and counties should establish policies for land use that are consistent with evolving flood risks.

The land use element policies addressing flooding should also be consistent with additional flood control policies required in the conservation and safety elements, as well as any policies related to climate change, and should consider the potential for groundwater recharge benefits for water supply. When linked to consistent policies in other elements, addressing flooding through hazard area identification and land use management policies may help jurisdictions reduce redundancy in their general plans

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Incorporate stormwater capture and low impact development (LID) for water supply benefits and safety into site planning.	Levee flood protection zones; 100-year floodplain maps; 200-year floodplain maps (if available); 500-year floodplain maps; Awareness floodplain maps; Best available maps.
Identify populations with evacuation challenges.	US Census data on disabled persons, the elderly, and households with transportation barriers.
Identify opportunities for integration between habitats.	Choices in site planning – see DWR Land Use Surveys.

Identification of Timberland Production Zone Lands

Requirement Description:

The land use element must designate "parcels of real property zoned for timberland production pursuant to the Timberland Productivity Act of 1982 ..." (Gov. Code § 65302(a)(1)). Under the Z'berg-Warren-Keene-Collier Forest Taxation Reform Act of 1976, land zoned for timber production receives substantial tax benefits. Such timber production zones (TPZ), also known as timber preserve zones, are restricted to the production of timber or compatible use for ten years, followed by annual automatic renewal unless otherwise terminated (Gov. Code § 51114, 51115). These acres of TPZ represent the State's long-term, privately owned forestland base.

As population increases, encroaching development threatens timberland production zones. The state discourages the expansion of urban services into timberlands and "premature or unnecessary conversion of timberland to urban and other uses" (Gov. Code § 51102(a)). Ensuring the continual growing and harvesting of timber is important "to ensure the long-term productivity of the forest resource, the long-term economic viability of the forest products industry, and long-term stability of local resource-based economies" (Gov. Code § 51101(c)). The land use element regarding TPZ should support and remain consistent with policy objectives in the conservation and open space elements

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Impact of New Growth on Military Readiness Activities

Requirement Description:

A land use element must include consideration of impacts to the military's operations. Specifically, Government Code section 65302(a)(2) requires consideration of impacts of land use decisions on military. The law states that the land use element of the general plan shall "[c]onsider the impact of new growth on military readiness activities carried out on military bases, installations, and operating and training areas, when proposing zoning ordinances or designating land uses covered by the general plan for land, or other territory adjacent to military facilities, or underlying designated military aviation routes and airspace" (Gov. Code § 65302(a)(2)).

To encourage collaboration between the military and local jurisdictions and to prevent land use conflicts with military installations and training activities, California law created a notification process to inform the military of local land use proposals that might have an impact on military facilities and operations. The law requires that local governments 1) use development permit applications that identify proposed projects within 1,000 feet of a military installation, beneath a low-level flight path, or within special use airspace and 2) notify the military when a proposed project, or an updated or revised general plan, might have an impact on military facilities and operations (Gov. Code § 65944(d)). The California Military Land Use Compatibility Analyst (CMLUCA) can help identify where military operations are in relation to cities and counties. CMLUCA can also generate a report to notify the military when there is a project proposed under military airspace.

Military Compatibility Planning Resources

For more information on military compatibility issues, please see OPR's California Advisory Handbook for Community and Military Compatibility Planning and the Community and Military Compatibility Planning: Supplement to the General Plan Guidelines.

Military staff are available to work with local governments on military compatible land use planning. For more information, and a memo on Government Code section 65352(a)(6)(A) and Government Code section 65944(e) notification requirements, please see OPR's California Strategic Coordination and Engagement Program.

Local military activity or Department of Defense Service points of contact can provide specific information about military installations and training areas within your county or city. It is important to check with the military points of contact to discuss the particular military operations in your area and how a local government's vision for development can be compatible with those operations. In the case of areas with low-level flight paths, it is particularly important to coordinate with the branch points of contact. OPR maintains a list of military branch points of contact.

Each city and county should implement a process to identify, coordinate, and assist in resolving potential land use conflicts within nearby military training areas or under military special use airspace to ensure that new development is compatible with military operations and with mission training and testing requirements. New development should be reviewed and regulated to avoid impact to military operations areas (MOAs) and to maintain public safety. The General Plan Mapping Tool and the CMLUCA both can help map locations of military operations. The local jurisdiction should inform the military officials of any changes by school districts, charter schools or other state level agencies that may affect military readiness.

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SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Map military sites in relation to general plan area.	CMLUCA

Identify Unincorporated Island or Fringe Communities (Cities) or Legacy Communities (Counties)

Requirement Description:

According to legislative findings in Senate Bill 244 (Wolk, 2011), hundreds of unincorporated communities in California lack access to basic community infrastructure like sidewalks, safe drinking water, and adequate waste processing. These communities range from remote settlements throughout the state to neighborhoods that have been surrounded by, but are not part of, California's fast-growing cities. This lack of investment threatens residents' health and safety and fosters economic, social, and education inequality. Moreover, when this lack of attention and resources becomes standard practice, it can create a matrix of barriers that is difficult to overcome.

The purpose of SB 244 is to begin to address the complex legal, financial, and political barriers that contribute to regional inequity and infrastructure deficits within disadvantaged unincorporated communities.

Including these communities in the long range planning of a city or county, as required by SB 244, will result in a more efficient delivery system of services and infrastructure, including sewer and water services, structural fire protection, and other needs. In turn, investment in these services and infrastructure will result in the enhancement and protection of public health and safety for these communities.

The land use element must identify fringe, island, and legacy communities that are disadvantaged unincorporated communities. The identification must include a description of the community and a map illustrating its location. General plan law defines a community as "an inhabited area within a city or county that is comprised of no less than 10 dwellings adjacent or in close proximity to one another" (Gov. Code § 65302.10(a)(1)). SB 244 defines a "disadvantaged community" as a community with an annual median household income that is less than 80 percent of the statewide annual median household income (Gov. Code § 65302.10(a)(2).)[1]

Building infill development can maximize urban space and conserve resources





Image by Urban Advantage, Contra Costa County, CA

1 It should be noted that this definition of "disadvantaged community" is slightly different than the definition that applies for purposes of the environmental justice element required by SB 1000 (Gov. Code § 65302(h)(4)(A)).

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"[I]sland communities" are defined as any inhabited and unincorporated territories that are surrounded or substantially surrounded by one or more cities or by one or more cities and a county boundary or the Pacific Ocean (Gov. Code § 65302.10(a)(4)); and "fringe communities" are defined as any inhabited and unincorporated territories that are within a city's sphere of influence (Gov. Code § 65302.10(a)(3)).

"Legacy communities" are defined as any geographically isolated communities that are inhabited and have existed for at least 50 years (Gov. Code § 65302.10(a)(5)).

Certain terms within these definitions can be interpreted differently based on local context. For example, terms such as "substantially surrounded" or "close proximity" can differ greatly between rural and urban communities.

Cities and counties should not rely solely on lists of disadvantaged unincorporated communities compiled by their LAFCO. Instead planners must do their own independent identification of all communities that meet the definition given above. Cities and counties may consult other agencies, organizations and reports that have identified unincorporated communities for assistance.

Planning for Disadvantaged Unincorporated Communities (Gov. Code § 65302.10)

(b) On or before the due date for the next adoption of its housing element pursuant to Section 65588, each city or county shall review and update the land use element of its general plan ... [to] include all of the following:

(1) In the case of a city, an identification of each island or fringe community within the city's sphere of influence that is a disadvantaged unincorporated community. In the case of a county, an identification of each legacy community within the boundaries of the county that is a disadvantaged unincorporated community but not including any area within the sphere of influence of any city. This identification shall include a description of the community and a map designating its location.

(1) For each identified community, an analysis of water, wastewater, stormwater drainage, and structural fire protection needs or deficiencies.

(1) An analysis, based on then existing available data, of benefit assessment districts or other financing alternatives that could make the extension of services to identified communities financially feasible.

(c) On or before the due date for each subsequent revision of its housing element pursuant to Section 65588, each city and county shall review, and if necessary amend, its general plan to update the analysis required by this section.

As part of the analysis of disadvantaged unincorporated communities, the land use element must analyze the water, water supply, wastewater, stormwater drainage, and structural fire protection needs or deficiencies for each community. The analysis should consider both the horizon year and the impacts of a changing climate. This analysis should also consider adequacy of groundwater resources, and be consistent with utilities planning in the circulation element and the fire and flood protection policies in the safety element. LAFCo municipal service reviews can be helpful in supporting this analysis.

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The analysis must also review the use of benefit assessment districts or other financing alternatives that could make the extension of services to identified communities financially feasible. Each time the housing element is updated, the analysis for these communities must be reviewed, and if necessary, updated.

For more information, please see OPR's SB 244 Technical Advisory.

Cities and counties should use this chart to ask these questions while undergoing disadvantaged communities analysis:

Type of Infrastructure	What is serving the community now?	What is the need for additional infrastructure?	How can finance mechanisms meet the need?	Which other programs and policies could address the infrastructure deficiency?	What is the community's input?
Required (§65302.10)					
Water					
Wastewater					
Stormwater Drainage					
Structural Fire Protection					
Potential Additional Services					
Police Protection					
Sidewalks					
Lighting					
Libraries, Schools, Community Centers, etc.					
Alleys and other unsafe roadways					
Public transit/ transportation					
Preschools and childcare providers					

The land use element should be updated to include disadvantaged unincorporated communities analysis (Gov. Code § 65302.10). Since all elements of a general plan must be internally consistent, the safety element, the circulation element, and other elements as necessary should be reviewed to ensure consistency (Gov. Code § 65300.5).

The disadvantaged unincorporated analysis should consider where there may be opportunities to provide more efficient, high quality service through consolidation, extension of services, and other regional solutions to address inadequacy of services and infrastructure. In addition, the analysis should consider whether the reorganization will unify or divide any other public agencies such as school districts, transit districts, and flood management agencies.

Correlation with Circulation Element

Senate Bill 375, the Sustainable Communities and Climate Protection Act of 2008 (Steinberg), hereinafter referred to as SB 375, supports the state's climate action goals to reduce GHG emissions through coordinated transportation and land use planning and to create sustainable communities. This concept is discussed further in the circulation element section.

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The Land Use Element and Regional Sustainable Communities Strategies

> *California's land is an exhaustible resource, not just a commodity, and is essential to the economy, environment and general well-being of the people of California. It is the policy of the state ... to protect California's land resource, to insure its preservation and use in ways which are economically and socially desirable in an attempt to improve the quality of life in California.* (Gov. Code § 65030).

Most land use approvals occur at the local government level. Nevertheless, local land use elements must reflect their statewide and regional contexts. For example, Government Code section 65030.1 states:

> [D]ecisions involving the future growth of the state, most of which are made and will continue to be made at the local level, should be guided by an effective planning process, including the local general plan, and should proceed within the framework of officially approved statewide goals and policies directed to land use, population growth and distribution, development, open space, resource preservation and utilization, air and water quality, and other related physical, social and economic development factors."

When adopting a general plan, local governments must consult with other entities that may be affected by the plan, such as neighboring cities, counties and special districts, school districts, local agency formation commissions, area-wide planning agencies, federal agencies, the military, water providers, and California Native American tribes (Gov. Code § 65352).

Several regional activities may directly bear on local land use planning. One significant example is the sustainable communities strategy contained within regional transportation plans. While the Government Code states that a sustainable communities strategy does not regulate the use of land (Gov. Code § 65080(b)(2)(K)), local governments should consider and, if appropriate, incorporate applicable policies into local land use elements for several reasons.

First, sustainable communities strategies should already reflect the basic outlines of local plans. Second, some transportation funding is tied to consistency with the regional transportation plan. Third, consistency with the sustainable communities strategy may help streamline benefits under the California Environmental Quality Act of 1970 (CEQA). Fourth, CEQA analysis for the general plan requires analysis of any inconsistency with the regional transportation plan.

A sustainable communities strategy might be relevant to a local land use element in several ways. A sustainable communities strategy should identify locations within the region where land use and transportation investments can be maximized. Therefore, a local government planning agency should consider whether the land use element places development in transportation-efficient locations as identified in the sustainable communities strategy. Other relevant policies include density and intensity maximums and minimums, as well as policies related to active transportation and protection of public health. Incorporating such policies into a local land use element and diagram may assist the local government in avoiding conflicts with neighboring jurisdictions and perhaps more importantly, in maximizing the benefits of transportation funding and regulatory streamlining.

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Transit Oriented Development (TOD)

Cities and counties should promote more livable communities by expanding opportunities for transit-oriented development (TOD) so that residents minimize traffic and pollution impacts from traveling for work, shopping, school, and recreation. TOD is defined as moderate to high-density development located within an easy walk of a major transit stop, generally with a mix of residential, employment, and shopping opportunities. TOD encourages walking and transit use without excluding the automobile. According to the California Department of Transportation, "TOD can be new construction or redevelopment of one or more buildings whose design and orientation facilitate transit use." A well-designed, vibrant TOD community can provide many benefits for local residents and businesses, as well as for the surrounding region. Compact development near transit stops can increase transit ridership and decrease rates of vehicle miles traveled (VMT) thereby yielding a good return on transit system investments. TOD can also provide mobility choices, increase public safety, increase disposable household income by reducing transportation costs, reduce air pollution and energy consumption rates, help conserve resources and open space, assist in economic development, and increase the housing supply. TOD is a strategy that may help a community achieve its general plan goals related to circulation, housing, environmental quality, and economic development. Additionally, by improving access to jobs and housing and revitalizing existing neighborhoods, TOD can be a tool for promoting environmental justice. A variety of factors need to be considered during the development and implementation of TOD. These factors include transit system design; community partnerships; understanding of local real estate markets; coordination among local, regional, and state organizations; and providing the right mix of planning and financial incentives and resources. A successful TOD will reinforce the community and the transit system. Transit operators, property owners, and residents should be involved in the development of TOD proposals. Planners should consult data to identify and assess potential locations for TOD during preparation of the land use, circulation, and housing elements of the general plan. An inventory of potential development (and redevelopment) sites within a quarter to a half mile of existing and proposed transit stops may reveal potential locations for TOD. Additional data may be used to verify the optimum location and mix of uses to further refine the viability of TOD at specific transit hubs. These data may include origin and destination studies, transit ridership protections, and information related to the appropriate jobs-to-housing ratio and level of retail services. The appropriate density and intensity will support a high level of transit service. Local governments can promote TOD through general plan policies that encourage supportive densities and designs and a mix of land uses. TOD-supportive policies provide for higher land use densities, reduced parking requirements, decreased automobile traffic levels of service, and increased transit levels of service. TOD policies should facilitate a pedestrian-oriented environment with features such as traffic calming strategies, traditional street grid patterns with smaller blocks, and architecture that orients buildings to sidewalks, plazas, and parks rather than to parking.

Land use policies should align with other elements to provide opportunities for innovation and co-benefits



Image by Urban Advantage, JBG Companies; Duany Plater-Zyberk & Company

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies and examples can be found here

Sample Policy	Example of Application	Relationship to Other Elements
Provide for and encourage the development of a broad range of uses in the [city/county]'s commercial centers and corridors that reduce the need to travel to adjoining communities and capture a greater share of local spending.	La Habra	Circulation, economic development, climate change
[City, county shall] require that new neighborhoods be designed to locate all housing within ½ mile of a central gathering place that incorporates public spaces, shopping areas, access to transit, and/or community-supportive facilities and services.	Sacramento	Circulation, open space, equitable and resilient communities, healthy communities, economic development
[City, county shall] prioritize the provision of necessary major street infrastructure and utility capacities for properly zoned land, consistent with the general plan so that such land can be developed in a timely manner to supports economic development.	Fresno	Circulation, economic development
[City, county shall] review the general plan's residential and commercial capacities every five years and modify, as necessary, to reflect development that has occurred, its impacts, evolving market and economic conditions, and consistency with community values.	Pasadena	Open space, conservation, healthy communities, climate change

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Circulation Element

Introduction

The circulation element is not simply a transportation plan, but rather a strategy addressing infrastructure needs for the circulation of people, goods, energy, water, sewage, storm drainage, and communications. By statute, the circulation element must correlate directly with the land use element, but also has direct relationships with other elements. The provisions of a circulation element affect a community's physical, social, and economic environment, as well as its health. The passage of SB 1000 in 2016 requires local governments to address environmental justice considerations related to circulation--such as access to transportation systems, air quality related to transportation, delivery routes and transit options for nutritional food access, and promotion of physical activity—upon the next revision of two or more elements in their general plan after January 1, 2018.

Government Code Section 65302 (b)

(1) A circulation element consisting of the general location and extent of existing and proposed major thoroughfares, transportation routes, terminals, any military airports and ports, and other local public utilities and facilities, all correlated with the land use element of the plan.

(2) (A) Commencing January 1, 2011, upon any substantive revision of the circulation element, the legislative body shall modify the circulation element to plan for a balanced, multimodal transportation network that meets the needs of all users of streets, roads, and highways for safe and convenient travel in a manner that is suitable to the rural, suburban, or urban context of the general plan.

(B) For purposes of this paragraph, "users of streets, roads, and highways" mean bicyclists, children, persons with disabilities, motorists, movers of commercial goods, pedestrians, users of public transportation, and seniors.

Transportation systems are essential to any city or county and its economy, and can be designed to enhance opportunity and improve equity. However, the implementation and maintenance of infrastructure and resources is costly, impacts the environment, and affects human health. Transportation planning in California is rapidly changing, driven by a number of key factors:

- An increasing focus on access to destinations (connectivity) rather than just mobility, and transportation solutions involving proximity that better accomplish livability and environmental goals
- Constrained local government budgets
- A mismatch of anticipated revenue and future maintenance obligations under current policies
- An increasing focus on greenhouse gas emissions reduction and an ongoing focus on air quality

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- An increasing recognition that we cannot "build our way out of congestion," in part because new capacity encourages more driving, but that congestion can be addressed with roadway pricing measures
- An increasing recognition of the transportation network's effect on land use, and in turn the effect of more disperse land use on the environment and human health
- Demographic and social trends creating increased demand for infill and walkable neighborhoods
- Emerging transportation solutions such as carshare, rideshare, and bikeshare services, which can reduce automobile dependence
- Enhanced technology and information such as Nextbus and Intelligent Transportation Systems (ITS) making navigation of multiple transportation systems more simple and convenient and in some cases influencing transportation choices.
- Introduction of emerging technologies such as partially or fully autonomous vehicles with potential to sharply increase VMT and alter land use scenarios

Further, recent legislation has driven change in the way local governments approach transportation and the types of solutions available:

- The Complete Streets Act
- Global Warming Solutions Act (AB 32)
- SB 32
- The Sustainable Communities and Climate Protection Act (SB 375) and the completion of Sustainable Communities Strategies
- CEQA Streamlining for infill projects (SB 226)
- Shift in CEQA transportation metric away from LOS to VMT (SB 743)

Many California communities are substantially revising their circulation elements to respond to and take advantage of this new legislation.

CORRELATIONS AMONG ELEMENTS

	Land Use	Housing	Conservation	Open Space	Noise	Safety	EJ
Circulation	IN STATUTE	RELATED	RELATED	RELATED	IN STATUTE	RELATED	RELATED

■ Identified in statute ■ Closely related to statutory requirements

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Completeness Checklist

Local agency staff can use the following checklist to help ensure that the draft circulation element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required in Government Code section 65302(b). Circulation elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied

Statutory Citation	Brief Description of Requirement
Gov. Code, § 65302(b)(1)	Existing and proposed major thoroughfares
Gov. Code, § 65302(b)(1)	Existing and proposed transportation routes
Gov. Code, § 65302(b)(2)	• Public transportation
Gov. Code, § 65302(b)(2)	• Bicycle
Gov. Code, § 65302(b)(2)	• Pedestrian
Gov. Code, § 65302(b)(2)	• Automobile
Gov. Code, § 65302(b)(2)	• Commercial goods
Gov. Code, § 65302(b)(1)	Existing and proposed terminals
Gov. Code, § 65302(b)(1)	Military airports and ports
Gov. Code, § 65302(b)(1)	Other local public utilities and facilities
Gov. Code, § 65302(b)(2)	Needs of children, persons with disabilities, and seniors?
Gov. Code, § 65302(b)(1); Fed. of Hillside & Canyon Assns. v. City of Los Angeles (2004) 126 Cal. App. 4th 1180, 1196	Identified funding for infrastructure identified in circulation element?
Gov. Code, § 65302(b)(1)	Circulation element is correlated with the land use element?

Required Contents

The circulation element must, consistent with Government Code Section 65302 (b), include the location and extent of existing and proposed

- Major thoroughfares
- Transportation routes
- Terminals
- Military airports and ports
- Public utilities and facilities

Statutory Requirements

The Government Code requires that any revision of circulation elements after Jan 1, 2011 must plan for a "balanced, multimodal transportation network that meets the needs of all users of streets, roads, and highways for safe and convenient travel in a manner that is suitable to the rural, suburban, or urban context of the general plan." Users are defined in statute as "bicyclists, children, persons with

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disabilities, motorists, movers of commercial goods, pedestrians, users of public transportation, and seniors." For more information on integrating complete streets concepts to help address these requirements, see OPR's "Complete Streets and the Circulation Element."

The circulation element must identify funding for capital, operations, and maintenance of planned additions to the network, additions that would be triggered by policies in the element, and the existing network.

Relationship with Regional Planning

California courts have recognized that general plans must reflect the regional context. Circulation elements must, therefore, account for both regional transportation plans and, in some cases, congestion management plans.

Regional Transportation Plans

Metropolitan planning organizations and regional transportation planning agencies prepare regional transportation plans in cooperation with Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Caltrans, the Air Resources Board, the Department of Housing and Community Development and other stakeholders, including system users. The purpose of the regional transportation plan is to establish regional goals, identify present and future transportation needs, deficiencies and constraints, analyze potential solutions, estimate available funding, and propose investments. In most regions in California, the regional transportation plan includes a sustainable communities strategy that aligns transportation investments with a land use pattern designed to reduce regional greenhouse gas emissions. In order to be eligible for federal and state funding, transportation projects must be consistent with the adopted regional transportation plan, including an applicable sustainable communities strategy.

Regional transportation plans are required to reflect certain population growth and distribution assumptions contained in local general plans. As a practical matter, circulation elements should also reflect the adopted regional transportation plan to ensure access to transportation funds. If adopting a circulation element that is not consistent with the regional transportation plan, that inconsistency and its impact on regional greenhouse gas reductions also should be discussed in the environmental analysis under the California Environmental Quality Act. (See, e.g., CEQA Guidelines § 15125(d).)

Correlation with the Land Use Element

Requirement Description:

Creating connected, accessible, and complete systems of circulation networks and ensuring access to opportunities within a community and region requires coordination between land use and circulation planning. Due in part to the connection between transportation funding and greenhouse gas reduction established in SB 375, vehicle miles traveled (VMT) is an increasingly important metric of impact in the circulation element. Because the circulation element is required to correlate with the land use element, it should account for the features of the particular community. For example, the circulation element can demonstrate

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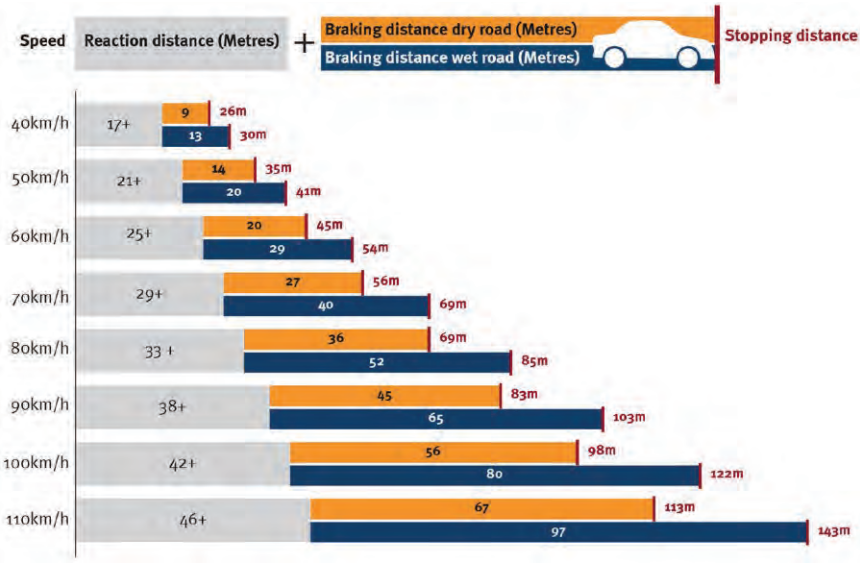
connectivity between residential uses, services and employment centers. Lack of transportation options from identified disadvantaged communities to essential destinations, such as grocery stores, may be improved through circulation (e.g. working with transit provider to increase transit frequency) or land use (e.g. new commercial development). Mapping transportation options as part of the general plan process may help identify gaps to address. The land use and circulation elements are useful places to plan for equitable access for all community members. Pedestrian and bicycle routes in the circulation element should connect residential areas identified in the land use element with jobs centers, parks, schools, and other destination centers. Truck routes should be directed away from noise- and emissions-sensitive residents and designated instead to serve areas designed for commercial and industrial uses in the land use element. The design speed of a roadway should equal its target speed (in other words, a street should be designed to accommodate intended auto speeds, not faster speeds).

Figure 4: How long a stop takes based on speed (driving an average family car)



Source: https://www.qld.gov.au/transport/safety/road-safety/driving-safely/stopping-distances

Regional Transportation Plans, SB 375, and Sustainable Community Strategies

The Sustainable Communities and Climate Protection Act of 2008 (Sustainable Communities Act, SB 375, Chapter 728, Statutes of 2008) supports the State's climate action goals to reduce greenhouse gas (GHG) emissions through coordinated transportation and land use planning with the goal of more sustainable communities.

Under the Sustainable Communities Act, ARB sets regional targets for GHG emissions reductions from passenger vehicle use. In 2010, ARB established these targets for 2020 and 2035 for each region covered by one of the State's metropolitan planning organizations (MPO). ARB will periodically review and update the targets, as needed.

Each of California's MPOs must prepare a "sustainable communities strategy" (SCS) as an integral part of its regional transportation plan (RTP). The SCS contains land use, housing, and transportation strategies that, if implemented, would allow the region to meet its GHG emission reduction targets. Once adopted by the MPO, the RTP/SCS guides the transportation policies and investments for the region.

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Special attention should be paid to ensure that all transportation facilities are designed to be safe, accessible, and connected for all users. Simply putting a sidewalk or a bike lane on one street, for example, without a complete system that connects residents and destinations, may not address the needs of a community. Using context sensitive, flexible designs can help increase access for all users while improving overall conditions or addressing common issues such as storm-water runoff, air quality, and bicyclist and pedestrian safety. For additional information on the design of complete streets, see NACTO Street Design Guidelines and Caltrans Complete Street Guidelines.

As noted above, the circulation element and the land use element must correlate. One of the most recent appellate court cases addressing the correlation requirement explained:

> [T]he internal consistency and correlation requirements do not require a city or county to limit population growth or provide traffic management measures to ensure that its transportation infrastructure can accommodate future population growth. The Planning and Zoning Law (Gov. Code, § 65000 et seq.) does not require a city or county to avoid adverse impacts on transportation. Rather, the city has broad discretion to weigh and balance competing interests in formulating development policies.... *(Federation of Hillside & Canyon Assns. v. City of Los Angeles* (2004) 126 Cal. App. 4th 1180, 1196.)

In characterizing the correlation requirement, the same court explained that "the circulation element of a general plan must provide meaningful proposals to address changes reflected in the land use element, and the land use element must provide meaningful proposals to reflect changes reflected in the circulation element" (Ibid). A proposal is "meaningful" if the element identifies reasonably reliable funding sources (Id. at 1196-1197). An element that identifies proposals with no reasonable expectation of implementation (i.e., funding) is not meaningful, and therefore would not satisfy the statutory correlation requirement (Id.; see also *Concerned Citizens of Calaveras County v. Board of Supervisors* (1985) 166 Cal. App. 3d 90, 103).

Proposals should address not just capital costs, but also costs associated with operations and maintenance. Because the circulation element addresses both transportation and local public utilities, the statutory correlation requirement applies to utilities infrastructure as well.

Appropriate fiscal analyses should be prepared to support the conclusion that the circulation element is capable of supporting the land uses planned in the land use element. Certain transportation funds are tied to consistency with regional sustainable communities strategies, so consistency with regional plans should be part of this analysis.

Tools are available to allow comparison of total infrastructure costs and benefits across several build-out scenarios. These tools enable communities to make decisions regarding land use patterns with long-term infrastructure costs and benefits in mind. More information on these tools and how to use them is available here.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Examine potential policies for local implementation of SCS	Modal split rates, transportation emissions data, transit access maps
Identify gaps in network connectivity	Transit maps, bicycle and pedestrian infrastructure maps, major destinations, and residential centers

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Major Thoroughfares

Requirement Description:

Consideration must be given in the general plan to the development and improvement of major thoroughfares, including future acquisitions and dedications, based on proposed land use patterns and projected demand. Cities and counties should consider the location and design of major thoroughfares in new developments, as well as street patterns (curvilinear, grid, modified grid, etc.), multi-modal use and safety, coordination with other infrastructure such as utilities, and relationships between destinations and transportation systems. Relationships between intended users of streets, including freight trucks, transit, automobiles, bicyclists, and pedestrians, should be considered. Design standards for local streets (including, but not limited to, width, block size, speed, and accommodation of parking and bicycle and pedestrian traffic) may also be included in the circulation element. Information on safety elements of design is available in Appendix B. Providing charging stations and alternative fuel stations can facilitate use of zero emissions vehicles, reducing air pollutants and greenhouse gas emissions.

Transportation Routes

Requirement Description:

The transportation system consists of means to transmit vehicles and people (e.g. roads, sidewalks), docks to station vehicles at their destination (e.g. parking lots, ports), and the vehicles themselves (e.g. busses, bicycles, cars). In developing a general plan, a jurisdiction should consider its overall objectives, and develop policies for each of these three components that support those objectives.

Local governments should coordinate transportation routes with larger regional route plans, such as regional or state freight plans, regional transportation plans, and regional transit corridors. Consideration of multiple modes as part of a transportation system, combined with data on projected needs and uses, and local land use data, may help prioritize routes based on community needs. For example, a county may designate a freight corridor to run parallel to existing regional transit lines, utilizing the same infrastructure where possible, and directing both away from sensitive land uses such as schools.

Roads

Requirement Description:

The underlying goal of transportation is to provide connectivity (also called "accessibility" or "access to destinations)." Connectivity is provided by mobility (increased speed) and proximity (reduced distance). The transportation system has traditionally been evaluated primarily through a mobility lens, measuring speed (e.g. via delay metrics like Level of Service). In addition, the primary focus of mobility has been on Automobile Level of Service (LOS), a localized (intersection or roadway segment) measure of auto-mobility. The Complete Streets Act of 2008, as well as recent changes in CEQA and congestion management law, highlight a need for circulation elements to have a broader focus that includes other modes.

Upon review of existing policies, many local governments may find that existing automobile LOS standards are not sustainable or even desirable. For example, a high automobile LOS may be too expensive to maintain, may be unsafe for non-auto users, and may force different uses to be spread so far apart that travel becomes inconvenient.

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Ideally, going forward, the circulation element of the general plan will include a discussion of the transportation system designed using metrics that capture connectivity (the fundamental purpose of transportation) rather than mobility (just one facet of connectivity). Examples of such measures include number of jobs accessible within 30 minutes, number of retail destinations reachable in a ten-minute walk, and number of hospitals accessible by a 45-minute transit ride. Even where metrics like Level of Service are still used, local governments should consider the following ways to account for limitations:

- Use Level of Service during the planning process to size roadways, but not as a measure of individual project impacts.
- Level of Service should be balanced with other metrics when used, rather than triggering decisions by itself. Other metrics are needed to measure the efficacy, comfort and safety of other transportation modes, and to measure the proximity benefits conferred by infill development. It is important to estimate the cost of achieving any Level of Service threshold, in order to determine whether that threshold is fiscally feasible, and to identify, where possible, funding for long-term maintenance costs associated with building to any Level of Service thresholds.
- Set Level of Service thresholds in consideration of the tradeoffs between mobility and other goals. Accommodating automobile traffic has direct tradeoffs with greenhouse gas emissions, other emissions that affect air quality, pedestrian collision risk, and active mode share and the resulting public health benefits. It also leads to sparser land development patterns, creating indirect tradeoffs with consumption of agricultural land and sensitive habitat, energy use, water use, and water runoff affecting water quality and flood risk. A general plan should consider these tradeoffs when recommending a Level of Service objective.

Planning for safe transportation systems has often used LOS to attempt to streamline automobile flow, accommodating driver error in an effort to reduce crash rates. This method of planning for safety may not most effectively increase safety or protect all users of the system. Rather, proactive roadway design, reduced speeds, and reduction of overall VMT may be more effective. For more information on analyzing transportation safety impacts, see Appendix B.

Transit

Requirement Description:

As more of the population chooses alternatives to driving, roadway capacity becomes filled, and California strives to reduce VMT and GHG emissions, transit availability becomes increasingly important. There are many important considerations for transit in general plans. Policies, such as increasing density around transit corridors and increased transit infrastructure, can promote and prioritize high quality transit, aligned with housing and economic development policies, which in turn increases efficiency of the overall transportation system. Promotion of equitable access to transit, through the analysis of available data to make decisions, can help ensure all community members have access to core destinations, such as employment centers, schools, and retail, and contribute to fulfillment of environmental justice requirements. Transit providers should be involved in general plan processes, ensuring their alignment with community priorities.

Well-planned transit infrastructure can improve access to opportunity by making job centers, housing, schools, and other major destinations accessible to a high numbers of residents. Providing infrastructure at transit stops for convenience and safety, such as proper lighting,

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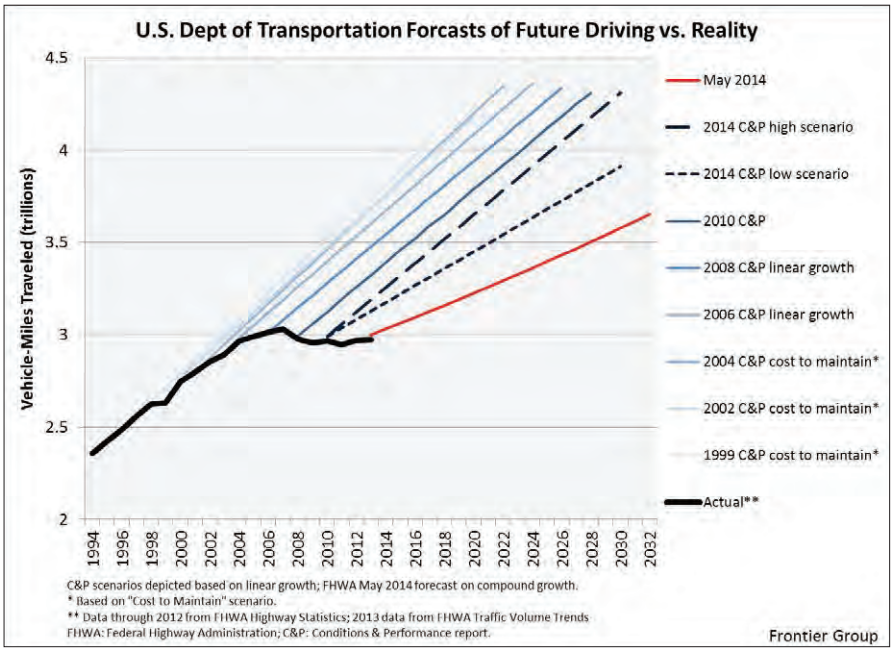
covered shelter, and safe crossings; implementing transit priority on streets and bridges, such as priority lanes, signals, and other types of infrastructure; and utilizing technology to communicate transit patterns in real time can help speed transit vehicles, shorten travel times, promote safety, and attract additional passengers.

Coordinating transit stops, stations, and routes with bicycle and pedestrian infrastructure can help create first and last mile connections, promoting reduced VMT for short trips and potentially increasing transit ridership for a greater range of residents.

Figure 5: People are choosing to drive less and less, at rates higher than expected



Source: Frontier Group http://www.uspirg.org/resources/usp/us-dept-transportation-forecasts-future-driving-vs-reality

Developers and employers can also incentivize transit ridership, and general plan policies can promote such programs through general visions and goals or through specific transit zones in the plan.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Assessment of potential needs for new transit routes	Maps highlighting residential centers, commercial centers, employment opportunities, schools, and recreation areas
Identifying potential targets areas for policies incentivizing transit use	Major employment centers, existing and planned transit routes, residential areas with demographic information

Active Transportation: Bicycle and Pedestrian Networks

Requirement Description:

The Active Transportation Program, enacted via Senate Bill 99 in 2013, funds pedestrian, bicycle, and Safe Routes to School programs (SRTS). This program ensures that at least 25% of investments benefit disadvantaged communities. Increasing safe, connected bicycle and pedestrian networks in a city or county improves health, economic mobility, GHG emissions, and increases accessibility for numerous populations. Ensuring that infrastructure is safe for residents from ages 8 to 80, if possible, captures the needs of recreational riders, ADA users, bicycle and pedestrian commuters, and all people in between. The Complete Streets Act (2008) requires cities and counties to plan for the development of multimodal transportation networks in the circulation element

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of their general plan. Caltrans and NACTO offer guidelines on complete streets implementation. The Sustainable Communities and Climate Protection Act of 2008 (SB 375), promotes regional coordination of transportation and land use planning, including support of active transportation. Prioritizing more forms of active transport policies in general plans will strengthen potential for regional transportation plans to meet GHG reduction targets established pursuant to SB 375.

Safe Routes to Schools (SRTS)

Less than 15% of children living within a 2 mile radius of a school walk or bike to school, and over half are driven in vehicles. Recognizing the implications of these statistics for childhood health, worsening air quality, and congestion around schools, the Safe Routes to School program established in one jurisdiction in 1997 quickly became a model to promote safe, accessible routes to schools nationwide. With federal funding through the Transportation Alternatives Program, state funding, and programming across the US, SRTS promotes infrastructure, design, policy, and education to promote active transportation for children and parents. Many jurisdictions have incorporated SRTS into their circulation and land use elements, and the national partnership offers numerous resources and examples to help communities implement safe routes to school.

Bicycle and pedestrian networks should be complete systems for transportation, including coordination with land use plans, housing, and transit systems. Bicycle and pedestrian networks should connect residents to employment centers, community centers, schools, commercial districts, and transit stops. Active transportation can be used to fill the gap in transit systems- the first and last mile between transit stops and destinations. Promoting infill and TODs may create additional opportunities for active transportation by decreasing the distance between origins and destinations.

Circulation elements should promote equitable distribution of active transportation networks that link residents to key destinations, and ensure equitable allocation of infrastructure investments and maintenance. Where feasible given right of way restrictions, cost, and other limitations, protected or buffered bikeway should be prioritized to reduce injuries and promote biking. Paths and facilities, both on and off road, should include user amenities such as shade trees, benches, and drinking fountains. Complete Streets policies should be integrated into bicycle and pedestrian policies as well. Some jurisdictions have separate bicycle and pedestrian plans, which should correspond and align with the general plan.

Terminals

Requirement Description:

Airports, seaports, bus and train stations, and other terminals play an important role in a region's transportation, social, and economic makeup. As such, the circulation element should include these facilities in its transportation discussion, and include operators in the general plan process. Often, terminals bring a specific set of land use issues that may need to be addressed as future growth occurs in existing infill areas. These issues include pollution, noise, traffic, and public safety. The location, type, and height of development in areas surrounding airports, should be considered in the context of the local Airport Land Use Plan. Airport Land Use Plans must coordinate with general plans' land use elements, but should be considered in relation to circulation and safety as well. Some actions to consider in the circulation element include:

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- Assess the adequacy of navigable waterways and port and harbor facilities, including the need for expansion and improvements.
- Project future demand based on new or expanded economic activities and recreational trends
- Assess the adequacy of and safety hazards associated with existing aviation facilities and the need for expansion and improvements.
- Limit potential noise and safety hazards posed by port activities to surrounding land uses
- Mitigate aviation-related hazards posed to and by aircraft
- Make access to and from aviation facilities available by all modes of transportation

Military Airports and Ports

Requirement Description:

The Department of Defense (DOD) has a significant presence in the State of California, using 10% of the State's land. Consequently, military ports and airports impose demands on local circulation infrastructure that should be factored into the overall analysis of local circulation planning in a general plan. Furthermore, changes to circulation patterns and routes may affect military operations. For example, development along formerly rural roads can significantly increase urban traffic and limit the use of routes for military transport purposes. Such changes can impede military operations, especially for units that commute to conduct training operations. On the other hand, improvements to circulation routes, such as ports, can contribute to operations. Additional information on military specific development can be found in the California Advisory Handbook for Community and Military Compatibility Planning.

Public Utilities and Facilities

Requirement Description:

In addition to transportation routes, the circulation element must identify the location and necessity of public utilities and facilities. Relevant utilities include water, sewers, storm-water systems, telecommunications and broadband, electric vehicle charging stations, electricity, and natural gas lines. These facilities relate directly to the land uses planned in the land use element, consequently, the circulation element should consider not just "right sizing" such infrastructure to serve only that growth that is actually planned in the land use element, but also placing infrastructure in areas that maximize efficiency and minimize impacts to the community. California courts have noted that plans for infrastructure should follow determinations regarding desired growth that reflect resource constraints and other broader considerations. (See, e.g., *County of Amador v. El Dorado County Water Agency* (1999) 76 Cal. App. 4th 931, 949-950.)

"Dig once" policies can help ensure efficiencies and reduce costs among circulation infrastructure. The underlying premise of a "dig once" policy is to coordinate conduit construction with unrelated civil works projects, such as digging up the roads and sewer construction, to create a usable infrastructure for future network deployment/provisioning. Dig once policies are flexible and may

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come in many forms. The goal and emphasis should be on impacting the rights of way as few times as possible by inviting multiple parties to lay their infrastructure together. While not always feasible, coordinating between circulation infrastructure agencies may help reduce costs and impacts on the local community. In identifying existing infrastructure and planning for future needs, local governments should work closely with any relevant service providers, including water districts, utilities and others.

Infrastructure needs of Disadvantaged Unincorporated Communities

In 2011, local governments were required to plan for infrastructure needs of disadvantaged unincorporated communities through Senate Bill 244. The bill requires the land use element to analyze needs for infrastructure in these communities. To ensure consistency, the circulation and land use elements' policies and programs should be coordinated. For additional information on planning for disadvantaged unincorporated communities, see the Land Use Element chapter of the GPG and Senate Bill 244: Land Use, General Plans, and Disadvantaged Communities Technical Advisory.

Broadband

Both state and federal governments are implementing various funding programs that serve the goal of expanding broadband access to unserved and underserved areas. Within California, the California Public Utilities Commission (CPUC) manages the California Advanced Services Fund (CASF), which invests hundreds of millions of dollars annually in broadband deployment. The state also created the California Emerging Technology Fund (CETF), which was designed to be a public-purpose venture capital fund.

Dig once policies can substantially reduce costs for providing broadband service to communities. A new provider can run fiber through leased conduit space at a fraction of the costs, incentivizing more private actors to deploy or reducing costs to the city if self-provisioning broadband services. For example, if conduit construction was promoted along ongoing civil work projects, fiber deployment costs drop by $30,000- $100,000 per mile. On average, 60 to 90 percent of network deployment costs come from civil works as opposed to equipment and maintenance.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Understanding transportation choices and multi-modal needs	Percentage of pedestrians and bicyclists commuting to work and other trips (National Household Travel Survey, California Household Travel Survey, American Community Survey)
Identifying necessary safety improvements	Number or % of injuries and fatalities (Transportation Injury Mapping System)
Analysis of existing and needed active transportation networks	Transit stops and centers, existing and planned bicycle routes, pedestrian facilities, destination centers

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Other Considerations

Transportation and Climate Change

Transportation is a significant source of greenhouse gases. In California, transportation is the largest source of emissions: according to the California Air Resources Board, about 37% of the state's GHG emissions come just from vehicle tailpipe emissions,[i] as compared to 28% nationally.[ii] Considering life-cycle emissions (extraction, fuel refining, fuel transport, roadway construction, etc.) in addition to tail pipe emissions, transportation is the source of over half of California GHG emissions. An update to the circulation element presents an opportunity to integrate measures for reducing vehicle travel that are critical to meeting our State's GHG reduction goals.

Strategies to reduce transportation-related GHG emissions fall into three general categories: vehicle efficiency, switching to low-carbon fuels, and reduction of vehicle miles traveled. General plans' most important policy levers focus on VMT reduction, by setting out low-VMT land use patterns and specifying transportation network characteristics and travel demand management strategies. Further, general plans can help jurisdictions become "ZEV-ready", e.g. by specifying provision of alternative fuel fueling and charging stations.

Parking

Many general plans set forth the goal of providing their communities with "adequate parking." Historically, this has meant directing new land use projects to exceed the full demand for free parking. This has resulted in a substantial subsidy to automobile users of roughly $20-40 Billion per year in California.[iii] Free parking is a community choice, but should be recognized as one that entails costs and leads to additional vehicle travel, which in turn can impact community goals for livability, mode shift, environmental protection, emissions reduction, and fiscal benefits.

The circulation element of a general plan provides a jurisdiction the opportunity to evaluate various tradeoffs, including the costs and benefits of parking, in conjunction with other planning goals. Tradeoffs a jurisdiction might consider include:

- Parking demand may change over time due to numerous factors including adjacent land uses, densifying urban development, transit and active transportation infrastructure, and emerging vehicle technologies such as automated vehicles
- Ready parking availability can induce increased vehicle miles traveled (VMT), leading to increased traffic and greenhouse gas emissions.
- Parking requires land that might be occupied by other land use, which may provide greater benefit (including fiscal benefit).
- Parking areas paved with standard asphalt can exacerbate impacts on water quality and runoff control.
- Free parking subsidizes drivers at the expense of transit users, pedestrians, and cyclists.

Many jurisdictions are already confronting parking tradeoffs and addressing these issues by managing parking demand and parking supply.

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Managing Demand for Parking

- Support alternative transportation. Travelers by non-auto modes do not require automobile parking. Quality bicycle, pedestrian, and transit access facilities and services (See e.g. City of Berkeley), and development proximate to those facilities, reduce motor vehicle mode share and therefore parking demand. Adequate, convenient, and secure bicycle parking, including around transit stations, facilitates cycling and increases cycling mode share.
- Convert parking to parklets, which increase public space and can improve neighborhood vibrancy.
- When providing on-street parking, design it in a manner that calms traffic and enhances bicycle and pedestrian safety and comfort. This may include reverse angle parking and parking-protected bicycle lanes.
- Attach a cost to parking. Construction and maintenance of parking is costly. Jurisdictions may wish to consider the benefits of optimizing parking prices to reflect the equilibrium between supply and demand, to help improve traffic flow, or to reduce VMT and GHGs. (See e.g. City of San Diego; City of Sacramento) Further, fees collected can be reinvested in a number of ways, including neighborhood benefits districts, that can increase neighborhood vibrancy.

Increased bicycle and pedestrian infrastructure, including shade, pathways, and safety features, help promote activity





Image by Urban Advantage, Cunningham Quill | Architects

Managing Supply of Parking

- Remove minimum parking requirements. Parking restrictions, such as residential parking permit programs, can be implemented to prevent spillover parking. Parking provision can be left to the market, pricing can be deployed, or parking maxima can be provided.
- Set parking maxima. Especially in TOD or mixed-use development areas, establishing maximum parking requirements instead of minimum requirements will mean that space is available for other uses (See e.g. Sacramento County; City of San Jose).
- Manage the use of existing spaces rather than provide additional parking. Prioritize spaces based on location (e.g. proximity to employment centers) and intended use (e.g. short- or long-term). Implement shared parking or establish parking benefit districts. (See e.g. Sacramento County) Optimizing use of existing parking will help make efficient use of land within the jurisdiction's boundaries.

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Traffic Control Around Schools

High volumes of pedestrian traffic, vulnerable users, and other factors create increased need for safety around schools. Considerations in roadway design should take in to account the specific needs of the population, including bicycle and pedestrian access, transit and drop off needs, and safety around crosswalks, intersections, and roundabouts. The Safe Routes to Schools National Partnership, with support from CalTrans' Safe Routes to School program, provides guidance and resources for improving traffic control around schools, including signage, pavement markings, signals, and other infrastructure. For additional guidance on traffic control specifically around schools, see the CalTrans Manual on Uniform Traffic Control Devices, including Section 3c on roundabout markings and Part 7 for traffic control around schools.

Addressing Tradeoffs and Maximizing Co-benefits in Circulation

The transportation network should be designed to accommodate multiple competing interests, as well as to maximize co-benefits. Potential areas for co-benefits, such as safer streets through slower traffic, greater economic activity through improved walkability, and increased positive health outcomes through improved active transportation, should be considered in making decisions around transportation.

The circulation element should address the tradeoffs between various interests rather than listing desirable but mutually exclusive outcomes. The following are some of tradeoffs that a circulation element might address. Some of these tradeoffs will involve agencies distinct from the city or county, such as some transit systems, highlighting the importance of coordination between stakeholders involved in circulation planning and implementation.

- Roadway motor vehicle throughput and speed v. impacts on community along roadway
- Roadway motor vehicle throughput and speed v. capacity for other modes

Aligning circulation and land use improves access and creates economic opportunities



Image by Urban Advantage, Clarion

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- Roadway design speed and risk to pedestrians and cyclists
- Breadth of coverage of transit system v. cost
- Provision of bicycle facilities v. provision of additional motor vehicle capacity
- Transit priority measures (e.g. signal priority and queue jump lanes) v. automobile capacity
- Accommodation of potential emergency vehicle turning movements v. design for pedestrian safety
- Accommodation of freight vehicles v. pedestrian safety
- Automobile throughput and speed v. traffic calming measures such as narrower travel lanes, roundabouts, raised medians, speed tables, small curb radii, etc.)

Goods Movement

Freight movement is essential for any community to thrive, by allowing the exchange of needed goods and stimulating local and regional economies. Depending upon geography and community characteristics, local governments should plan for goods movement in multiple modes, including air, rail, ship, and truck. A general plan should address transportation improvements that facilitate the timely movement of goods, meet the needs of local business and industry, and support the efficient transfer of goods between truck, rail, and other transportation modes. These interests of goods movement must be balanced with the trade-offs that may include negative impacts to safety, air quality, and noise described in the previous paragraph. Increasing general purpose roadway capacity on a congested roadway may not facilitate freight vehicle travel, due to induced travel effects (mostly passenger vehicles); freight-only facilities may better accomplish this objective.

While freight moves throughout the state in multiple ways, trucks specifically:

- Emit diesel particulate matter (DPM), which is a localized pollutant that is particularly hazardous to human health
- Generate high noise levels
- Pose special collision hazards because of their size, especially to vulnerable road users, and especially during turning movements, where rear wheels can follow a shortcut-track and collide with pedestrians and cyclists

For these reasons, truck routes should be designed to minimize risk to areas containing concentrations of sensitive receptors and vulnerable road users. Also, goods movement facilities (distribution centers, rail yards, and ports) should be placed in locations that do not bring high levels of truck traffic near residential areas or schools whenever possible. Engaging school boards, goods distributors, and community members to coordinate the land use element with the circulation element, freight mobility plans, and other relevant efforts may help assess tradeoffs and needs in locating facilities.

Land use and circulation elements may also be coordinated for freight movement in congested or high traffic corridors, such as by designating specific freight zones, lanes, or management practices, to improve efficiency overall. Policies specific to the needs of a community, depending on factors such as density, proximity to goods movement facilities, and average daily traffic (vehicle and non-vehicle) may help ease safety and congestion issues associated with urban freight movement.

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Congestion Management Plans

Each county that includes an urbanized area must establish a congestion management agency to prepare and adopt a congestion management plan (Gov. Code §65089). The congestion management plan establishes programs for mitigating the traffic impacts of new development, including deficiency programs where congestion is extreme, and monitoring the performance of system roads. The congestion management plan is expected to link land use, transportation, and air quality concerns. At a minimum it must include all state highways and all principal arterial roads. Performance of the congestion management plan is measured through the land use approval process.

As noted above, many jurisdictions have traditionally focused their circulation elements on automobile transportation, planning to certain "level of service" standards. It is important to note, however, that congestion management law does not require general plans to designate level of service standards for every roadway and intersection, only for the "system of highways and roadways designated by the agency," with special considerations for infill opportunity zones. In fact, there are many reasons that a circulation element should not do so, as noted in this section. Moreover, congestion management plans address far more than just automobile transportation. They must also include an evaluation of the performance of multiple modes of travel and provide a program for travel demand management. Notably, projects identified in a congestion management plan must be consistent with the regional transportation plan, and its sustainable communities strategy, in order to be funded (Gov. Code § 65082). In updating a circulation element, therefore, a local government must put the congestion management plan in a context that includes reductions in vehicle miles traveled, and provides for multiple users of the transportation system, including transit, bicycles and pedestrian transportation.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Sample Policy	Example of Application	Relationship to Other Elements
[City, county] shall design intersections and public right-of-ways to include adequate and safe access for all users including pedestrians, bicyclists, and motorists of all ages and abilities.	San Pablo	Land use, safety, equitable and resilient communities, economic development
[City, county] shall balance commercial goods movement with the health and quality of life priorities of the community by routing heavy truck traffic away from residential zones and promoting safety at rail crossings.	San Pablo	Land use, safety, air quality, equitable and resilient communities, healthy communities
[City, county] shall limit parking within the public right of way based upon considerations of safety, street width, visibility and access to properties	San Pablo	Land use, healthy communities, safety
[City, county] shall establish travel demand management programs to reduce peak-hour traffic congestion and help reduce regional vehicle miles traveled	San Pablo, Pasadena	Air quality, healthy communities, equitable and resilient communities, economic development, climate change
Incorporate Americans with Disabilities Act (ADA) requirements throughout the [city, county], but especially in high-volume pedestrian areas.	City of El Monte	Healthy communities, economic development, equitable and resilient communities
[City, county] shall create indoor air quality guidelines for residential and commercial units located along higher density corridors and areas where increased intensity of use may result in higher levels of vehicular traffic on adjacent streets. Identify recommendations for mitigation, including design standards and public transportation	City of Richnond	Land use, air quality, equitable and resilient communities
[City, county] shall provide safe routes to school for children and families walking, bicycling, and taking public transportation to schools in the community	City of Santa Cruz	Land use, healthy communities

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Housing Element

Introduction

Providing adequate housing for all residents is a priority for cities and counties throughout California. The housing element implements the declaration of State law that "the availability of housing is a matter of vital statewide importance and the attainment of decent housing and a suitable living environment for all Californians is a priority of the highest order" (Gov. § Code 65580). Provisions in the housing element are more specific and directive than other elements, and contain detailed guidance and reviews. The law also provides the Department of Housing and Community Development (HCD) with unique authority over the housing element.

Housing element updates must be consistent with other general plan elements, including the land use element and diagrams. Integrating considerations of general plan goals and policies through the housing element and each update may improve efficiency by ensuring consistency. Additionally, incorporating a holistic view of the document will allow the housing element to compliment other elements in addressing challenges such as climate change mitigation and adaptation, and working towards local goals, such as promoting infill development, Transit Oriented Developments, and healthy, safe, and equitable communities.

Periodic updates assure that local governments "will prepare and implement housing elements...toward the attainment of the state housing goal" (Gov. Code §65581). The law requires that HCD review and certify the housing element and that local jurisdictions submit annual progress reports to HCD. The housing element must be revised and submitted periodically on a four, five, or eight year cycle, depending on various factors (Gov. Code §65588). See the HCD's website for a schedule of statutory deadlines. Specific questions about update cycles and related housing element requirements should be directed to HCD and the HCD website. These Guidelines provide a general overview of the housing element, with links to more detailed information. Because of the more precise requirements applicable to the housing element, users should consult the detailed requirements for each section (following the links provided), including specificity and timelines.

CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Conservation	Open Space	Noise	Safety	EJ
Housing	IN STATUTE	RELATED	RELATED	RELATED	RELATED	RELATED	IN STATUTE

■ Identified in statute ■ Closely related to statutory requirements

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Completeness Checklist

Local agency staff can use the following checklist to help ensure that the housing element addresses all required issues. Please note that use of this checklist is advisory, and only contains issues that are legally required in Government Code section 65583. Housing elements may include additional content at the discretion of the local jurisdiction. For example, the housing element is well suited to address requirements related to environmental justice and disadvantaged unincorporated communities. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied.

Statutory Citation	Brief Description of Requirement
Gov. Code §65583(c)(8)	Public Participation: description of diligent effort to include all economic segments of the community
Gov. Code §65588	Review and Revise: • Progress in implementation • Effectiveness of the element • Appropriateness of goals- objectives, policies and programs
Gov. Code §65583(a)(1 and 2)	Housing Needs Assessment: Quantification and analysis of existing and projected housing needs Populations and employment trends, including documentation of projections Housing and Household characteristics, including; • Level of payment compared with ability to pay (overpaying households) • Housing stock conditions • Overcrowded households Existing and projected needs for all income levels, including: • Regional Housing Need Allocation (RHNA) • Existing housing need for extremely low income households • Projected housing need for extremely low income households based on RHNA or Census
Gov. Code §65583(a)(7)	Persons with Special Needs: Identification and analysis of any special housing needs including: • Elderly • Persons with disabilities, including developmental disabilities • Large Households • Farmworkers (seasonal and permanent) • Female headed households • Homeless (annual and seasonal) • Other
Gov. Code §65583(a)(9)	At-risk Units: Inventory of at-risk units (10 years from the housing element due date) • Estimate of replacement versus preservation costs • Identification of qualified entities • Identification of potential funding
Gov. Code §65583(a)(5 and 6)	Potential Governmental Constraints: Include an analysis of actual and potential governmental constraints for each of the following: • Land use controls • Building codes and their enforcement • Site improvement requirements • Fees and other exactions • Local processing and permit procedures • Housing for persons with disabilities • Transitional housing and supportive housing as a residential use of property and subject only to those restrictions that apply to other residential dwelli ngs of the same type in the same zone
Gov. Code §65583(a)(5 and 6)	Potential Non-governmental Constraints Include an analysis of actual and potential non-governmental constraints for each of the following: • Availability of financing • Price of land • Cost of construction

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Statutory Citation	Brief Description of Requirement
Gov. Code §65583 (a) (3) and 65583.2	Sites Inventory and Analysis: • Listing of properties by parcel number or other unique reference showing for each parcel • General description of environmental constraints to the development of housing • General description of infrastructure (planned/available) including water, sewer and other dry utilities, including availability and access to distribution facilities • For Non-vacant sites, specify the additional development potential for each site within the planning period and provide an explanation of the methodology to determine development potential • Demonstration of zoning to accommodate the housing need for lower income households • Map of sites included in the inventory • Number of units built between the start of the projection period and the deadline for adoption of the housing element (optional) • Number of units proposed using alternative provisions such as rehabilitation, conversion, preservation or accessory dwelling units (optional) • Analysis of whether inventory provides for a variety of housing types (Multifamily rental housing, Factory-built housing, Mobile homes, Housing for agricultural employees, Emergency Shelters, Transitional and supportive housing) • Carryover obligation (AB 1233), if applicable
Gov. Code §65583(b) and (c) (1 through 6)	Quantified Objectives and Housing Programs: Provide statement of quantified objectives; Maximum number of units, by income group, including extremely low-income of: • New construction; • Rehabilitation; and • Conservation.
Gov. Code §65583(c)	Include programs with: • Schedule of specific actions; and • Timeline for implementation with a beneficial impact in the planning period; and Identification of agencies and officials responsible for implementing each program.
Gov. Code §65583(c)(1)	Program(s) providing adequate sites: • Programs to rezone and any other programs needed to address a shortfall of sites to accommodate the regional housing need, if applicable, and any programs included pursuant to Section 65583.2(h) and (i) or carryover obligation pursuant to Section 65584.09. • Programs to rezone and any other programs needed to address a shortfall of capacity for housing for farmworkers that could not be accommodated on sites identified in the inventory, if applicable. • If applicable, programs to facilitate a variety of housing types, including multifamily rental, factory-built housing, mobile homes, housing for agricultural employees, supportive housing, single room occupancy, emergency shelters and transitional and supportive housing.
Gov. Code §65583(c)(2)	Programs to assist in the development of housing for extremely low, very low, low and moderate income households.
Gov. Code §65583(c)(3)	Programs to address governmental constraints and where appropriate and legally possible, to remove constraints to the maintenance, improvement and development of housing.
Gov. Code §65583(c)(3)	Program to remove constraints on housing for persons with disabilities and provide reasonable accommodation for housing for persons with disabilities.
Gov. Code §65583(c)(4)	Program(s) to conserve and improve the condition of the existing affordable housing stock.
Gov. Code §65583(c)(5)	Program(s) to promote housing opportunities for all persons.
Gov. Code §65583(c)(6)	Program(s) to preserve at-risk units.
	Other Requirements
Gov. Code §65583 (c) (7)	Description of general plan consistency.
Gov. Code §65585	Review by HCD and legislative body.
Gov. Code §65588	Analysis of construction, demolition and conversion of housing for lower income households in the Coastal Zone.
Gov. Code §65583 (a) (8)	Description of opportunities for energy conservation in residential development.
Gov. Code §65589.7	Water and Sewer Priority See the HCD Memo at http://www.hcd.ca.gov/hpd/memo_sb1087.pdf. *
Gov. Code §65589.5	Housing accountability act; analysis for rejection.

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Required Contents

State law requires the housing element to address particularly detailed statutory requirements. For more information on these requirements, see the HCD's website. A housing element must generally include the following parts, which are described in further detail below and through links:

- Review of previous element
- Housing needs assessment
- Inventory and analysis of adequate sites
- Analysis of potential governmental and non-governmental constraints
- Housing policies and programs
- Quantified objectives

Planning and Zoning Law also requires planning agency staff to: 1) collect and compile public comments regarding a proposed housing element; and 2) provide the comments to each member of the legislative body prior to adoption (Gov. Code § 65585(b)(2)). The scope of the housing element requires a strong relationship to other elements of the general plan, and linkages between sections should be taken in to consideration. The housing element should integrate community health, climate change, and other considerations affecting and affected by housing throughout each section. More information on additional considerations is presented at the end of this chapter.

Public Engagement:

Housing issues affect the entire community, and can be confusing and contentious. The public participation requirement of housing element law presents an opportunity to engage constituents in a dialogue – defining problems and creating solutions. Public participation should include community stakeholders, including residents, and examine how different housing strategies are identified, evaluated, developed, and implemented. An inadequate public participation process may lead to community conflict or anti-development initiatives. Public engagement strategies to address multiple communities are outlined in Chapter 3 of these Guidelines. The housing element must document how outreach and public engagement is carried out, from planning through implementation (Gov. Code § 65583(c)(7)). This documentation should include current and future plans to involve a cross-section of the community in the full process.

Review and Revise:

The review and revise requirement is an important feature of the housing element update. A review facilitates a comprehensive update and ensures that the housing element can be effectively implemented in the next planning period (Gov. Code § 65588). Review and revise requires analysis in three areas:

Progress in implementation: A description of the actual results or outcomes of the prior element's goals, objectives, policies, and programs. The results should be quantified where possible (e.g., number of units rehabilitated) and may be qualitative where necessary (e.g., mitigation of governmental constraints).

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Effectiveness of the element: An evaluation of the effectiveness in achieving the objectives of each program, such as analyzing differences between what was projected or planned in the earlier element and what was achieved.

Appropriateness of goals, objectives, policies and programs: A description of what has been learned based on the analysis of progress and effectiveness of the previous element. A description of how the goals, objectives, policies, and programs in the updated element are being changed or adjusted to incorporate what has been learned from the results of the previous element.

Examples of review and revise analysis can be found here.

General Plan Consistency:

The goals, policies, and objectives and various accompanying analyses and text of the housing element must be reviewed in the context of the rest of the elements of the general plan such the land use, circulation, and open space elements (Gov. Code § 65300.5). The element must include a discussion of how internal consistency within the general plan has been achieved and how internal consistency will be maintained throughout the planning period (Gov. Code § 65583(c)(7)). If appropriate, other elements may need to be updated concurrently with the housing element.

Coastal Zone Requirements:

To assist a locality's determination of whether the affordable housing stock in the coastal zone is being protected and provided as required by Government Code Section 65590, the element must contain data on the new construction, demolition, conversion and replacement housing units for low- and moderate-income households within the coastal zone.

Based on this analysis, localities should consider appropriate programs to provide incentives and regulatory concessions in order to preserve housing for low- and moderate-income households within the coastal zone. See also the Coastal Act section of the GPG.

Aligning transportation and land use increases access and vibrancy for all residents



Image by Urban Advantage, Santa Clara Valley Transportation Authority

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Internal Consistency in Updates:

Updates to other sections of the general plan often require a review of land use, with consideration to the potential impacts to existing housing stock and the housing element land inventory. For example, should the update of these elements demonstrate that certain parcels within the community would not be able to be developed or require significant mitigation; the sites inventory of the housing element should be updated to reflect these constraints. As a result, new parcels to accommodate the Regional Housing Needs Allocation (RHNA) may need to be identified.

Land Use Element:

Government Code section 65302.10(a) requires that each city and county review and update the land use element of its general plan, based on available data, including, but not limited to, the data and analysis developed pursuant to Government Code section 56430, of unincorporated island, fringe, or legacy communities inside or near its boundaries.

Safety and Conservation Elements: Government Code Section 65302 requires amendment of the safety and conservation elements of the general plan to include analysis and policies regarding flood hazard and management information. In addition, the safety element must be updated to analyze risk and include policies for the protection of the community from any unreasonable risks associated with the effects of wildland and urban fires.

Environmental Justice Element:

Government Code Section 65302(h) (1) requires cities and counties with identified disadvantaged communities to create an environmental justice element, or related goals, policies, and objectives integrated in other elements. The environmental justice element must include objectives and policies to promote safe and sanitary homes.

> Neighborhood-based Policies and Programs: Some jurisdictions will evaluate household and housing characteristics at a neighborhood level to target funding and other programs. For example a jurisdiction could evaluate housing conditions at a neighborhood level to target revitalization efforts or consider tenure and income to better utilize resources for conserving and improving affordable housing stock.

Analysis of Existing Housing Needs

Requirement Description:

An assessment of existing housing needs must include an analysis of population and employment trends and documentation of projections and a quantification of the locality's existing and projected housing needs for all income levels, including extremely low-income households (Gov. Code §65583(a)(1and 2)). The assessment must also include an analysis of household characteristics such as tenure (whether renting or owning) and overpayment; housing characteristics such as overcrowding; and housing stock conditions. The purpose of the assessment is to evaluate existing housing needs to formulate appropriate policies and programs. The assessment can be combined with other areas of the housing element such as evaluation of past programs and comments through public participation. An assessment of housing needs can utilize a variety of quantitative and qualitative information and should use current information when available. An assessment may also evaluate trends over time and consider information or maps at a

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neighborhood level to better formulate appropriate policies and programs to address existing housing needs in the planning period. Items that must be included, as well as links to more information, are discussed below. The HCD website includes detailed information on housing elements as well as examples, tools, and resources for updating the element. As with all elements of the general plan, the required items provide a base, and jurisdictions can add other considerations as appropriate for their community.

Population and Employment:

In order to understand and prepare for the housing needs of a community, population trends and demographics, including employment trends and needs, must be assessed. The analysis should include current population and employment industry trends, using the most recent Census data available; comparisons in growth rates to countywide and regional rates; and analysis of population by age and other demographic characteristics. Employment analysis should examine shifts and anticipated shifts in employment and the potential impact on the housing market; identification of large employers, job types, and earnings; and analysis of potential methods for improving job-housing relationships.

Existing Housing Needs, Including Extremely Low-income Households:

The element must include a description of existing households by income level, including a specific quantification and analysis of extremely low-income (ELI) households, defined as households with income at 30% or below of area median. Analysis of existing housing needs should include an estimate of existing and projected households with ELI, as well as proposed actions to address identified needs (Gov. Code §65583(a), 65583(c)(2)).

The analysis should assess the resources available to address the housing need, such as the kind of housing available and suitable for ELI households (including Supportive Housing and Single-Room Occupancy [SROs] units) and whether existing zoning permits those housing types.

ELI households often need additional assistance outside of market mechanisms, and may require specific housing solutions such as deeper income targeting for subsidies; housing with supportive services; single-room occupancy (SRO's) and/or shared housing; and rent subsidies (vouchers).

Housing Data

Data for the housing needs assessment may be obtained from many sources. The US Census, American Community Survey (ACS), the Department of Finance and Employment Development Department are the most common data sources for population and employment trends. These data sources can also be used to quantify the number of those living in overcrowded housing conditions, as well as those overpaying for housing. Overpayment data may also be found by utilizing HUD's Comprehensive Housing Affordability Strategy (CHAS) data. Data for at-risk housing can be found via the California Housing Partnership Corporation (CHPC), and data on housing stock conditions may be found by using local sources like a windshield survey or local building department. Many of these data sources are available in one comprehensive site via the General Plan Mapping Tool. Jurisdictions should augment the tool with additional data available locally.

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Housing and Household Characteristics

Housing and household characteristics must be assessed in line with population and employment to determine current and future needs for homes available to renters and owners (Gov. Code §65583(a)). A quantification and analysis of household characteristics addresses the number of households and trends and evaluates various factors such as tenure and the level of payment compared to their gross income or the ability to pay (overpayment).

An analysis of overpayment must identify and analyze the number of lower-income households, by tenure, paying more than 30 percent of their gross income for housing and the number of households who pay 50 percent or more of their gross income for housing (Gov. Code §65583(a)). Where possible, the analysis should also identify households most significantly impacted by cost burdens (large families, seniors, etc.). The analysis should also identify potential resources and programs to address the need.

A quantification and analysis of housing characteristics must address housing stock conditions and overcrowding to help determine housing need, potential health impacts, and possible reduction of affordable housing. The analysis can also address a variety of characteristics related to housing such as housing units by type (e.g., single family, multifamily, manufactured housing) and their conditions, housing units by age, vacancy rates, rent and sales prices, and the development patterns of the housing stock by various characteristics.

Analysis of Projected Housing Needs

Requirement Description:

The housing element process begins with HCD allocating a region's share of the statewide housing need to the appropriate Councils of Governments (COG) based on Department of Finance population projections and regional population forecasts used in preparing regional transportation plans (Gov. Code §65583(a)(1)). The COG develops a Regional Housing Need Plan (RHNP) allocating the region's share of statewide need to the cities and counties within the region. The RHNP is generally required to promote objectives that align with the state's priorities, including increasing the housing supply and the mix of housing types, tenure, and affordability in all cities and counties within the region in an equitable manner; promoting infill development and socioeconomic equity, the protection of environmental and agricultural resources, the encouragement of efficient development patterns; and promoting improved intraregional relationship between jobs and housing. The RHNP should align with the region's Sustainable Communities Strategy (SCS), utilizing infill development plans, development around transit and active transportation, and other policies to reduce GHG emissions and enhance sustainability.

Analysis of Special Housing Needs

Requirement Description:

Statutes require an analysis of specific categories of persons with special housing needs, including the elderly; persons with disabilities, including developmental disabilities; large families (households with 5 or more persons); farmworkers; families with female heads of households; and families and persons in need of emergency shelters. Each of these analyses must include detailed quantitative

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and qualitative data, including estimates of the number of persons in each category, discussions of available and needed resources, identification of housing types and numbers, and analysis of specific needs for identified categories (Gov. Code §65583(a)(7)).

Additional considerations and categories should be identified by each community and analyzed as appropriate. These may include transitional housing, assisted living, homelessness, and any other special housing needs specific to the jurisdiction. Consideration of homelessness specifically may affect estimates of needed housing. The need for emergency shelter must be assessed based on annual and seasonal need, and may be reduced by the number of supportive housing units that are identified in an adopted 10-year plan to end chronic homelessness. To be credited toward the need, these supportive housing units must be either vacant or have funding identified for construction during the planning period.

For assistance with the analysis of housing needs, including a discussion of resources such as existing housing, services and needs, cities and counties should contact local service providers. These include continuum of care providers, local homeless shelter and service providers, food programs, operators of transitional housing programs, local drug and alcohol program service providers, county mental health and social service departments, local Salvation Army, Goodwill Industries, churches and schools. Additional information on local services and needs may also be available by contacting one of 15 countywide Designated Local Boards certified by the HCD's Emergency Housing and Assistance Program.

Sites Inventory and Analysis

Requirement Description:

Local governments must prepare an inventory of land suitable for residential development, including both vacant and non-vacant sites, and an analysis of the relationship of zoning and public facilities and services to these sites (Gov. Code § 65583(a)(3) and 65583.2). The inventory must address the following components:

Inventory of Land Suitable for Residential Development:

The land inventory must identify specific sites suitable for the development of housing within the planning period that are sufficient to accommodate the jurisdictions share of the regional housing need for all income levels (Gov. Code § 65583). Land suitable for residential development includes vacant sites zoned for residential use, vacant sites zoned for nonresidential use that allow residential development, residentially zoned sites capable of being developed at a higher density, and sites zoned for nonresidential use that can be redeveloped for, and as necessary, rezoned for, residential use. The inventory may also list sites by characteristics such as city owned, proximity to services and amenities, infill and equity opportunity areas, transit and other priority development areas and areas potentially eligible for CEQA streamlining. Access to resources, including water, should also be considered (Pub. Resources Code § 21094.5, 21155.1-21155.4; CEQA Guidelines § 15183.3).

Analysis of Sites and Zoning:

The site specific listing must be accompanied by analysis to demonstrate that the land is suitable for development in the planning period and sites and zoning are sufficient and appropriate to accommodate the jurisdiction's share of the regional housing need for all income levels. This analysis should include whether the impacts of a changing climate will affect the suitability of sites and

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Targeting Opportunity Sites

One purpose of the site listing is to allow the housing element to function as a working land use document, showing the community and developers where the City intends to target its growth and accommodate households for all income levels. Some jurisdictions identify sites by various characteristics to focus evaluation, resources, incentives and other actions to promote their intended use. For example, some jurisdictions may denote sites within priority development areas, transit priority areas, downtown areas, city-owned sites, areas meeting proximity criteria for funding (e.g., distance to amenities, infill, etc.).

zoning by subjecting sites to risks such as fire, flooding, sea level rise, seismic activity, etc. More information on these risks can be found in the safety and climate change chapters. Including an analysis of sites identified by the previous housing element update, and the factors responsible for projected housing having been built or not built, may help jurisdictions plan with implementation in mind. The site inventory and analysis must be consistent with the land use element and accompanying diagram. Analysis of sites coordinated with other elements of the general plan, including land use, circulation, and open space, will help jurisdictions identify potential co-benefits toward their local goals. For example, identifying sites for higher density, mixed income, or low income housing near transit centers, active transportation routes, employment centers, services, or parks, may promote health and economic development, reduce GHG emissions and climate change impacts, and assist in affordability and quality of life.

Zoning for a Variety of Housing Types:

The analysis of sites must indicate whether the inventory can provide for a variety of housing types, including multifamily rental housing, factory-built housing, mobile homes, housing for agricultural employees, transitional and supportive housing, single-room occupancy units and emergency shelters. Providing development opportunities for a variety of housing types promotes diversity in housing price, style and size, and contributes to neighborhood stability by offering more affordable and move-up homes and accommodating a diverse income mix. Additionally, needs for housing types vary among jurisdictions, from high density needs in urban areas to smaller scale mid density rental housing, additional dwelling units, and other housing types in suburban and rural areas. Determining the analysis of a variety of housing types must account for a number of specific factors. This includes identification of zoning districts where each of the housing types are permitted, discussion of how development standards and processing requirements facilitate development of each of the housing types; and a description of capacity and its suitability to accommodate development or improvement opportunities

In addition, the statute provides flexibility to local governments in identifying sites to accommodate their share of the regional housing need (Gov. Code § 65583).

Adequate Alternative Sites:

Local governments can address up to 25 percent by income group of their adequate sites requirement, under prescribed conditions, including units that are substantially rehabilitated, converted from market-rate to affordable, or where the affordability of certain multifamily housing units are preserved.

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Accessory Dwelling Units:

Local governments can address a portion of their adequate sites requirement through the provision of accessory dwelling units based on a number of factors including the number of accessory dwelling units developed in the prior planning period, community need and resources and/or incentives available that will encourage their development. Accessory dwelling units are a valuable housing type that can facilitate affordability for a variety of housing needs. For more information, see the HCD's website.

Jurisdictions may also use other alternatives to accommodate the regional housing need including units constructed since the beginning of the planning period, motel conversions, potential for manufactured housing on rural lots and sites with permanent housing on military bases undergoing closure or conversion.

Accessory Dwelling Unit Ordinance, Santa Cruz

In 2002, the City Council of Santa Cruz supported staff efforts to increase the pool of affordable housing by initiating a comprehensive strategy and implementation plan for promotion of accessory dwelling units which resulted in adoption of the Accessory Dwelling Unit Ordinance. The plan offered approximately a 1:1 match from city in lieu fees, lower interest mortgage loans, partial subsidy of wages for a construction training program for women, and credit for in-kind staff time funded through the competitive award of a state Sustainable Communities Grant from the California Pollution Control Financing Authority. The city produced manuals and design handbooks distributed at no cost. The two pronged benefit accruing to the city would increase rental housing opportunities and strengthen home owner's ability to retain ownership in an increasingly expensive housing market.

The ordinance reduced the uncertainty and risk of application denial, provided technical and design support, facilitated partial loan assistance at a pre-determined low interest tax rate (4.5% in 2002) and programmatic support through the city approval process. Permit fees were revised and reduced and waived for units deed restricted to low and extremely low income renters by depth of affordability. The city subsidized the wages of construction workers hired through the city's training program. The city has since determined how constraints might be further loosened.

Identification of Zoning for Emergency Shelters

Requirement Description:

Every jurisdiction must identify a zone or zones where emergency shelters are permitted without a conditional use or other discretionary permit (Gov. Code § 65583(a)(4)). The identified zone(s) must include sufficient capacity to accommodate the need for emergency shelter as identified in the housing element, EXCEPT that each jurisdiction must identify a zone(s) to accommodate at least one year-round shelter. Adequate sites can include sites with existing buildings that can be converted to accommodate need. Shelters may only be subject to development and management standards that apply to residential or commercial development in the same zone. However, local governments may apply written and objective standards that include maximum number of beds, off-street

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parking based upon demonstrated need, size and location of on-site waiting and intake areas, provision of on-site management, proximity to other shelters, length of stay, lighting, and security during hours when the shelter is open.

For more information, see the HCD's technical assistance on zoning for emergency shelters.

Analysis of Governmental and Non-governmental Constraints

Requirement Description:

Governmental: The element must describe and analyze governmental constraints for impacts on housing such as costs, supply and approval timing and certainty (Gov. Code §65583(a)(5) and (6)). This analysis must include constraints in land use controls, codes and enforcement, on and off site improvement requirements, fees and exactions, processing and permit procedures, and housing for persons with disabilities. Other governmental constraints specific to localized areas should also be addressed as appropriate.

The analysis of potential governmental constraints must describe past or current efforts to remove them. Where the analyses identify that a constraint exists, program responses to address and mitigate or remove its effects should be included in the element.

Ordinances, policies, procedures, or measures imposed by the local government that specifically limit the amount or timing of residential development should be analyzed as a potential governmental constraint and mitigated where necessary. The analysis will vary depending on the nature of the measure. In general, the measure and its implementation procedures should be specifically described and analyzed as to the impact on the cost and supply of housing.

Non-governmental: The housing element must include an analysis of non-governmental constraints, including land prices, construction costs, and financing availability. Although nongovernmental constraints are primarily market-driven and generally outside direct government control, localities can significantly influence and offset the negative impact of nongovernmental constraints through responsive programs and policies.

Analysis of Energy Conservation Opportunities

Requirement Description:

The energy conservation section of the element must inventory and analyze the opportunities for energy conservation in residential development such as energy saving features, energy saving materials, and energy efficient systems and design for residential development (Gov. Code §65583(a)(8)). Planning to maximize energy efficiency and the incorporation of energy conservation and green building features can contribute to reduced housing costs for homeowners and renters, in addition to promoting sustainable community design. Such planning, development, and building standards can also significantly contribute to reducing greenhouse gases. Updated policies and programs can address a variety of factors related to energy conservation and even broader environmental goals such as climate change by highlighting the environmental significance and operational benefits of employing energy conservation in the siting, building and retrofitting of decent, safe and affordable housing.

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Analysis of Assisted Housing At-risk of Converting to Market Rate Uses

Requirement Description:

The element must include a project inventory of assisted housing that could be converted to market rate rents because of expiration of affordability restrictions in mortgage and/or rental subsidy contracts (Government Code Section 65583(a)(9)). Thousands of publicly assisted housing units in California are eligible to change from low-income to market-rate housing during the next decade due to the termination of various government subsidy programs and/or restrictions on rental rates. These units, known as at-risk units, are a valuable source of affordable housing for families statewide and as a result, the housing element must include a detailed analysis and proactive policies and programs to preserve these at-risk units. The at-risk analysis must prepare an inventory of all units at-risk of conversion within 10 years of the beginning of the housing element planning period, assess the conversion risk, estimate and analyze the costs of replacement versus preservation for units at-risk in the current five-year planning period, identify entities qualified to preserve at-risk units, and specify financing and subsidy resources.

Quantified Objectives

Requirement Description:

Quantified objectives must establish the maximum number of housing units by income category that can be constructed, rehabilitated, and conserved over a five-year time period (Gov. Code §65583(b)).

Housing Programs

Requirement Description:

Local governments have the responsibility to adopt a program that implements the policies, goals and objectives of the housing element through their vested powers, particularly over land use and development controls, regulatory concessions and incentives, and the utilization of financial resources. SB 375 amended sections of housing law to include specific requirements, including timelines and consequences, referenced in these guidelines and described here.

Programs are the specific action steps the locality will take to implement its policies and achieve its goals and objectives. Programs must include a specific time frame for implementation to have a beneficial impact toward the goals and objectives during the planning period. Programs must also identify the agencies or officials responsible for implementation. Effective program descriptions also include immediate, short-term and long-term action steps, proposed measurable outcomes, objectives or performance measures, and specific funding sources, where appropriate (Gov. Code §65583(c)).

All housing elements must include programs to address the following six areas:

Adequate Sites: The sites inventory must demonstrate adequate site capacity with appropriate zoning to accommodate the regional housing need for all income groups. Where the analysis of a local government's sites inventory does not demonstrate sufficient suitable and appropriately zoned sites to accommodate the regional housing need by income level, the element must include a program to make sites available during the planning period with appropriate zoning and development standards including meeting specific statutory

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Beneficial Impact: Programs must have a schedule of actions, each with a timeline, to have a beneficial impact on the goals and objectives of the housing element within the planning period. The purpose of the clarification is to ensure program effectiveness in addressing housing needs in the planning period to better assist in meeting the housing objectives, including the objectives of SB 375. Programs must include a definitive date or deadline, or benchmarks for implementation early enough in the planning period to realize "beneficial impacts" and successful program implementation within the planning period.

requirements such as permitting residential development without discretionary action and providing sites zoned for owner occupied and rental multifamily residential uses by right. In addition, sites shall be identified as needed to facilitate and encourage the development of a variety of types of housing for all income levels, including multifamily rental housing, factory-built housing, mobile homes, housing for agricultural employees, emergency shelters, and transitional and supportive housing. In coordination with other general plan elements, aligning siting of adequate sites with goals can help communities improve outcomes, such as promoting infill development to address affordability, climate change, and community health issues.

Infill development and circulation improvements can create lively communities for all





Image by Urban Advantage, Joint Venture: Silicon Valley Network

Assist in the development of adequate housing to meet the Needs of Extremely Low-, Low- and Moderate-income Households: Having assessed and identified the housing needs of extremely low-, very low-, low-, and moderate-income households, including special needs households, localities must employ a sufficient number of strategies to assist in developing adequate housing to meet those needs. To address this requirement, localities can utilize a variety of methods such as proactive outreach with the development community, assisting with funding and land acquisition, streamlining entitlement processes and providing concessions and incentives for development. Jurisdictions may also prioritize funding for certain income levels and special needs and focus efforts in priority growth areas.

Address and Remove Governmental Constraints: For each policy, procedure or requirement identified as a governmental constraint, the element must include programs to address and remove or mitigate the constraint.

Conserve and Improve the Condition of the Existing Affordable Housing Stock: The existing affordable housing stock is a valuable resource and the element must include programs to conserve and improve the existing affordable housing

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stock. Improvement includes physical activities that improve the housing stock such as rehabilitation. Conservation includes both maintenance activity such as code enforcement in deteriorating buildings or in response to complaints and improvements to the housing stock such as weatherization programs which help reduce housing costs or other actions, policies or programs to conserve the affordability of housing such as a mobile home park preservation ordinance.

The housing element can be a tool to identify and address displacement issues by including policies and programs to replace lost affordable housing, conserve existing housing, encourage new opportunities, provide rental subsidies to existing families, and increase the competitiveness of affordable housing development through removal of governmental barriers, assisting with land assemblage, developing a land banking program, or requiring a set-aide for below market rate units.

Promote Housing Opportunities for All Persons: Since State and federal laws uniformly outlaw most kinds of housing discrimination, the local government's role is to identify program strategies that support and implement these laws and affirmatively further fair housing opportunities for all persons. Such strategies may include consultation with fair housing and counseling organizations in the community to document the incidence of housing discrimination, evaluation of the availability of services and identification of opportunities to promote housing and community development choices throughout the community. At minimum, a local equal housing opportunity program must provide a means for the resolution of local housing discrimination complaints and commitment to disseminate fair housing information and information about housing resources throughout the community.

Preservation of Units At-risk of Converting to Market Rate Uses: The nature of conversion risk varies significantly among projects depending on the type of subsidy and related affordability controls. When units are identified at-risk, the element must include actions to preserve the units such as monitoring, assisting with funding, outreach with developers, meeting noticing requirements and actions to assist tenants. Individual program responses should be tailored to the results of the analyses and specific local situations.

Innovation in Affordable Housing and Regional Housing Needs

Moylan Terrace, San Luis Obispo

The City of San Luis Obispo is the largest employment center in San Luis Obispo County, but many workers choose to live in more affordable surrounding communities. Moylan Terrace – an 80-unit for sale town home project – transforms an existing industrial/manufacturing area for smaller, affordable housing units close to downtown, in the Broad Street Corridor. Tandem parking, variable street setbacks and reduced parking and greater height allow for 24 du/ac. Form based coding encourages density and mixed use residential close to public transit, bike lanes and within walking distance of employment centers. Small by design with efficiencies 28-32% above California energy code requirements, the buildings house structurally independent units in an auto court layout have individual entry off of landscaped courtyards.

The land had been purchased a decade ago by the Housing Authority and held for affordable housing. The City provided a long term forgivable loan to cover impact fees, a direct transfer of in-lieu fees from a separate local development, and will again transfer profits upon sale forward to the next affordable housing project under construction in the city. The Inclusionary Housing Program screens applicants intending to insure occupancy over speculative ownership, with an equity gain back to the Housing Authority IHP if a unit does not go to another low income borrower upon resale.

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Parc on Powell, Emeryville

Just north of Oakland and directly across the Bay Bridge from San Francisco, Emeryville grew 46% between 2000 and 2010, with double digit growth projected. The city adopted an Affordable Housing Set Aside program in 1990. Parc on Powell received 900 applications for 36 below market rate units. The site is in a transitional area between medium density residential development to the east and mixed use to the west, and is within a one mile radius of shopping including grocery stores, restaurants, two schools, a walking trail, Amtrak station and bus service, a post office and three public parks.

The 166 unit project includes studio, one-, two- and three-bedroom apartments, live/work units and flexible units with 22% units affordable to renter households below 120%. Density bonus, parking, height and setback concessions allowed a density of 71 units in a 45 du/acre zone. The project repurposed an historic building, and incorporates a municipal recycled water system, highly efficient irrigation and surface water management. Two four-level towers include commercial, live/work and flexible units on the ground floor, and the courtyard between the towers connects to an existing public park. City parking on site is decoupled from the unit cost to reduce on-site parking zoning requirements and reduce rents for households without cars.

Other Considerations

Displacement

The opportunity to promote infill and transit oriented development (TOD) can place significant displacement pressures on existing lower income residents; potentially exacerbating the challenge to address important planning objectives such as climate change. As population continues to grow in California, the pressure on housing grows as well. In these circumstances, programs and policies to address displacement issues may be appropriate, such as policies and programs to prioritize the preservation and creation of housing affordable to lower-income households in TOD and infill areas. Additionally, ensuring that various types of housing supply for multiple income levels continue to be built, while protecting existing residents from market forces has many challenges. HCD has compiled a set of best practices to prevent displacement. California's Statewide Housing Assessment examines the need for diverse housing options in the state, and presents both research and options for local governments. Partnerships and collaborations between private developers, public agencies, community groups, and other stakeholders have utilized creative tools to meet housing needs, such as reduced parking requirements, zoning and building codes that support smaller building footprint and design, set back reductions, height increases and density bonuses.

Climate Change

Location and types of housing affect resource conservation in numerous ways, so are worth considering in conjunction with climate change and resource impacts. Infill development can reduce demand on natural resources, and inclusion of additional conservation strategies can reduce the burden even further. Reducing water and energy use can benefit from policies incentivizing conservation, reuse, and recycling in housing developments.

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Development patterns influence greenhouse gas (GHG) emissions. Siting housing near services, transportation options, and jobs increases the effectiveness of a multi-modal transportation system. Further, when affordable housing is not available near jobs, people may have to commute long distances, generating high rates of vehicle miles traveled (VMT) and GHG emissions.

Denser forms of development can increase the effectiveness of these relationships, while reducing travel time, travel costs, and the GHG emissions responsible for elevating the risks of climate change. Smaller footprint and parking requirements, mixed uses, innovative ownership strategies and higher densities typical of affordable housing development, are strategies that can contribute to more efficient development patterns.

Transit accessibility is important for housing, jobs, and the environment. Transit hubs record highest levels of ridership within a quarter to half-mile radius. Studies reveal that public transit ridership drops off dramatically after a distance of four miles from transit stations, particularly for those commuting to and from places of employment, as ridership generally depends on variables including quality, frequency of stops and travel time. Lower income households account for nearly one third of all transit riders, and three quarters rely solely on public transportation. Preserving and increasing housing choice for communities that utilize public transit most will continue to contribute to the reduction of carbon emissions.

The housing element is a critical tool in implementing policies and programs that lower GHG emissions and promoting sustainable development. SB 375. Through the housing element's site's inventory, jurisdictions must plan for where housing development will occur and adopt policies and programs to facilitate the development of housing. The jurisdiction can identify sites and adopt programs that direct growth in areas that promote efficient development patterns and transit use and alternative modes of transportation such as biking or walking. Programs to incentivize development such as mixed-use, affordable housing, and transit oriented development could include flexible development standards, fee reductions, expedited processing, and offer by-right permitting of projects that meet sustainability objectives. In addition, the housing element focuses on opportunities for rehabilitation and preservation of existing housing. This provides an important tool to target housing rehabilitation dollars to preserve older housing stock and achieve various objectives such as energy efficiency, health and transit options.

Finally, the impacts of climate change on housing affordability, insurability and viability should be considered.

Utilizing guidance included in the safety element, climate change chapter and the Integrated Climate Adaptation and Resiliency Program (ICARP) can help guide the process of addressing climate change.

Health

Housing affordability significantly impacts health. Affordable housing can provide increased stability, which allows families more resources for other goods and services, health care needs, and basic necessities such as healthy food. Housing location also affects access to parks, recreation, and grocery stores with healthy food, jobs, schools, and other community necessities. Positive health benefits, including decreasing stress-related illnesses associated with long drive times and increased physical activity result from locating housing thoughtfully. Housing opportunities for all income levels should be incorporated throughout cities and counties, rather than concentrated in existing low income neighborhoods. Distribution of affordable housing opportunities, through land use and zoning decisions as well as other tools, can ensure a jurisdiction's commitment to affirmatively furthering fair housing, maintaining equity, and improving health outcomes.

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Neighborhoods designed to facilitate active transportation - walking, and biking - facilitate weight control and other health benefits. Walkability is influenced by neighborhood design and accessibility to transit, employment, schools, services and recreational opportunities and amenities. "Safe routes to school," for example, is an important benefit for parents and children. New housing development presents a significant opportunity to engage developers in enhancing the surrounding built environment to promote the health and well-being of residents. Construction and reconstruction efforts can coordinate with infrastructure upgrades, new transit and active transportation facilities, and open space facilities as part of the development project. Cities and counties should consider the needs of the existing community and projected new members and collaborate with developers and stakeholders throughout the process when possible.

Multifamily housing developments are often used as platforms for integrating healthcare, especially for the elderly. A number of housing developments in major metropolitan areas include health clinics and community spaces, and tenant services for special needs populations such as elderly and disabled. Supportive services have multiple benefits, for both tenants and property management. Integrated service delivery plays a critical role with populations at risk of homelessness or institutionalization.

The quality of housing available impacts the health of residents and community members. Factors such as indoor air quality, mold and moisture, pests, safe drinking water availability, lead, and second-hand smoke affect the safety and health of residents' homes. Housing policies can direct housing quality by mitigating or preventing health impacts. For more information on relationships between housing and health, see the air quality and healthy communities chapters. SB 1000 now requires jurisdictions with disadvantaged communities to address promotion of safe and sanitary housing particularly for that population. See EJ section for more details.

Economic Development

Stable housing (adequate, safe and affordable) is a foundation for family economic well-being and thriving communities. Families in stable housing have more income in their budget available for basic living necessities, such as food, utilities, transportation to and from work, school, day care, and healthcare. Planning housing connected to transit, employment centers, services, schools, and destinations reduces living costs and also reduces greenhouse gas emissions.

As a communitywide asset, adequate, stable housing can boost the surrounding economy, through increased local spending, employment, and revenues for local governments. Cost of shelter is the largest, non-negotiable expense for most families. When this cost is excessive, families fall behind on rent or mortgage payments, have little or no disposable income, and often go without food, utilities, or healthcare.

Employers and regional economies are at competitive disadvantages without a sufficient supply of affordable housing. A survey of 300 companies found that one in the three reported that the lack of affordable housing nearby impacts the ability to attract or retain qualified entry- and mid-level workers.

The housing element is a jurisdiction's primary tool to address issues of overcrowding, rehabilitation, and access to affordable housing opportunities. Through the housing element's public participation process, the jurisdiction has an opportunity to identify those housing issues in the community that are of most concern and include policies and programs to address those concerns.

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The Location Affordability Index (LAI) gives estimates of the percentage of a family's income dedicated to the combined cost of housing and transportation in a given location. The goal of the LAI is to help individuals, planners, developers, and researchers get a more complete understanding of the costs of living in a given location by accounting for variations between households, neighborhoods, and regions, all of which impact affordability.

Education

Affordable housing is a key ingredient for the educational well-being of families, facilitating educational attainment. Stable and safe housing provides a learning environment. Studies indicate that stable home environments are critical to educational outcomes. Areas of socioeconomic distress may have additional needs for educational support.

The housing element can provide the linkage between housing and education through identifying key resources and policies to promote safe, decent, stable and affordable housing and educational attainment. For example, the sites inventory of a housing element can identify housing opportunities near schools, libraries, and educational services, promote policies to increase affordable housing opportunities, and encourage affordable housing developments to include essential educational programs. Coordination between housing and local school districts can help achieve mutual goals and benefits.

Infill

Housing that is affordable to a broad range of households and income groups is constrained in many communities. Infill development can be an attractive option for accommodating growth and providing a mix of housing choices in many communities – particularly as it can result in lower municipal costs for both capital improvements and long-term operations and maintenance as compared to "greenfield" development. Infill development provides an opportunity to revitalize economically-underutilized land, and also conserves resources and provides environmental and health benefits. Infill development also has the potential to reduce GHG emissions to the extent that it spurs more pedestrian activity, increases transit usage, and reduces the number and lengths of trips. Infrastructure and utilities must be able to support the infill envisioned through the general plan so it is important to coordinate planned infill priority areas with Capital Improvement Plans and other infrastructure investment planning.

The sites inventory requirement of the housing element is one opportunity for identifying opportunities for infill development.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate A full list of recommended policies can be found here.

Sample Policy	Example of Application	Relationship to Other Elements
[City, county] shall encourage development of residential uses in strategic proximity to employment, recreational facilities, schools, neighborhood commercial areas, and transportation routes.	Long Beach	Circulation, land use, healthy communities, economic development, climate change
[City, county] shall revise County ordinances and fees to encourage development of secondary dwellings, and further promote secondary dwellings. For example, the County will consider revising road requirements and public facility fees for secondary dwellings or according to home size.	San Luis Obispo County	Equitable and resilient communities, economic development, healthy communities, circulation
[City, county] shall integrate and disperse special needs housing within the community and in close proximity to transit and public services.	Long Beach	Land use, circulation, equitable and resilient communities, economic development
[City, county] shall invest in infrastructure and public facilities to ensure that adequate water, sewer, roads, parks, and other needed services are in place to serve existing and future residential developments.	Kings County	Air quality, healthy communities, equitable and resilient communities, economic development, climate change
The [city, county] shall encourage the development of senior housing and assisted living facilities, especially near transit, recreational facilities, medical centers and hospitals, neighborhoods well served by pedestrian facilities, and access to healthy food.	City of Chino	Healthy communities, economic development, equitable and resilient communities

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4

Conservation Element

Introduction

The conservation element describes the jurisdiction's natural resources: land, water, ecosystem services and living resources, and the benefits that these resources provide to the community. The conservation element establishes goals and policies for their retention, enhancement and development. The open space element and the land use element should work in coordination with the conservation element to guide conservation and development, balancing community needs with environmental preservation and the effects of climate change. All three of these mandatory elements must be consistent with the others.

Conservation of environmental and agricultural resources is one of the State's three planning priorities, and helps to achieve the State's climate goals. Land conservation policies may have many benefits. Agricultural land conservation can be a foundation for more permanently preserving lands at the edge of cities for their intrinsic open space values. As agricultural activities produce self-sustaining revenue, agricultural conservation can be amongst the most cost-effective means of protecting open space and promoting infill development. By maintaining a buffer zone between urban developments, agricultural lands can reduce sprawl and help to preserve the unique cultural character of separate communities. Prime agricultural lands also help to conserve key environmental values, including quality soil, air, and water. Finally, agricultural lands can provide a critical role in planning strategies to maintain connectivity of conserved lands, successfully preserving wildlife corridors and wetlands.

This section describes the required components of the conservation element, and provides links to suggested policies and tools to help communities in their updates and help to achieve the State's goals.

CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Housing	Open Space	Noise	Safety	EJ
Conservation	IN STATUTE	RELATED	RELATED	IN STATUTE	-	IN STATUTE	-

■ Identified in statute ■ Closely related to statutory requirements

Government Code section 65302(d):

(d) (1) A conservation element for the conservation, development, and utilization of natural resources including water and its hydraulic force, forests, soils, rivers and other waters, harbors, fisheries, wildlife, minerals, and other natural resources. The conservation element shall consider the effect of development within the jurisdiction, as described in the land use element, on natural resources located on public lands, including military installations. That portion of the conservation element including waters shall be developed in coordination with any countywide water agency and with all district and city agencies, including flood management, water conservation, or groundwater agencies that have developed, served, controlled, managed, or conserved water of any type for any purpose in the county or city for which the plan is prepared. Coordination shall include the discussion and

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evaluation of any water supply and demand information described in Section 65352.5, if that information has been submitted by the water agency to the city or county.

(2) The conservation element may also cover all of the following:

(A) The reclamation of land and waters.

(B) Prevention and control of the pollution of streams and other waters.

(C) Regulation of the use of land in stream channels and other areas required for the accomplishment of the conservation plan.

(D) Prevention, control, and correction of the erosion of soils, beaches, and shores.

(E) Protection of watersheds.

(F) The location, quantity and quality of the rock, sand, and gravel resources.

(3) Upon the next revision of the housing element on or after January 1, 2009, the conservation element shall identify rivers, creeks, streams, flood corridors, riparian habitats, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management.

Completeness Checklist

Local agency staff can use the following checklist to help ensure that the draft conservation element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required and the optional issues listed in Government Code section 65302(d)(2). Conservation elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied.

Statutory Citation	Brief Description of Requirement
Gov. Code, §§ 65302(d)(1), 65352.5	Water and its hydraulic force
Gov. Code, § 65302(d)(3)	Floodwater Accommodation
Gov. Code, § 65302(d)(1)	Forests
Gov. Code, § 65302(d)(1)	Soils
Gov. Code, § 65302(d)(1)	Rivers and other waters
Gov. Code, § 65302(d)(1)	Harbors
Gov. Code, § 65302(d)(1)	Fisheries

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Statutory Citation	Brief Description of Requirement
Gov. Code, § 65302(d)(1)	Wildlife
Gov. Code, § 65302(d)(1)	Minerals
Gov. Code, § 65302(d)(1)	Other natural resources
Gov. Code, § 65302(d)(2)	Reclamation of land and waters (optional)
Gov. Code, § 65302(d)(2)	Pollution of streams and other waters (optional)
Gov. Code, § 65302(d)(2)	Land use in stream channels and other areas (optional)
Gov. Code, § 65302(d)(2)	Erosion (optional)
Gov. Code, § 65302(d)(2)	Protection of watersheds (optional)
Gov. Code, § 65302(d)(2)	Rock, sand, and gravel resources (optional)

Required Contents

The conservation element must address the "conservation, development, and utilization of natural resources including

- Water and its hydraulic force
- Forests
- Soils
- Rivers and other waters
- Harbors and fisheries
- Wildlife
- Minerals, and other natural resources

The Government Code further requires the conservation element to "consider the effect of development within the jurisdiction, as described in the land use element, on natural resources located on public lands, including military installations" (Gov. Code § 65302(d)(1)). Evaluation of a jurisdiction's natural resource systems based on sound science and ecological principles is an important first step in preparing the conservation element. One role of the conservation element is to establish policies that reconcile conflicting demands on those resources. In recent years, some jurisdictions have adopted policies related to mitigation banking, conservation easement programs, and the state and federal Endangered Species acts in their conservation elements. Other local jurisdictions have incorporated policies related to regional greenprints or Natural Community Conservation Planning (NCCP) programs. Both of these methods present a broad-based approach to the regional protection of plants and animals and their habitats while allowing for compatible and appropriate economic activity. The California Department of Fish and Wildlife, Department of Conservation, Natural Resources Agency, and Department of Water Resources are some of the many resources available for examining current and future conservation needs. In addition, resource data is available for jurisdictions through the General Plan Mapping tool. Jurisdictions should assess the current condition of their natural resource systems, the ecological processes and compatibilities upon which they depend and their sustainability based on anticipated uses. Analysis of the sustainability of resource uses should take into account changing burdens

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on local ecosystems as a result of a changing climate or other environmental conditions, and should measure the values that these resources contribute to the community and state (see above sidebar on nature's services). In their evaluation of natural resources, local governments should identify priority areas to conserve that offer the most effective and efficient protection of the natural resource systems, and focus policies on those resources or areas. Greenprints, or sustainability plans seeking to balance conservation with growth, are one example of incorporating "green infrastructure" into general plans (see more in text box).

Local governments can dramatically impact the type and amount of water used and conserved within their jurisdictions through land use decisions. For example, requiring more compact development types can significantly reduce per capita water use. Limiting new impervious cover in key recharge areas can protect groundwater supplies. Low impact development strategies such as green roofs, bioretention, and soil amendments, can redirect storm water from sewer lines to recharge areas, and thereby enhance water supplies. The California Water Plan provides strategies, resources, and tools for water management and conservation throughout the State.

The following sections include descriptions of each of the requirements with links to model policies and useful information. Some of the requirements will not be locally relevant for all communities. For example, a land-locked county with no river ports would likely not need to address harbors in its conservation element. It is up to the jurisdiction to choose how to arrange their treatment of the various required issues, which may overlap with one another when addressed in the conservation element's goals and policies.

Planning with conservation in mind can create thriving spaces in the community



Image by Urban Advantage, Community Design + Architecture

Water and Its Hydraulic Force

Requirement Description:

The discussion of water in the conservation element must be prepared in coordination with "any countywide water agency and with all district and city agencies, including flood management, water conservation, or groundwater agencies that have developed, served, controlled, managed, or conserved water of any type for any purpose in the county or city for which the plan is prepared," and must include any information on water supply and demand (Gov. Code § 65302(d)(1)).

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Specific information must be shared with groundwater agencies. The Sustainable Groundwater Management Act (SGMA) allows local jurisdictions to customize groundwater plans based on their specific needs. Discussion of water should analyze water needs for domestic, agricultural, ecological and industrial uses, and provide for the conservation of water supplies and protection of aquatic ecosystems as a beneficial use. Land use choices affect water demand long into the future. When evaluating the feasibility of possible land use patterns, cities and counties should work with water agencies to consider projected available water resources under a changing climate, and water conservation measures to ensure a sustainable water supply, rather than simply deferring to water

Natural Resources as Nature's Benefits; Greenprints and Conservation

A conservation element can include a quantification and explanation of the benefits that the community obtains from their surrounding ecosystems. Communities' well-being depends on the benefits that nature provides for free, every day and everywhere. For example, we depend on ecosystems such as forests and wetlands, for clean water, fertile soils, food, fuel, storm protection, minerals and flood control.

These benefits, often called "nature's benefits," are commonly categorized into four broad categories. Provisioning benefits include the production of food and water, while regulating benefits include the control of climate and disease. Supporting benefits include nutrient cycles and crop pollination. Lastly, cultural benefits include spiritual and recreational opportunities. To help inform planning decisions, these benefits can be assigned economic values, values that measure other non-monetary benefits to the community, and values that demonstrate the benefits gained when various natural resources mutually reinforce each other. These benefits and services can be expressed in a "Greenprint," such as those developed under the federal sustainable communities initiative, which can help local governments to analyze and plan for these cross-cutting and community-supporting benefits in their general plan updates and apply innovative and successful strategies for implementation. For more information on ecosystem services see

http://www.fs.fed.us/ecosystemservices/

http://www.nature.org/science-in-action/ecosystem-services.xml

agencies to meet any projected demand. Jurisdictions may want to form joint committees to synchronize planning timelines between water and land use, coordinate with local integrated regional water management plans (IRWM), consider using watersheds as their planning area, or explicitly acknowledge their relationship to an existing watershed. Smaller urban development footprints (i.e. concentrated development) protect and enhance the watershed, improving water supply, flood management, and water quality. The California Water Plan currently projects diminishing reliability in water supplies of 3-5% in the next twenty years. Existing water sources may also become less reliable due to climate change and development. The conservation element is inextricably connected to the land use and open space elements.

The decision in *County of Amador v. El Dorado County Water Agency* helps to further clarify the relationship between availability of water and development: "in determining whether and where to permit development, a county must necessarily

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consider the availability of consumptive water supplies. If additional water supplies are available, growth and development are feasible. Conversely, if that water is not available, growth is necessarily limited." The Government Code and Water Code additionally require water supply districts to prepare water supply verifications and assessments for some large-scale projects, including subdivisions of over 500 dwelling units (Gov. Code § 66473.7)). When amending its general plan, a jurisdiction shall coordinate with any public water agency pursuant to Government Code section 65352.5 to analyze available water supply information and identify adequate water for anticipated growth. Additionally, Urban Water Management Plans, where required, rely on build-out data from general plans, highlighting the importance of consistency and communication between agencies. For specific projects, the water supply verification comes at the final approval stage of project development, and a subdivision cannot be approved if adequate water supplies do not exist at this stage. (Gov. Code § 66473.7(b)(1)).

National Flood Insurance Rate Program maps, dam failure inundation maps, information available from the California Department of Water Resources, U.S. Army Corps of Engineers, the Federal Emergency Management Agency and historical data on flooding all provide useful information for identifying flood-prone areas for floodwater management purposes. Aspects of floodwater management must also be addressed in the land use and safety elements, and local governments may want to consider combining these discussions in their general plans (Gov. Code §§ 65302(a), 65302(g)(2)). The Government Code also provides further requirements on development in flood hazard zones as defined in Government Code section 65007(d) in the Sacramento-San Joaquin Valley (Gov. Code §§ 65302.9, 65860.1, 65865.5, 65962, 66474.5).

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Assessment of existing and projected demands on water supply sources	Inventory of quality and boundaries of watershed, aquifer recharge areas, groundwater basins, and other water resources
Risk assessment for flooding	Flood maps
Examination of ability to align policies, zoning, and goals regarding housing built	Number of housing units allocated through SCS
Assessment of potential housing developments	Documented interest by developers and landowners

Forests

Requirement Description:

The conservation element must provide for the management, enhancement, protection, and potential modification of the current agroforestry practices for wildlife protection, watershed protection, recreation, and aesthetic purposes. Possible topics to address include protection of oak woodlands and urban forests, analysis of possible future development within resource areas, the need for suitable and predicted-to-be suitable habitat management for the mitigation of climate change, precipitation retention for watershed management and attenuation of flood waters, aesthetics, cultural use, commercial value of forests, and protection of timber resources subject to timberland production zoning (Gov. Code § 51104(e-g); 51110-51119.5)

California's forests are valuable assets and their conservation provides many benefits to the natural and built environments. As trees grow and develop, their value to the forest ecosystem and climate change mitigation increases. Older trees sequester significantly more carbon than young trees and are necessary for nutrient cycles for nitrogen and phosphorous. These nutrients are limited,

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and without proper maintenance, could eventually deplete the soil. Trees and source wood left on site significantly contribute to the abundance of biodiversity and the prevention of habitat loss and displacement. Trees in forest and urban areas act as micro and macro climate buffers by moderating temperatures and moisture.

Conservation of forests should be balanced with the proper action to prevent risk from wildfires (see the safety element for more information). As climate change persists and temperatures rise, wildfires will continue to grow in size, frequency, and total area burned. Throughout its history, California experienced frequent fires by lightning and burning regimes, critical in developing the composition, structure, and pattern of vegetation throughout the state's landscapes.

In order to prevent destructive wildfires and restore and maintain resilient landscapes, policies should be developed that are appropriate for local conditions to mitigate potential losses due to wildfire. Policies for mitigating potential losses should also consider approaches to maintain healthy forests, including prescribed burns, fuel breaks, wildfire protection zones, and forest thinning and grazing. Fuel treatment manipulates and removes fuel to reduce fire intensity with methods such as lopping, chipping, crushing, piling, and burning. Fuel treatment is critical to enhance protection of forests as well as develop resilience. As a guiding resource, OPR's Fire Hazard Planning Technical Advisory includes a detailed discussion about how to incorporate and comply with the fire hazard requirements in a general plan.

Forest conservation practices also present the opportunity to conserve species in their native habitat. Collaboration with local tribes, resource conservation districts, non-government conservation organizations, and other government entities may help determine the best tools for ecosystem restoration, wildfire prevention, and wildlife habitat enhancement.

The management and protection of forests should take into account anticipated changes in coming decades in temperature, the viability or presence of particular wildlife populations in response to warming trends, and the impact on forestry resources of increased extreme weather events and more intense forest fire seasons. For reference, visit http://www.fs.fed.us/maps/.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Analysis of conservation needs	Type, location, amount, and ownership of forests by category
Reduce risk of wildfire and post-fire mitigation needs	Fire hazard zone maps

Soils

Requirement Description:

Soils provide the fundamental resources necessary for the production of food, fiber and other agricultural products. Healthy soil resources, rich in soil organic matter, are essential to crop production, watershed functioning, carbon sequestration, and the support of vegetation. Highly productive soil resources that support agricultural production and ecosystem services are a finite resource; thus requiring long-term conservation. Soil management and conservation practices, such as cover cropping, crop rotation, mulching, and nutrient management, may help support healthy soils and conservation goals.

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The Official Soil Series Descriptions (OSDs) and the Storie Index provide useful tools for assessing and inventorying farmland soils, as does the Farmland Mapping & Monitoring Program of the state Department of Conservation. Consultation with the city or county's local Resource Conservation District may also be helpful in assessing soil resources and developing policies focused on the management of agricultural soils; consistent with the Resource Conservation District's broader agricultural strategy. The conservation element should identify soils necessary for agricultural production and include policies that promote the conservation of these resources. Preservation of prime agricultural land, and identification of water availability for that land, can be a foundation for improving and maintaining soil while more permanently preserving lands, improving the economy, and preserving biological resources, and should be coordinated with the land use element. Local governments should identify areas included in agricultural preserves under the Williamson Act (Gov. Code § 51200). Additionally, conservation easements on agricultural lands, working with willing landowners and land trusts, can also serve to protect soil resources and constitute feasible mitigation to lessen impacts on agricultural resources, including highly productive soils. The soils section may also identify areas subject to slides and erosion and include policies focusing on erosion prevention, one of the optional issues listed in Government Code section 65302(d)(2).

Daylighting Existing Waters

Cities and counties across California and the country are recognizing the potential benefits of revitalizing rivers, streams, and creeks long hidden by previous development. Waterways have historically been covered, especially in urban areas, to quickly redirect stormwater, create more room for commercial districts, and enable automobile transport. In the past decade, however, planners have begun to note the possible advantages of daylighting and restoring waterways, including:

- Reducing flooding
- Conserving groundwater
- Reducing heat island effects
- Providing greenspace for the community
- Activating urban spaces

Examples of programs to restore urban waterways include the LA River in Los Angeles, Strawberry Creek in Berkeley, and San Luis Obispo Creek in San Luis Obispo.

Rivers and Other Waters

Requirement Description:

The rivers and other waters requirement examines water quality in local bodies of water. As with water and its hydraulic force, any discussion of water in the conservation element must be prepared in coordination with "any countywide water agency and with all district and city agencies, including flood management, water conservation, or groundwater agencies that have developed, served,

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controlled, managed, or conserved water of any type for any purpose in the county or city for which the plan is prepared," and must include any information on water supply and demand prepared pursuant to Government Code section 65352.5 (Gov. Code § 65302(d)(1)). Topics to address include identification of existing and potential water pollution sources, the benefits that water resources provide to the community, opportunities for protection and restoration, and identification of water sources for which reclamation is feasible. Policies should take into account the impacts of future development on water bodies and aim to protect or improve water quality. Preservation of flood plains and innovative methods of flood control, such as making "room for the river," can have positive benefits for related elements of the plan. Certain areas may also be important for groundwater recharge.

Rivers, lakes, streams, bays, harbors, estuaries, marshes, and reservoirs might be affected by climate change impacts such as decreased snow pack, changes in precipitation, and sea level rise. Cities and counties should consider taking these projected impacts into account when planning for the protection of their water bodies.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Compliance with total maximum daily load (TMDL) regulations	Current loads, expected project impact

Harbors and Fisheries

Requirement Description:

The harbors and fisheries requirement addresses the development and improvement of port, harbor, and waterway facilities. This issue has significant overlap with the circulation element, and may be combined with it at the local government's discretion. Policies in general plans should be consistent with harbor and port master plans developed under the California Coastal Act (Pub. Resources Code § 30000 et seq.).

Fisheries are an important component of California's economy, and their careful management ensures their viability into the future. Possible topics to address in the fisheries section include evaluation of existing and projected future water quality; temperature; sources of contaminants in bodies of water used for subsistence, recreational, and commercial fishing; expected impacts of climate change on habitat and fisheries and policies that protect and rehabilitate those water bodies; existence and purpose of marine protected areas (MPAs); and preservation of riparian, tidal, and wetland habitat connected to waterways.

Wildlife

Requirement Description:

California is home to a diverse array of wildlife, and the conservation element should provide plans for the protection and preservation of these populations and their habitats. This must include wildlife that is classified as a rare, threatened, or endangered species under state and federal law (Fish & G. Code § 2050 et seq.; 16 U.S.C. § 1531). Planning for wildlife habitats should account for current habitats, health of wildlife, projected changes in such habitat due to climate change, wildlife conservation, furthering responsible development and addressing the needs of a growing human population, habitat connectivity and potential threats to such habitat from development

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pressures, fragmentation and edge effects. The conservation element's focus on wildlife should be consistent with the State Wildlife Action Plan, California Essential Habitat Connectivity Project, Regional Advance Mitigation Plans, conservation plans developed by the state and regional entities, Habitat Conservation Plans (e.g. California Endangered Species Act (CESA), California Environmental Quality Act Review (CEQA), Lake and Streambed Alteration Program (LSA), Timberland Conservation Program, Natural Community Conservation Planning (NCCP), Conservation and Mitigation Banking, Invasive Species Program, Native Plant Program) and other management plans, and should include coordination with other government agencies involved in wildlife preservation. Due to the considerable overlap between habitat lands and agricultural lands, multiple benefits for wildlife and agriculture may be gained by coordinating conservation plans and strategies. The California Agriculture Vision Document highlights relationships between habitat and agricultural conservation, and presents strategies for the conservation of both.

The Marine Life Protection Act of 1999 (MLPA) recognized the need to safeguard the long-term health of California's marine life. By establishing a statewide network of marine protected areas (MPAs) designed, created, and managed using sound science and stakeholder input, MLPA aimed to protect the diversity and abundance of marine life, the habitats they depend on, and the integrity of marine ecosystems in California. MPAs are named, discrete geographic marine or estuarine areas designed to protect or conserve marine life and habitat. Potential interactions between MPAs and planned land uses may affect wildlife, harbors and fisheries, and other considerations related to conservation and open space in some communities. Cities and counties should consult the interactive MarineBIOS map available from the Department of Fish and Wildlife, or the General Plan Mapping Tool to examine MPAs around their communities.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identify specific tools and approaches to restore natural areas to benefit fish and wildlife as part of a sustainable flood management plan	DWR Conservation Strategy
Project impacts on critical habitat for listed species	Map of critical habitats
Analysis of existing conservation projects	SGC Review of Conservation lands

Minerals and Other Natural Resources

Requirement Description:

According to California Public Resources Code section 2005, minerals "means any naturally occurring chemical element or compound, or groups of elements and compounds, formed from inorganic processes and organic substances, including, but not limited to, coal, peat, and bituminous rock, but excluding geothermal resources, natural gas, and petroleum." While not explicitly required, local governments may also want to consider geothermal, petroleum, and natural gas in their assessment of mineral resources as appropriate. The minerals section should locate and inventory mineral resources designated by the State Mining and Geology Board under the Surface Mining and Reclamation Act (Pub. Resources Code § 2710 et seq.), and include polices that plan for the protection, use, and development of mineral resources. This section should also locate and plan for the protection, use and development of rock, sand and gravel resources, one of the optional issues listed in Government Code section 65302(d)(2) if those resources are found in the jurisdiction.

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'Other natural resources' may include agricultural resources, wetlands, urban forestry, air, and energy producing resources. Some cities and counties also include paleontological and archaeological resources in this section. Model policies include those that assess air quality and coordinate with other agencies and jurisdictions to improve it; identify agricultural resources using the Natural Resources Conservation Service's land inventory and monitoring criteria inventory; include plans for the preservation of wetlands; and inventory energy resources including wind, solar, hydroelectric, and biomass resources. Air quality policies should be consistent with regional air quality and transportation plans.

Floodwater Management

Requirement Description:

To address floodwater management in the conservation element, the city or county should collect information concerning its flood plains and its watershed. DWR has updated its Best Available Maps to display the latest floodplains. DWR has expanded the floodplains to cover all counties in the State and to include 100, 200, and 500-year floodplains. The Office of Emergency Services (OES) and DWR have information on past floods and flood levels. Local levee districts and resource conservation may also have information to share.

DWR also completed the 2012 Central Valley Flood Protection Plan (CVFPP), which provides a guide for state participation with managing flood risk along the Sacramento River and San Joaquin River. The CVFPP provides data and analysis that include the locations of flood hazard zones; goals, policies, and objectives based on that data and analysis; and feasible implementation measures designed to carry out these goals, policies, and objectives. The CVFPP includes a Groundwater Recharge Opportunity Analysis, which can also be useful. This document summarizes an evaluation of groundwater recharge project types and general locations that could be used to integrate groundwater recharge and groundwater storage with the flood management system to increase both flood management flexibility and water supply reliability.

DWR also recommends working with applicable agencies to incorporate improvements in flood control channels that provide opportunities for stormwater retention and groundwater recharge, when major upgrades and/or reconstruction are required. Low impact development strategies may also help protect communities from floodwater by redirecting stormwater.

For additional data and analysis related to flood safety, see the safety element. For data and analysis related to identification and annual review of areas subject to flooding, see the land use element.

Optional Issues

Pursuant to Government Code section 65302(d)(2), the conservation element may also cover the reclamation of land and waters; prevention and control of the pollution of streams and other waters; regulation of the use of land in stream channels and other areas required for the accomplishment of the conservation plan; prevention, control, and correction of the erosion of soils, beaches, and shores; protection of watersheds; protection of habitat connectivity, and the location, quantity, and quality of rock, sand, and gravel resources. Local governments might choose to integrate these optional issues into their analyses of and policies for the mandatory requirements.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here:

Sample Policy	Example of Application	Relationship to Other Elements
[City, county] shall identify and develop a coordinated biological preserve system that includes Pre–Approved Mitigation Areas, Biological Resource Core Areas, wildlife corridors, and linkages to allow wildlife to travel throughout their habitat ranges. Avoid adverse impacts to wildlife movement corridors and nursery sites (e.g., nest sites, dens, spawning areas, breeding ponds).	San Diego County, Yolo County	Land use, open space, climate change
[City, county] shall allow for appropriate public access to open space lands for recreation activities while protecting and restoring the natural ecosystem and minimizing environmental damage, as appropriate	Redwood City	Land use, open space, circulation, equitable and resilient communities, economic development
[City, county] shall in conjunction with new development located along existing creeks and streams and where appropriate, incorporate daylighting for culverted portions or other bank naturalizing approaches for channeled sections as a means of creek and stream restoration.	Redwood City	Land use, open space
[City, county] shall establish a coherent and logical pattern of urban uses that protect and enhance open space and agricultural uses by providing a clear and permanent boundary for urban uses with the [city, county]'s planning area.	City of Livermore	Land use, circulation, housing, conservation, safety, climate change, economic development

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Open Space Element

Introduction

"California legislative policy strongly favors the preservation of open spaces" (*Gisler v. County of Madera* (1974) 38 Cal. App. 3d 303, 307; see also Cal. Const. art. XIII, § 8). Together with the conservation element, an open space element identifies areas that provide value in an essentially undeveloped condition and creates a plan to preserve such areas. The open space element reinforces the conservation element by guiding the comprehensive and long-range preservation of open space lands that are important to the conservation of the State's natural resources. The conservation element should be used to inform and support both the open space element and the land use element, guiding the identification of resource areas that should remain undeveloped and those that are appropriate for future development. Open space is defined as any parcel or area of land or water that is essentially unimproved and devoted to open-space use (Gov. Code § 65560(b)). Such lands or waters may provide value related to, among other things, recreation, health, habitat, biodiversity, wildlife conservation aesthetics, economy, climate change mitigation and adaptation, flood risk reduction, managed natural resources production, agricultural production, and protection from hazardous conditions.

Because open space issues are broad in nature and overlap those of several elements, consistency among elements must be considered carefully. The open space element is interrelated with other elements, overlapping with the conservation element when referring to open space dedicated to the preservation of natural resources and the managed production of resources; the safety element when considering open space for public health and safety; and the housing and land use elements when determining the suitability of sites for future development.

CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Housing	Conservation	Noise	Safety	EJ
Open Space	RELATED	RELATED	RELATED	IN STATUTE	RELATED	IN STATUTE	RELATED

■ Identified in statute ■ Closely related to statutory requirements

Government Code Section 65560

(a) "Local open-space plan" is the open-space element of a county or city general plan adopted by the board or council, either as the local open-space plan or as the interim local open-space plan adopted pursuant to Section 65563.

(b) "Open-space land" is any parcel or area of land or water that is essentially unimproved and devoted to an open-space use as defined in this section, and that is designated on a local, regional, or state open-space plan as any of the following:

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(1) Open space for the preservation of natural resources, including, but not limited to, areas required for the preservation of plant and animal life, including habitat for fish and wildlife species; areas required for ecologic and other scientific study purposes; rivers, streams, bays, and estuaries; and coastal beaches, lakeshores, banks of rivers and streams, and watershed lands.

(2) Open space used for the managed production of resources, including, but not limited to, forest lands, rangeland, agricultural lands, and areas of economic importance for the production of food or fiber; areas required for recharge of groundwater basins; bays, estuaries, marshes, rivers, and streams that are important for the management of commercial fisheries; and areas containing major mineral deposits, including those in short supply.

(3) Open space for outdoor recreation, including, but not limited to, areas of outstanding scenic, historic, and cultural value; areas particularly suited for park and recreation purposes, including access to lakeshores, beaches, and rivers and streams; and areas that serve as links between major recreation and open-space reservations, including utility easements, banks of rivers and streams, trails, and scenic highway corridors.

(4) Open space for public health and safety, including, but not limited to, areas that require special management or regulation because of hazardous or special conditions such as earthquake fault zones, unstable soil areas, flood plains, watersheds; areas presenting high fire risks; areas required for the protection of water quality and water reservoirs; and areas required for the protection and enhancement of air quality.

(5) Open space in support of the mission of military installations that comprise areas adjacent to military installations, military training routes, and underlying restricted airspace that can provide additional buffer zones to military activities and complement the resource values of the military lands.

(6) Open space for the protection of places, features, and objects described in Sections 5097.9 and 5097.993 of the Public Resources Code.

Completeness Checklist

Local agency staff can use the following checklist to help ensure that the open space element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required by Government Code section 65560 et seq. Open Space elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied

Statutory Citation	Brief Description of Requirement
Gov. Code § 65563	Long range and comprehensive
Gov. Code § 65563	Plan for preservation and conservation of open space lands, including the following:

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Statutory Citation	Brief Description of Requirement
Gov. Code § 65560(b)(1)	Open Space for Natural Resources • Areas required for the preservation of plant and animal life, including habitat for fish and wildlife species; • Areas required for ecologic and other scientific study purposes; • Rivers, streams, bays and estuaries; and • Coastal beaches, lakeshores, banks of rivers and streams, and watershed lands
Gov. Code § 65560(b)(2)	Open Space for Managed Production of Resources • Forest lands, rangeland, agricultural lands (reflecting Department of Conservation agricultural resources maps and inventory) and areas of economic importance for the production of food or fiber; • Areas required for recharge of groundwater basins; • Bays, estuaries, marshes, rivers and streams which are important for the management of commercial fisheries; and • Areas containing major mineral deposits, including those in short supply
Gov. Code § 65560(b)(3)	Open Space for Outdoor Recreation • Areas of outstanding scenic, historic and cultural value; • Areas particularly suited for park and recreation purposes, including access to lakeshores, beaches, and rivers and streams; and • Areas which serve as links between major recreation and open-space reservations, including utility easements, banks of rivers and streams, trails, and scenic highway corridors
Gov. Code § 65560(b)(4)	Open Space for Public Health and Safety • Areas which require special management or regulation because of hazardous or special conditions such as o Earthquake fault zones, o Unstable soil areas, o Flood plains, o Watersheds, o Areas presenting high fire risks, o Areas required for the protection of water quality and water reservoirs and o Areas required for the protection and enhancement of air quality
Gov. Code § 65560(b)(5)	Open Space for Military Support • Areas adjacent to military installations, • Military training routes, and • Areas underlying restricted airspace
Gov. Code § 65560(b)(6)	Open Space for Tribal Resources • Public land containing any Native American o Sanctified cemetery, o Place of worship, o Religious or ceremonial site, or o Sacred shrine • Native American historic, cultural, or sacred sites, that are listed or may be eligible for listing in the California Register of Historic Resources pursuant to Section 5024.1 • Tribal consultation is required to determine the level of confidentiality needed (§ 65562.5)
Save El Toro Assn. v. Days (1977) 74 Cal. App. 3d 64, 73 Gov. Code § 65560(b)	Inventory of the above lands • Include any parcel that is essentially unimproved (i.e., need not be completely vacant)
Gov. Code § 65562(a)	Policies provide that open space "must be conserved wherever possible"
Gov. Code § 65562(b)	Co-ordinated with state and regional plans
Gov. Code § 65564 • § 65566 • § 65567 • § 65910	Action plan • Acquisition and disposal of open space must be consistent with the open space plan • Building permits, subdivision maps and zoning must be consistent with the plan • Open-space zoning pursuant to § 65910 (e.g., exclusive agriculture zones, large-lot zones, overlay zones for hazards areas, etc.) must be consistent with the plan

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Required Contents

The Government Code § 65560 requires an open space element to contain detailed information about several categories of undeveloped land. Specifically, the open space element must inventory the following broad categories of open space:

- Open space for natural resources
- Open space for managed production of resources
- Open space for outdoor recreation
- Open space for public health and safety
- Open space for military support
- Open space for tribal resources

The inventory should be reflected on maps, and policies must provide for conservation of such areas wherever possible (Gov. Code § 65562(a)). The General Plan Mapping Tool is a useful tool to help communities identify existing resources, including natural resources, roads, buildings, and demographics, and develop open space inventories accordingly. The tool pulls data from multiple state and federal sources, and allows supplemental data layers from local jurisdictions. The tool allows mapping of known resources, assets, and needs of the community. The local open space plan, together with state and regional plans, must form a comprehensive open space plan (Gov. Code § 65562(b)). Every city and county must prepare, and submit to the Secretary of Natural Resources, an open space plan for comprehensive and long-term preservation of open spaces (Gov. Code § 66563). The plan must include an action program with specific programs to implement the plan(Gov. Code § 65564). These specific requirements are described in greater detail below.

Inventory

Requirement Description:

The open space element must contain an inventory of specified categories of open space resources (*Save El Toro Assn. v. Days* (1977) 74 Cal.App.3d 64, 73). The inventory must include any parcel in one of the listed categories that is: (1) "essentially unimproved" and (2) designated on any local, regional or state open-space plan (Gov. Code § 65560(b)(1)). Note that a particular parcel need not be completely vacant to be included in the inventory. Also, categories of open space are defined in very broad terms in the statute. Thus, designations in local, regional and state plans need not actually use the words "open space" in order to be included in the inventory. In general, a plan should err on the side of inclusion.

Examples of regional and state plans that could include open space designations include, among others:

> *Sustainable Communities Strategies and alternative planning strategies adopted by metropolitan planning organizations in regional transportation plans*
>
> *Habitat Conservation Plans (HCPs) and Natural Community Conservation Plans (NCCPs)*
>
> *Regional greenprints*

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Regional conservation assessments

Regional park district plans

Agricultural lands designated on Department of Conservation farmland maps

The specific categories of open space that must be included in the inventory are set forth below.

Open space for natural resources

Requirement Description:

The inventory must identify open space for natural resources, including, but not limited to:

Areas required for the preservation of plant and animal life, including habitat for fish and wildlife species. Such areas may include:

- Areas designated in HCPs and NCCPs
- Critical habitat identified pursuant to the Endangered Species Act (ESA)
- Conservation easements
- Marine protected areas (MPAs)
- Areas identified in greenprints and Regional Conservation Assessments (RCAs)
- Parks and trails
- Areas designated by federal, state, regional and local agencies and governments as important habitat
- Existing forest and woodland areas set aside for mitigation
- Areas important for habitat connectivity

Areas required for ecologic and other scientific study purposes. Such areas may include preserves, parks and other land used by universities to study agricultural systems, wildlife habitats, and other natural systems.

Rivers, streams, bays and estuaries; riparian areas; and coastal beaches, lakeshores, banks of rivers

Simple improvements can create better spaces for recreation and activity





Image by Urban Advantage, Canopy

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and streams, and watershed lands. Virtually all waters within a jurisdiction should be identified in the open space element. Upland areas connected to such waters should also be identified. Such areas may be identified in basin plans, watershed plans, and other planning documents produced by the State Water Resources Control Board, Regional Water Quality Control Boards, and other regional entities.

SAMPLE OF OPR RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identification of protected areas to preserve	Marine protected areas (MPAs), critical habitat areas, areas identified in local conservation plans
Potential effects of development on water sources	Watershed maps

Open Space For Managed Production Of Resources

Requirement Description:

The inventory must include lands that are used for the production, enhancement, or maintenance of natural resources.

Forest lands must be maintained in an efficient way to support the continued cultivation of timberland (Gov. Code § 51101, § 51102). With an increasing state population, these forest areas need to be protected against encroaching development to preserve their ecological services as well as economic vitality. Timberland Production Zones are designated for the production of timber or compatible uses and should not be converted for urban services.

Forest and rangelands information is available from the California Department of Forestry and Fire Protection's California Forest and Range Assessment. Information regarding agricultural lands is available from the Department of Conservation's maps and inventory, California Protected Areas Database, CCED - California Conservation Easement Database, National Conservation Easement Database (NCED), and Conservation Easements Registry.

Many local governments also produce their own information regarding locally important lands.

Areas required for recharge of groundwater basins: Information regarding groundwater recharge should be available from urban water management plans and integrated water resource management plans. Cities and counties must also confer with any locally designated groundwater sustainability agency (SGMA).

Bays, estuaries, marshes, rivers and streams that are important for the management of commercial fisheries: Information on fisheries is available from the Department of Fish and Wildlife.

Areas containing major mineral deposits, including those in short supply: Information regarding mineral resources is available from the Department of Conservation.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identification of areas to protect in order to maintain groundwater management	Groundwater supply agency, DWR, urban water management plans

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Open Space For Outdoor Recreation

Requirement Description:

The open space inventory must reflect open space currently used or planned for outdoor recreation. A city or county should consult with any regional park and open space district in identifying such areas. Jurisdictions should inventory existing recreational space, including marine protected areas adjacent to landside parks, and assess present and future demand based on population, demographic, and development trends. Including existing and planned open space for recreation on the land use map can help coordinate future development with anticipated recreational needs.

Access to open space for recreation impacts individual and community health, and should be planned equitably and with accessibility considerations, to ensure underserved communities are included.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Determine level of access to open space facilities	Transit, bike, and pedestrian paths and routes leading to open space centers
Ensure equitable distribution of recreational open space facilities	Demographic information alongside maps of current and planned open space

Open Space for Public Health and Safety

Requirement Description:

Clean air and water, recreational and natural spaces, farms, ranches, and open spaces conducive to active transportation and healthy lifestyles foster health benefits for communities. The inventory should include areas that require special management or regulation because of hazardous or special conditions. These areas are important for protection or enhancement of public health. Hazardous conditions specifically identified in the statute are:

- Earthquake fault zones
- Unstable soil areas
- Flood plains
- Watersheds
- Areas presenting high fire risks
- Areas required for protection of water quality and water reservoirs
- Areas required for protection and enhancement of air quality

(Gov. Code 65560(b)(4)). Information about those areas is available through the State of California Geoportal site. Much of the information and policies related to hazards will also be relevant to the safety element. For additional ideas on data and analysis, see the healthy communities section and safety element.

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SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Risks associated with designated open space areas	Earthquake fault zones, flood plains, and fire risk areas mapped alongside open space
Identification of areas for enhancement or protection of air quality	Air quality levels by area, circulation maps, inventory of trees and greenery

Open Space for Military Support

Requirement Description:

The open space element must identify military installations and training routes. It should include policies for areas adjacent to or related to military activity. For additional information please review the California Advisory Handbook for Community and Military Compatibility Planning.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identify areas to protect from development for military purposes	Mapping of military installations and training routes

Open Space for Tribal Resources

Requirement Description:

Consultation with the appropriate tribes is essential to both accurately identify those areas needing protection, and to protect the confidentiality and dignity of sensitive resources. Jurisdictions must consult with Native American tribes during an amendment or update to a general plan (Gov. Code § 65352). The Native American Heritage Commission can help identify the appropriate tribes to engage in consultation. The following are categories of tribal resources that should be included in the open space element and the inventory of open space resources (Gov. Code § 65560(b)(6)); also see adjacent box):

- Public land containing any Native American sanctified cemetery, place of worship, religious or ceremonial site, or sacred shrine. The Native American Heritage Commission can provide access to such information.
- Native American historic, cultural, or sacred sites that are listed or may be eligible for listing in the California Register of Historic Resources pursuant to Public Resources Code Section 5024.1.

Before the adoption or any amendment of a city or county's general plan, the city or county must conduct consultations with California Native American tribes that are on the contact list maintained by the Native American Heritage Commission for the purpose of preserving or mitigating impacts to places, features, and objects described in Public Resources Code Sections 5097.9 and 5097.993 that are located within the city our county's jurisdiction (Gov. Code § 65352.3(a)(1)). From the date on which a city or county pursuant to this subdivision contacts a California Native American tribe, the tribe has 90 days in which to request a consultation, unless a shorter timeframe has been agreed to by that tribe (Gov. Code § 65352.3(a)(2)).

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Government Code § 65560(b)(6):

- Public land containing any Native American
  - » sanctified cemetery,
  - » place of worship,
  - » religious or ceremonial site,
  - » sacred shrine,
  - » burial sites,
  - » historic or prehistoric ruins, or
  - » Native American inscriptions or rock art
- Native American historic, cultural, or sacred site that is listed or may be eligible for listing in the California Register of Historic Resources pursuant to Public Resources Code Section 5024.1
- Tribal consultation is required to determine the level of confidentiality needed (Gov. Code § 65562.5)

Consistent with the guidelines developed and adopted by the Office of Planning and Research pursuant to Government Code Section 65040.2, the city our county shall protect the confidentiality of information concerning the specific identity, location, character, and use of those places, features and objects. (Gov. Code § 65352.3(b)).

In addition, if new areas containing tribal resources are designated as open space after 2005, Government Code Section 65562.5 requires additional consultation. When consulting tribes, refer to Section V of the 2005 Tribal Consultation Guidelines, Supplement to the GPG:

On and after March 1, 2005, if land designated, or proposed to be designated as open space contains a place of cultural significance, and if an affected tribe has requested notice of public hearing under Government Code §65092, then local governments must consult with the tribe. The purpose of this consultation is to determine the level of confidentiality required to protect the specific identity, location, or use of the cultural place, and to develop treatment with appropriate dignity of the cultural place in any corresponding management plan (Gov. Code §65562.5).

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identification of Tribal resources to be protected	Inventory of locations and descriptions of resources, obtained through Tribal consultation

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here

Sample Policy	Example of Application	Relationship to Other Elements
[City/county] shall work with the Park District to seek locations for and the development of neighborhood parks in those neighborhoods which lack park acreage.	City of Citrus Heights	Land use, conservation, healthy communities
[City/county] shall establish an open space acquisition program that identifies acquisition area priorities based on capital costs, operation and maintenance costs, accessibility, needs, resource preservation, ability to complete or enhance the existing open space linkage system and unique environmental features.	City of Riverside	Land use, conservation, economic development, safety
[City/county] shall maximize public benefits in the reclamation of mineral extraction and sanitary landfill areas	City of Rialto	Land use, conservation, safety, climate change
[City/county] shall maintain habitat corridors to connect conservation areas such as parks, [marine protected areas], and open space, protect biodiversity, accommodate wildlife movement and sustain ecosystems	City of Citrus Heights	Land use, conservation, climate change
City/county] shall develop, wherever possible, recreation facilities that have multi-use capabilities and high degree of adaptability to more intensive use or uses as recreation demand changes and/or population density increases	City of Brea	Land use, conservation, equitable and resiliant communities, economic development, healthy communities

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Noise Element

Introduction

Noise surrounds us; it is a constant presence in everyday life. A noisy community can be an excellent indicator of a healthy community: the noise from busy shops, children playing, and public transportation are all signs of a thriving environment. Noise is often defined subjectively, surrounding busy transportation corridors, recreational areas, construction zones, and schools as unwanted sound, while welcomed when supporting the presence of activity in a commercial business area. In addition, some development goals, such as infill, may create acceptably higher levels of noise. The purpose of the noise element is to ensure that a local planning area limits the exposure of the community to excessive noise levels in noise-sensitive areas and at noise-sensitive times of day.

In 1976, the Department of Health Services Office of Noise Control issued the first Noise Element Guidelines pursuant to Health and Safety Code section 46050.1, followed shortly thereafter by a model noise ordinance.

Although the Office of Noise Control no longer exists, the principles that it developed are still valid and widely used. Its Noise Element Guidelines, which are in Appendix D, are an additional resource that local governments may consult in addition to this chapter to develop noise elements.

Government Code 65302(f):

(1) A noise element that shall identify and appraise noise problems in the community. The noise element shall analyze and quantify, to the extent practicable, as determined by the legislative body, current and projected noise levels for all of the following sources:

(A) Highways and freeways.

(B) Primary arterials and major local streets.

(C) Passenger and freight online railroad operations and ground rapid transit systems.

(D) Commercial, general aviation, heliport, helistop, and military airport operations, aircraft overflights, jet engine test stands, and all other ground facilities and maintenance functions related to airport operation.

(E) Local industrial plants, including, but not limited to, railroad classification yards.

(F) Other ground stationary noise sources, including, but not limited to, military installations, identified by local agencies as contributing to the community noise environment.

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(2) Noise contours shall be shown for all of these sources and stated in terms of community noise equivalent level (CNEL) or day-night average level (Ldn). The noise contours shall be prepared on the basis of noise monitoring or following generally accepted noise modeling techniques for the various sources identified in paragraphs (1) to (6), inclusive.

(3) The noise contours shall be used as a guide for establishing a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise.

(4) The noise element shall include implementation measures and possible solutions that address existing and foreseeable noise problems, if any. The adopted noise element shall serve as a guideline for compliance with the state's noise insulation standards.

Many noise related planning resources are available. The Caltrans Office of Transportation Laboratory publishes the Traffic Noise Analysis Protocol and numerous reports on mitigating transportation noise. The California Airport Land Use Planning Handbook, published by Caltrans' Division of Aeronautics, includes noise information relating to airports. The Federal Highway Administration has published multiple noise reports, including a Construction Noise Handbook, Highway Traffic Noise: Analysis and Abatement Guide, Transit Noise and Vibration Impact Assessment, and Synthesis of Noise Effects on Wildlife Populations.

The process to create the noise element should include, but is not limited to, the following steps:

- Survey the community to determine the type, location and extent of noise incompatibility in the community
- Explore methods of noise attenuation to minimize exposure to excessive noise
- Research methods to protect residences and other sensitive receptors from excessive noise
- Draft implementation measures that offer solutions to existing and foreseeable noise problems

CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Safety	EJ
Noise	IN STATUTE	IN STATUTE	RELATED	-	RELATED	-	RELATED

■ Identified in statute ■ Closely related to statutory requirements

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Completeness Checklist

Local agency staff can use the following checklist to help ensure that the noise element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required by Government Code section 65302 (f). Noise elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied.

Statutory Citation	Brief Description of Requirement
Gov. Code § 65302(f)(1)	(1) A noise element that shall identify and appraise noise problems in the community and shall analyze and quantify, to the extent practicable, as determined by the legislative body, current and projected noise levels for all of the following sources: (A) Highways and freeways.
Gov. Code § 65302 (f)(1)(B)	(B) Primary arterials and major local streets.
Gov. Code § 65302 (f)(1)(C)	(C) Passenger and freight online railroad operations and ground rapid transit systems.
Gov. Code §65302 (f)(1)(D)	(D) Commercial, general aviation, heliport, helistop, and military airport operations, aircraft overflights, jet engine test stands, and all other ground facilities and maintenance functions related to airport operation.
Gov. Code § 65302(f)(1)(E)	(E) Local industrial plants, including, but not limited to, railroad classification yards
Gov. Code § 65302 (f)(1)(F)	(F) Other ground stationary noise sources, including, but not limited to, military installations, identified by local agencies as contributing to the community noise environment
Gov. Code § 65302(f)(2)	(2) Noise contours shall be shown for all of these sources and stated in terms of community noise equivalent level (CNEL) or day-night average level (Ldn). The noise contours shall be prepared on the basis of noise monitoring or following generally accepted noise modeling techniques for the various sources identified in paragraphs (1) to (6), inclusive.
Gov. Code § 65302(f)(3)	(3) The noise contours shall be used as a guide for establishing a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise.
Gov. Code § 65302(f)(4)	(4) The noise element shall include implementation measures and possible solutions that address existing and foreseeable noise problems, if any. The adopted noise element shall serve as a guideline for compliance with the state's noise insulation standards.

Required Contents

The noise element should utilize the most accurate and up-to-date information available to reflect the noise environment, stationary sources of noise, predicted levels of noise, and the impacts of noise on local residents. It should be as detailed as necessary to describe the local situation and offer solutions to local noise issues. It must include the considerations of noise levels from:

(A) Highways and freeways.

(B) Primary arterials and major local streets.

(C) Passenger and freight online railroad operations and ground rapid transit systems.

(D) Commercial, general aviation, heliport, helistop, and military airport operations, aircraft overflights, jet engine test stands, and all other ground facilities and maintenance functions related to airport operation.

(E) Local industrial plants, including, but not limited to, railroad classification yards.

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(F) Other ground stationary noise sources, including, but not limited to, military installations, identified by local agencies as contributing to the community noise environment.

The general plan's noise element must show contours for these noise sources, to the extent practicable, in either Community Noise Equivalent Levels (CNEL) or Day-Night Average Level (Ldn). These noise contours must be prepared using noise monitoring or accepted noise-modeling techniques. The noise contours must be used as a guide to establish a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise (Gov. Code § 65302 (f)(2), (f)(3)). The noise element must include implementation measures and possible solutions to existing and foreseeable noise issues. Furthermore, the policies and standards must be sufficient to serve as a guideline for compliance with the state's noise insulation standards (Gov. Code § 65302(f)(4)).

The noise element should be used to guide decisions concerning land use and the location of new roads and transit facilities since these are common sources of excessive noise levels. Proposed land uses should be analyzed to ensure they are compatible with existing uses in the surrounding area, especially residential developments and sensitive receptors, such as schools, hospitals, and places of worship. Additionally, construction noise, especially in urban areas, can be mitigated with policies such as limiting construction hours or days.

Definitions

Decibel, dB: A unit of measurement describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micropascals (20 micronewtons per square meter).

A-Weighted Level: The sound level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the response of the human ear and gives good correlation with subjective reactions to noise.

L10: The A-weighted sound level that is exceeded ten percent of the sample time. Similarly, L50, L90, etc.

Leq: Equivalent energy level. The sound level corresponding to a steady-state sound level containing the same total energy as a time-varying signal over a given sample period. Leq is typically computed over 1-, 8-, and 24-hour sample periods.

CNEL: Community Noise Equivalent Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of five decibels to sound levels in the evening from 7 p.m. to 10 p.m. and after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

Ldn: Day-Night Average Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after the addition of 10 decibels to sound levels in the night after 10 p.m. and before 7 a.m. (Note: CNEL and Ldn represent daily levels of noise exposure averaged on an annual or daily basis, while Leq represents the equivalent energy noise exposure for a shorter time period, typically one hour.)

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Noise Contours: Lines drawn about a noise source indicating equal levels of noise exposure. CNEL and Ldn are the metrics utilized herein to describe annoyance due to noise and to establish land use planning criteria for noise.

Ambient Noise: The composite of noise from all sources near and far. In this context, the ambient noise level constitutes the normal or existing level of environmental noise at a given location.

Intrusive Noise: That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence, and tonal or informational content as well as the prevailing noise level.

Noisiness Zones: Defined areas within a community wherein the ambient noise levels are generally similar (within a range of 5 dB, for example). Typically, all other things being equal, sites within any given noise zone will be of comparable proximity to major noise sources. Noise contours define different noisiness zones.

Local airports are subject to the noise requirements of the Federal Aviation Administration and noise standards under the California Code of Regulations, Title 21, section 5000, et seq. These standards are designed to encourage the airport proprietor, aircraft operators, local governments, pilots, and Caltrans to work cooperatively to diminish excessive aircraft noise impacts. However, the U.S. Secretary of Transportation must review and approve all local airport noise and access restrictions adopted after 1990, and they must meet specified criteria (49 U.S.C. § 47524).

Proposed school sites within two nautical miles of an airport runway or potential runway in an airport master plan are subject to review by CalTrans Division of Aeronautics (Cal. Code Regs., tit. 21, § 3570, and Ed. Code § 17215). The regulations authorize CalTrans to object to the acquisition or lease of a school site within a 65 decibel annual CNEL aircraft noise contour. If Caltrans recommends against it based on noise considerations, the board may not acquire or lease the site (Ed. Code § 17215(d)).

Specific considerations for noise generated by or related to military facilities can be found in the California Advisory Handbook for Community and Military Compatibility Planning.

Noise Measurement and Modeling

The local planning agency should select the method of measurement or modeling that best suits its needs, either CNEL or Ldn. See Appendix D for more information about these two types of noise measurements and noise descriptors.

Noise should be measured at multiple receptors. The volume of traffic noise, construction noise, and the noise of an environment (such as loud schools, playgrounds, or agricultural areas) depends on many factors, including the location of dwellings and the location and types of trips made in neighborhoods en route to school, work, or shopping.[iv] Measuring noise at multiple receptors throughout a community will ensure that the noise element is accurate. The noise element should address the following:

- Major noise sources, both mobile and stationary
- Ground borne noise, ground borne vibration from public transit, freight trains, or light rail transit lines

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- Existing and projected levels of noise and noise contours for major noise sources
- Existing and projected land uses in relation to existing and projected noise sources
- Existing and proposed sensitive receptors, including:
  - » Residential land uses
  - » Hospitals
  - » Convalescent homes
  - » Schools
  - » Churches
  - » Sensitive wildlife habitat, including the habitat of rare, threatened, or endangered species
- Time-of-day, day-of-week, or seasonable variability of noise sources

Projections of future noise sources, noise levels, and anticipated impacts, including health impacts, upon existing and proposed land uses should provide information useful for guiding decisions about land use, locations of noise generating sources, and noise reduction mitigation measures. Mapping noise contours creates an opportunity to engage the community in a practical discussion about noise, and the tradeoffs between noise and other local priorities.

Mitigation Measures

Not all noise can be minimized, and there may even be areas where noise is desired. Some noise sources are inherent to a region, such as noise generated from farming activities in agriculture intensive areas, wildlife noise from nearby habitat, and noise associated with urban infill developments. Creating healthy communities includes minimizing harmful exposure to excessive noise. Local planning areas are encouraged to embrace the noise characteristics inherent to their region and "design with noise in mind" to minimize harmful exposure to excessive noise.

There are many ways to minimize harmful exposure to excessive noise. Mitigation measures include soundproofing with soundproof windows and insulation, landscaping and berms, building design and setbacks, buffer areas, operating hours of major sources, roadway maintenance and traffic flow, quieter pavement strategies, and other techniques.

Noise mitigation measures are not one-size-fits-all solutions: some noise mitigation measures are better suited for some communities than others. For example, while sound walls may be a fitting mitigation measure for a rural area, they may not be the best solution for urban infill areas, because they impair community connectivity. Increased building setback zones or buffer zones are likely not appropriate in more urban areas where land is limited. In areas where available land is limited, alternative mitigation measures should be employed. The noise element should be flexible and consider the different needs of various communities to determine the best measures to minimize exposure to excessive noise.

Caltrans administers several freeway noise control programs. In general, these are applied to residential and school uses that existed before a freeway was constructed. For instance, the New Construction or Reconstruction and Community Noise Abatement programs

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provide for installation of noise attenuating walls. In addition, the School Noise Abatement Program funds acoustical attenuation of classrooms. Considering possible co-benefits, such as safety improvements, and potential negative implications of soundwalls, such as community isolation and disconnection, is essential to ensure noise mitigation is effective and unobtrusive.

Implementation Measures

Implementation of the noise element may require a variety of methods. Some tools communities may use include

- The adoption of noise impact and attenuation standards, consistent with the noise element guidelines and the Uniform Building Code
- Guidance for zoning and development through the adoption of specified noise mitigation
- The establishment of local standards and guidelines for noise evaluation, including baseline specifications. The evaluation of new residential and other sensitive uses for consistency with noise standards in areas adjacent to major sources of noise
- The review of all land use and development proposals for compliance with noise and land use compatibility standards
- The control of stationary noise at the source through the use of insulation, berms, building design/orientation, buffer areas, staggered operating hours, and other techniques
- The correlation of noise element concerns with the objectives, policies, and plan proposals of the land use, circulation, and open-space elements in order to minimize community noise exposure
- Noise control ordinances-generally used to resolve short-term noise problems, but they can also be helpful when evaluating development that might create a nuisance, or expansion of a major source near sensitive receptors.

Noise can be the sign of a vibrant community if planned for at appropriate levels and hours



Image by Urban Advantage, Peerless Green

Other Considerations

Noise and Health

Exposure to excessive noise can have health impacts.[v] The most common health impact from excessive noise exposure is sleep disturbance. Sleep disturbance can impair cognitive performance, and alter hormone levels, heart rate, sleep patterns, and mood. Other potential health impacts from exposure to excessive noise include increased levels of hypertension, high blood pressure, and cardiovascular disease.[vi]

There are multiple options to minimize excessive noise exposure and reduce potential health impacts. Minimization measures such as soundproofing a residence to reduce outdoor-to-indoor noise and requiring new residences to place bedrooms in the quietest part of the floor plan will minimize exposure to excessive noise and reduce potential health risks.

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Ground-borne Vibration and Infill Development Considerations

Ground-borne vibration is manmade noise caused by oscillations of the ground due to explosions, construction, or railway and transit movement. Especially for local planning areas where sensitive use areas are, or will be, located near transit centers or railway lines, ground-borne vibration should be included in the noise element. Ground-borne vibration is already included in the noise section of the California Environmental Quality Act (CEQA) Guidelines Environmental Review Checklist (Cal. Code Regs., tit. 14, § 15000 et seq., Appendix G, subd. XII (b)). Addressing ground-borne vibration in the noise element of a general plan will ensure greater consistency between a general plan and CEQA.

Rail and public transit are key tools for infill development, which helps reduce greenhouse gas emissions and is encouraged as part of the State's planning priorities. Ground-borne vibration associated with new rail and transit should be considered and mitigated during the planning process.

Ground-borne vibration from cars and buses is usually caused by rough or uneven roadways. The repair of any bumps, cracks, and potholes on the roadway surface will dramatically reduce or solve ground-borne vibration from vehicles.

Ground-borne vibration from rail systems typically stems from degraded wheel and rail surfaces. Routine maintenance of wheel and rail surfaces is critical to control ground-borne vibration. When vibration persists despite routine wheel and rail maintenance, other solutions to control vibration from rail systems include:

- Special track support systems such as floating slabs, resiliency supported ties, high reliance fasteners and ballast mats
- Trenches along the railway to act as a vibration barrier
- Reduction in vehicle speed near sensitive use sites
- Building modifications for nearby buildings with vibration-sensitive equipment affected by rail vibration
- Expansion of the rail right-of-way or purchase of a vibration easement

The Federal Transit Authority (FTA) Transit Noise and Vibration Impact Assessment contains further guidelines on ground-borne vibration and various mitigation strategies.

Ground-borne vibration is especially relevant for areas near the route of California's High Speed Rail. The project will stretch from Sacramento to San Diego, with up to twenty-four stations. The project will also invest in local and regional rail lines. Areas near the High Speed Rail route should consider effects of ground-borne vibration in their noise element. See the project's Environmental Impact Report/Statement Noise and Vibration Mitigation Guidelines Technical Appendix for more information.

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Resources

Infill Development

- ChangeLab Building in Healthy Infill

Traffic Noise

- Caltrans Quieter Pavement Research Plan
- Caltrans Traffic Noise Analysis Protocol
- Federal Highway Administration Highway Traffic Noise: Analysis and Abatement Guide
- Caltrans Noise and Vibration Studies
- Caltrans Technical Noise Supplement
- Federal Highway Administration's Traffic Noise Model
- Federal Highway Administration, Highway Traffic Noise, Construction Noise Handbook
- Federal Highway Administration, Synthesis of Noise Effects on Wildlife Populations

Airport Noise

- Caltrans Airport Land Use Planning Handbook
- Federal Aviation Administration, Policy, International Affairs and Environment Noise and Emissions

Public Health

- World Health Organization Burden of Disease from Environmental Noise
- World Health Organization Guidelines for Community Noise

Groundborne Vibration Noise

- Federal Transit Authority (FTA) Transit Noise and Vibration Impact Assessment

Construction Noise

- Caltrans Transportation and Construction Vibration Guidance Manual

Military Compatibility Considerations

- California Advisory Handbook for Community and Military Compatibility Planning

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SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Identify noise sensitive land uses within high impact noise areas	Map of noise contours, land use designations
Plan for potential construction noise in residential areas	Map of planned development areas

OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Sample Policy	Example of Application	Relationship to Other Elements
[City/county] shall avoid placing noise sensitive land uses (e.g. residential, hospitals, assisted living facilities, group homes, schools, day care centers, etc.) within the high noise impact areas (over 65 dB CNEL) for (designated airports) in accordance with the (city/county) Airport Land Use Compatibility Plan	City of Riverside	Land use, circulation, healthy communities
[City/county] shall orient buildings such that the noise sensitive portions of a project are shielded from noise sources.	City of San Diego	Land use, circulation, housing, healthy communities
[City/county] shall require new development to include noise mitigation to assure acceptable interior noise levels appropriate to the land use type: 45 dBA Ldn for residential, transient lodgings, hospitals, nursing homes and other uses where people normally sleep; and 45 dBA L eq (peak hour) for office buildings and similar uses.	City of Sacramento	Land use, housing, healthy communities
[City/county] shall protect schools, hospitals, libraries, churches, convalescent homes, and other noise sensitive uses from excessive noise levels by incorporating site planning and project design techniques to minimize noise impacts. The use of noise barriers shall be considered after all practical design-related noise measures have been integrated into the project. In cases where sound walls are necessary, they should help create an attractive setting with features such as setbacks, changes in alignment, detail and texture, murals, pedestrian access (if appropriate), and landscaping	City of Murrieta	Land use, equitable and resilient communities, healthy communities
[City/county] shall integrate noise considerations into land use planning decisions to prevent new noise/land use conflicts.	City of Murrieta	Land use

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4

Safety Element

Introduction

The goal of the safety element is to reduce the potential short and long-term risk of death, injuries, property damage, and economic and social dislocation resulting from fires, floods, droughts, earthquakes, landslides, climate change, and other hazards. Other locally relevant safety issues, such as airport land use, emergency response, hazardous materials spills, and crime reduction, may also be included. Some local jurisdictions have chosen to incorporate their hazardous waste management plans into their safety elements.

The safety element directly relates to topics also mandated in the (1) land use, (2) conservation, (3) environmental justice and (4) open-space elements, as development plans must adequately account for public safety considerations and open space for public health and ecological benefits often incorporate areas of increased hazard risk. The safety element must identify hazards and hazard abatement provisions to guide local decisions related to zoning, subdivisions, and entitlement permits. The safety element should also contain general hazard and risk reduction strategies complementary with those of the Local Hazard Mitigation Plan (LHMP). Ideally, the LHMP will be incorporated into the safety element as outlined below in accordance with provision of Assembly Bill 2140, General Plans: Safety Element (Hancock, 2006)(Gov. Code § 65302.6).

The recent introduction of climate risk to the discussion of the safety element, adds a focus on longer term preparation of a community for a changing climate. Policies in a safety element should identify hazards and emergency response priorities, as well as mitigation through avoidance of hazards by new projects and reduction of risk in developed areas. As California confronts mounting climate change impacts, local governments are now required, in accordance with Senate Bill 379, Land Use: General Plan: Safety Element (Jackson, 2015) to include a climate change vulnerability assessment, measures to address vulnerabilities, and comprehensive hazard mitigation and emergency response strategy as explained further in this section

Government Code 65302(g):

(g) (1) A safety element for the protection of the community from any unreasonable risks associated with the effects of seismically induced surface rupture, ground shaking, ground failure, tsunami seiche, and dam failure; slope instability leading to mudslides and landslides; subsidence; liquefaction; and other seismic hazards identified pursuant to Chapter 7.8 (commencing with Section 2690) of Division 2 of the Public Resources Code, and other geologic hazards known to the legislative body; flooding; and wildland and urban fires. The safety element shall include mapping of known seismic and other geologic hazards. It shall also address evacuation routes, military installations, peakload water supply requirements, and minimum road widths and clearances around structures, as those items relate to identified fire and geologic hazards.

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(Gov. Code § 65302(g)(4)). Policies may include methods of minimizing risks, as well as ways to minimize economic disruption and expedite recovery following disasters. Since virtually all incidents disproportionately affect individuals with access and functional needs (AFN) (i.e. people with disabilities, seniors, children, limited English proficiency, and transportation disadvantaged). All policies should include consideration of AFN populations.

Climate change will affect and potentially exacerbate the impact of other hazards rather than being solely a distinct hazard with unique impacts. For example, extreme heat and heat waves are existing hazards that will be exacerbated by climate change. The impacts of climate change on the frequency, timing, and magnitude of flooding vary by geography throughout the state. Areas that experience early run off from snow melt coupled with intensified rain or coastal areas experiencing sea level rise may be more greatly impacted by flooding. Hazards that have the potential to be affected by climate change are further outlined in this element and linked resources described below.

Assembly Bill 2140

The federal Disaster Mitigation Act of 2000 (42 U.S.C. § 5121 et seq.), outlines how a Local Hazard Mitigation Plan (LHMP) can be developed individually or through a multi-jurisdictional LHMP. The successful completion of an LHMP makes the jurisdiction eligible to apply for federal Hazard Mitigation Grant Program (HMGP) post-disaster funding, Pre-Disaster Mitigation (PDM) funding or Flood Management Assistance (FMA) funding. See reference in the 44 CFR, Section 201.6(a) and 201.6(a)(2)

At the state level, AB 2140 authorizes local governments to adopt their LHMPs with the safety elements of their general plans (Gov. Code § 65302.6). Integration or incorporation by reference is encouraged through a post-disaster financial incentive that authorizes the state to use available California Disaster Assistance Act funds to cover local shares of the 25% non-federal portion of grant-funded post-disaster projects when approved by the legislature (Gov. Code § 8685.9).

AB 2140 is one of the most important links between general plans and hazard mitigation in California. Adopting the LHMP with the safety element provides a vehicle for implementation of the LHMP. This integration allows hazard mitigation strategies to be

Climate Change

An increasingly important factor affecting disaster management functions is climate change. Climate change reflects new uncertainties and factors shaping and conditioning hazard mitigation planning. Chapter 4.5 in the 2013 California State Hazard Mitigation Plan (SHMP) addresses a specific approach for local communities to evaluate their risk as a result of climate change. The safety element of the general plan plays an important role in ensuring consistency with the Local Hazard Mitigation Plan (LHMP) and the SHMP. The general plan and LHMP both provide a local vehicle for implementation of the SHMP, including the provisions dealing with climate change. The SHMP outlines tools, resources, and a process for addressing climate change at the local level. The resources the SHMP and LHMP guidance materials reference are the same materials referenced in Chapter 8 of the General Plan Guidelines, Climate Change. This provides for consistency across multiple documents such as an adaptation plan, climate action plan, general plan, implementation plan, local hazard mitigation plan, etc.

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implemented and local hazard awareness to be upgraded and enhanced. An LHMP must document what existing plans, studies, reports, and technical information were reviewed during the formation of the plan, as well as if and how any of that information was incorporated into the final product (44 CFR, Section 201.6(b)(3)).

Completeness Checklist

Local agency staff can use the following checklist to help ensure that the safety element addresses all required issues. Please note that use of this checklist is purely advisory, and only contains issues that are legally required by Government Code section 65302(g). Safety elements may address additional issues at the discretion of the local government. Because general plan formats may vary, this checklist suggests identifying where the particular government code provision is satisfied.

Statutory Citation	Brief Description of Requirement
Gov. Code § 65302(g)(1)	Identification of unreasonable risks and policies for the protection of the community from such risks.
Gov. Code § 65302(g)(1)	Slope Instability Slope instability leading to mudslides and landslides.
Gov. Code § 65302(g)(1)	Seismic risks, including: Seismically induced surface rupture, ground shaking, ground failure, tsunami, seiche, and dam failure; subsidence, liquefaction, and other seismic hazards identified pursuant to Chapter 7.8 (commencing with Section 2690) of Division 2 of the Public Resources Code, and other geologic hazards known to the legislative body • Mapping of known seismic and other geologic hazards. • Address o Evacuation routes o Military installations o Peakload water supply requirements, and o Minimum road widths and clearances around structures
Gov. Code § 65302(g)(2)	Flooding Identify • Flood Hazard Zones • FEMA Flood Insurance Maps • Army Corps of Engineer Flood information • Flood maps from the Central Valley Flood Protection Board • Dam Failure Maps (Office of Emergency Services) • DWR Floodplain Maps • Maps of Levee Protection Zones • Areas subject to inundation in the event of the failure of levees and floodwalls • Historic flood information • Existing and planned development in flood hazard areas • Agencies with responsibility for flood protection Mandatory Goals, Policies, and Objectives • Avoid and minimize flood risks for new development. • Should new development be located in flood hazard zones? If so, what are appropriate mitigation measures? • Maintain the integrity of essential public facilities. • Locate, when feasible, new essential public facilities outside of flood hazard zones, including hospitals and health care facilities, emergency shelters, fire stations, emergency command centers, and emergency communications facilities, or identifying mitigation measures. • Establishing cooperative working relationships among public agencies with responsibility for flood protection. Feasible Mitigation Measures, to implement the policies above.

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Statutory Citation	Brief Description of Requirement
Gov. Code § 65302(g)(3)	Wildland and Urban Fires Identification of, and policies for, the protection of the community from, any unreasonable risks associated with wildland and urban fires. State Responsibility Areas and Very High Fire Hazard Severity Zones Consider advice in OPR's Fire Hazard Technical Advisory Identify • CALFire Fire Hazard Severity Zone Maps • Historical data on wildfires • USGS wildfire hazard areas • Existing and planned development within these areas • Agencies with responsibility for fire protection in these areas Mandatory Goals, Policies and Objectives • Protect the community from unreasonable risks • See mitigation measures below. Feasible Mitigation • Avoid and minimize fire risks for new development. • Should new development be located in fire hazard zones? If so, what are appropriate mitigation measures? • Maintain the integrity of essential public facilities. • Locate, when feasible, new essential public facilities outside of fire hazard zones, including hospitals and health care facilities, emergency shelters, fire stations, emergency command centers, and emergency communications facilities, • If essential facilities are located in high fire zones, identify mitigation measures, such as safe access for emergency response vehicles, visible street signs, and water supplies for structural fire suppression. • Establishing cooperative working relationships among public agencies with responsibility for fire protection.
Gov. Code § 65302(g)(4)	Climate Change Adaptation and Resilience Address climate change adaptation and resiliency strategies by using the process in the Adaptation Planning Guide and reflected in referenced tools such as Cal-Adapt. Vulnerability Assessment (Gov. Code § 65302(g)(4)(A)) Create a vulnerability assessment that identifies the risks that climate change poses to the local jurisdiction and the geographic areas at risk from climate change impacts, the following: • Information that may be available from federal, state, regional, and local agencies that will assist in developing the vulnerability assessment and the adaptation policies and strategies, including, but not limited to, all of the following: (I) Information from the Internet based Cal-Adapt tool. (II) Information from the most recent version of the California Adaptation Planning Guide. (III) Information from local agencies on the types of assets, resources, and populations that will be sensitive to various climate change exposures. (IV) Information from local agencies on their current ability to deal with the impacts of climate change. (V) Historical data on natural events and hazards, including locally prepared maps of areas subject to previous risk, areas that are vulnerable, and sites that have been repeatedly damaged. (VI) Existing and planned development in identified at-risk areas, including structures, roads, utilities, and essential public facilities. (VII) Federal, state, regional, and local agencies with responsibility for the protection of public health and safety and the environment, including special districts and local offices of emergency services. Mandatory Goals, Policies and Objectives (Gov. Code § 65302(g)(4)(B)) • Create a set of adaptation and resilience goals, policies, and objectives based on the information above for the protection of the community.

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Statutory Citation	Brief Description of Requirement
Gov. Code § 65302(g)(4) CONTINUED	Feasible Mitigation (Gov. Code § 65302(g)(4)(C)) • Create a set of feasible implementation measures designed to carry out the goals, policies, and objectives identified above, including, but not limited to, all of the following: (i) Feasible methods to avoid or minimize climate change impacts associated with new uses of land. (ii) The location, when feasible, of new essential public facilities outside of at-risk areas, including, but not limited to, hospitals and health care facilities, emergency shelters, emergency command centers, and emergency communications facilities, or identifying construction methods or other methods to minimize damage if these facilities are located in at-risk areas. (iii) The designation of adequate and feasible infrastructure located in an at-risk area. (iv) Guidelines for working cooperatively with relevant local, regional, state, and federal agencies. (v) The identification of natural infrastructure that may be used in adaptation projects, where feasible. Where feasible, the plan shall use existing natural features and ecosystem processes, or the restoration of natural features and ecosystem processes, when developing alternatives for consideration. For the purposes of this clause, "natural infrastructure" means the preservation or restoration of ecological systems, or utilization of engineered systems that use ecological processes, to increase resiliency to climate change, manage other environmental hazards, or both. This may include, but is not limited to, floodplain and wetlands restoration or preservation, combining levees with restored natural systems to reduce flood risk, and urban tree planting to mitigate high heat days. Other documents (Gov. Code §§ 65302(g)(4)(D)(i), 65302(g)(4)(D)(ii): • If a city or county has adopted the local hazard mitigation plan, or other climate adaptation plan or document that fulfills commensurate goals and objectives and contains the information required pursuant to this paragraph, separate from the general plan, an attachment of, or reference to, the local hazard mitigation plan or other climate adaptation plan or document. • Cities or counties that have an adopted hazard mitigation plan, or other climate adaptation plan or document that substantially complies with this section, or have substantially equivalent provisions to this subdivision in their general plans, may use that information in the safety element to comply with this subdivision, and shall summarize and incorporate by reference into the safety element the other general plan provisions, climate adaptation plan or document, specifically showing how each requirement of this subdivision has been met.
Gov. Code 65302(g)(5) – (g)(8)	Other Considerations: • Cities and counties that have flood plain management ordinances that have been approved by FEMA that substantially comply with this section, or have substantially equivalent provisions to this subdivision in their general plans, may use that information in the safety element to comply with this subdivision, and shall summarize and incorporate by reference into the safety element the other general plan provisions or the flood plain ordinance, specifically showing how each requirement of this subdivision has been met. • Prior to the periodic review of its general plan and prior to preparing or revising its safety element, each city and county shall consult the California Geological Survey of the Department of Conservation, the Central Valley Flood Protection Board, if the city or county is located within the boundaries of the Sacramento and San Joaquin Drainage District, as set forth in Section 8501 of the Water Code, and the Office of Emergency Services for the purpose of including information known by and available to the department, the agency, and the board required by this subdivision. • To the extent that a county's safety element is sufficiently detailed and contains appropriate policies and programs for adoption by a city, a city may adopt that portion of the county's safety element that pertains to the city's planning area in satisfaction of the requirement imposed by this subdivision • Review the safety element for fire and flood impacts upon each Housing Element update, • Review the safety element for climate change at each update to the Local Hazard Mitigation Plan, Jurisdiction may also choose to do a comprehensive review of the safety element upon each housing element update to streamline review.

CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Noise	Air Quality	EJ
Safety	IN STATUTE	RELATED	RELATED	IN STATUTE	RELATED	-	RELATED	RELATED

■ Identified in statute ■ Closely related to statutory requirements

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Required Contents

The safety element must, consistent with Government Code Section 65302(g), provide for the protection of the community from any unreasonable risks associated with the effects of:

- Seismically induced surface rupture, ground shaking, ground failure
- Tsunami, seiche, and dam failure
- Slope instability leading to mudslides and landslides
- Subsidence
- Liquefaction
- Other seismic hazards identified pursuant to Chapter 7.8 (commencing with Section 2690) of Division 2 of the Public Resources Code, and other geologic hazards known to the legislative body
- Flooding
- Wildland and urban fires
- Climate change

The safety element must include mapping of known seismic and other geologic hazards. It must also address evacuation routes, military installations, peakload water supply requirements, and minimum road widths and clearances around structures, as those items relate to identified fire and geologic hazards.

The safety element must also identify information regarding flood hazards, establish a set of comprehensive goals, policies, and objectives for the protection of the community from the unreasonable risks of flooding, and establish a set of feasible implementation measures designed to carry out the goals, policies, and objectives for flood protection. It is recommended that the safety element do the same for drought impacts.

The safety element must also be reviewed and updated as necessary to address the risk of fire for land classified as

Changes in planning and design can increase community safety and resilience



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state responsibility areas and land classified as very high fire hazard severity zones. Because climate change will likely increase California's frequency and intensity of fire weather conditions, even historically less vulnerable regions should reevaluate wildfire risk and prevention strategies in their general plan's safety element.

Most of the information needed to complete the analysis for the safety element, can be obtained through a combination of sources: the State Hazard Mitigation Plan and federal requirements outlined in the Disaster Mitigation Act (DMA) of 2000, MyPlan tool, the General Plan Mapping Tool, Cal-Adapt and the Adaptation Planning Guide (APG). Some information may need to be generated at the local or regional level, particularly for those facilities considered critical to the community.

Consultation Requirements

Before the periodic review of its general plan and before preparing or revising its safety element, each city and county shall consult the California Geological Survey of the Department of Conservation, the Central Valley Flood Protection Board, if the city or county is located within the boundaries of the Sacramento and San Joaquin Drainage District, as set forth in Section 8501 of the Water Code, and the Office of Emergency Services for the purpose of including information known by and available to the department, the agency, and the board required by this subdivision. In particular, the Office of Emergency Services can assist local governments with developing their safety element and aligning general plan strategies with those of the local hazard mitigation and emergency operation plans to ensure consistency. The Governor's Office of Planning and Research's Integrated Climate Adaptation and Resiliency Program (ICARP), established by SB 246 (Wieckowski, 2015), also supports local government's compliance with SB 379 (Pub. Resources Code § 71350 et seq.).

Each city and county must provide a draft of its safety element or amendment of its safety element to the California Geological Survey of the Department of Conservation prior to adoption, for review to determine if all known seismic and other geologic hazards are addressed (Gov. Code § 65302.5)(a)). A city or county that contains a state fire responsibility area or a very high fire hazard severity zone must provide a draft of its safety element or amendment of its safety element to the State Board of Forestry and Fire Protection for review before adoption, and the Board may recommend changes regarding uses of land, policies, or strategies for reducing fire risk (Id. at § 65302.5)(b)). Similarly, each city and county located in the Sacramento and San Joaquin Drainage District must provide a draft of its safety element or amendment of its safety element to the Central Valley Flood Protection Board before adoption, and the Board may provide recommended changes regarding uses of land, policies, or strategies for reducing flood risk and protecting areas subject to flooding (Id. at § 65302.7).

Statutory Requirements

This section offers a general guide to the contents of the safety element. Note that while the focus is on the minimum requirements for an adequate safety element, an effective general plan will focus more extensively on those issues of greatest relevance to the community. The effects of climate change in particular will influence emergency management issues through varying impacts across local communities statewide. Increases in average temperature, a greater incidence of extreme weather conditions, and sea level rise all will not only exacerbate existing hazards mentioned in this section, but may also create new hazards where none previously existed.

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Useful Definitions

Alquist-Priolo Earthquake Fault Zone: A regulatory zone, delineated by the State Geologist, within which site-specific geologic studies are required to identify and avoid fault rupture hazards prior to subdivision of land and/or construction of most structures for human occupancy.

Climate Adaptation: Adjustment or preparation of natural or human systems to a new or changing environment that moderates harm or exploits beneficial opportunities.

Climate Mitigation (Greenhouse Gas Emissions Reductions): A human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. Refer to Chapter 7, Climate Change, for more information.

Critical Facility: Facilities that either (1) provide emergency services or (2) house or serve many people who would be injured or killed in case of disaster damage to the facility. Examples include hospitals, fire stations, police and emergency services facilities, utility facilities, and communications facilities.

Extreme Weather Event: In most cases, extreme weather events are defined as lying in the outermost ("most unusual") ten percent of a place's history. Analyses are available at the national and regional levels.

Fault: A fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. A fault zone is a zone of related faults which commonly are braided, but which may be branching. A fault trace is the line formed by the intersection of a fault and the earth's surface.

Active Fault: A fault that has exhibited surface displacement within Holocene time (approximately the past 11,000 years).

Potentially Active Fault: A fault that shows evidence of surface displacement during Quaternary time (the last 2 million years).

Flooding: A rise in the level of a water body or the rapid accumulation of runoff, including related mudslides and land subsidence, that results in the temporary inundation of land that is usually dry. Riverine flooding, coastal flooding, mud flows, lake flooding, alluvial fan flooding, flash flooding, levee failures, tsunamis, and fluvial stream flooding are among the many forms that flooding takes.

Ground Failure: Mudslide, landslide, liquefaction or soil compaction.

Hazardous Building: A building that may be hazardous to life in the event of an earthquake because of partial or complete collapse. Hazardous buildings may include:

(1) Those constructed prior to the adoption and enforcement of local codes requiring earthquake resistant building design.

(2) Those constructed of unreinforced masonry.

(3) Those which exhibit any of the following characteristics:

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- exterior parapets or ornamentation which may fall on passersby
- exterior walls that are not anchored to the floors, roof, or foundation
- sheeting on roofs or floors incapable of withstanding lateral loads
- large openings in walls that may cause damage from torsional forces
- lack of an effective system to resist lateral forces
- non-ductile concrete frame construction

Hazardous Material: An injurious substance, including pesticides, herbicides, toxic metals and chemicals, liquefied natural gas, explosives, volatile chemicals, and nuclear fuels.

Hazard Mitigation: Sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects.

Landslide: A general term for a falling, sliding, or flowing mass of soil, rocks, water, and debris. Includes mudslides, debris flows, and debris torrents.

Liquefaction: A process by which water-saturated granular soils transform from a solid to a liquid state during strong ground shaking.

Maladaptation: Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Natural Infrastructure: The preservation or restoration of ecological systems, or utilization of engineered systems that use ecological processes, to increase resiliency to climate change, manage other environmental hazards, or both. This may include, but is not limited to, floodplain and wetlands restoration or preservation, combining levees with restored natural systems to reduce flood risk, and urban tree planting to mitigate high heat days.

Peakload Water Supply: The supply of water available to meet both domestic water and fire fighting needs during the particular season and time of day when domestic water demand on a water system is at its peak.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Seiche: An earthquake-induced wave in a lake, reservoir, or harbor.

Seismic Hazard Zone: A regulatory zone, delineated by the State Geologist, within which site-specific geologic, soils, and foundation engineering studies are required to identify and avoid earthquake-caused ground-failure hazards, or selected other earthquake hazards, prior to subdivision of land and for construction of most structures for human occupancy.

Storm surge: An abnormal rise of water generated by a storm, over and above the predicted astronomical tides.

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Subsidence: The gradual, local settling or sinking of the earth's surface with little or no horizontal motion (subsidence is usually the result of gas, oil, or water extraction, hydrocompaction, or peat oxidation, and not the result of a landslide or slope failure).

Seismically Induced Surface Rupture: A break in the ground's surface and associated deformation resulting from the movement of a fault.

Tsunami: A wave, commonly called a tidal wave, caused by an underwater seismic disturbance, such as sudden faulting, landslide, or volcanic activity.

Wildland Fire: A fire occurring in a suburban or rural area that contains uncultivated lands, timber, range, watershed, brush, or grasslands. This includes areas where there is a mingling of developed and undeveloped lands.

Climate Change Adaptation and Resilience

Requirement Description:

In accordance with the requirements of SB 379, codified at Government Code section 65302(g)(4), climate change adaptation and resilience must be addressed in the safety element of all general plans in California. Specifically, "upon the next revision of a local hazard mitigation plan, adopted in accordance with the federal Disaster Mitigation Act of 2000 (Public Law 106-390), on or after January 1, 2017, or, if a local jurisdiction has not adopted a LHMP, beginning on or before January 1, 2022, the safety element shall be reviewed and updated as necessary to address climate adaptation and resiliency strategies applicable to the city or county. This review shall consider advice provided in the Office of Planning and Research's General Plan Guidelines..." (Gov. Code § 65302(g)(4)). This section provides advice to support a jurisdiction's compliance with the requirements of Government Code section 65302(g)(4).

Government Code 65302(g):

(4) Upon the next revision of a local hazard mitigation plan, adopted in accordance with the federal Disaster Mitigation Act of 2000 (Public Law 106-390), on or after January 1, 2017, or, if a local jurisdiction has not adopted a local hazard mitigation plan, beginning on or before January 1, 2022, the safety element shall be reviewed and updated as necessary to address climate adaptation and resiliency strategies applicable to the city or county. This review shall consider advice provided in the Office of Planning and Research's General Plan Guidelines and shall include all of the following:

(A) (i) A vulnerability assessment that identifies the risks that climate change poses to the local jurisdiction and the geographic areas at risk from climate change impacts, including, but not limited to, an assessment of how climate change may affect the risks addressed pursuant to paragraphs (2) and (3).

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(ii) Information that may be available from federal, state, regional, and local agencies that will assist in developing the vulnerability assessment and the adaptation policies and strategies required pursuant to subparagraph (B), including, but not limited to, all of the following:

(I) Information from the Internet based Cal-Adapt tool.

(II) Information from the most recent version of the California Adaptation Planning Guide.

(III) Information from local agencies on the types of assets, resources, and populations that will be sensitive to various climate change exposures.

(IV) Information from local agencies on their current ability to deal with the impacts of climate change.

(V) Historical data on natural events and hazards, including locally prepared maps of areas subject to previous risk, areas that are vulnerable, and sites that have been repeatedly damaged.

(VI) Existing and planned development in identified at-risk areas, including structures, roads, utilities, and essential public facilities.

(VII) Federal, state, regional, and local agencies with responsibility for the protection of public health and safety and the environment, including special districts and local offices of emergency services.

(B) A set of adaptation and resilience goals, policies, and objectives based on the information specified in subparagraph (A) for the protection of the community.

(C) A set of feasible implementation measures designed to carry out the goals, policies, and objectives identified pursuant to subparagraph (B) including, but not limited to, all of the following:

(i) Feasible methods to avoid or minimize climate change impacts associated with new uses of land.

(ii) The location, when feasible, of new essential public facilities outside of at-risk areas, including, but not limited to, hospitals and health care facilities, emergency shelters, emergency command centers, and emergency communications facilities, or identifying construction methods or other methods to minimize damage if these facilities are located in at-risk areas.

(iii) The designation of adequate and feasible infrastructure located in an at-risk area.

(iv) Guidelines for working cooperatively with relevant local, regional, state, and federal agencies.

(v) The identification of natural infrastructure that may be used in adaptation projects, where feasible. Where feasible, the plan shall use existing natural features and ecosystem processes, or the restoration of natural features and ecosystem processes, when developing alternatives for consideration. For the purposes of this clause, "natural infrastructure" means the preservation or restoration of ecological systems, or utilization of engineered systems that use ecological processes,

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to increase resiliency to climate change, manage other environmental hazards, or both. This may include, but is not limited to, floodplain and wetlands restoration or preservation, combining levees with restored natural systems to reduce flood risk, and urban tree planting to mitigate high heat days.

(D) (i) If a city or county has adopted the local hazard mitigation plan, or other climate adaptation plan or document that fulfills commensurate goals and objectives and contains the information required pursuant to this paragraph, separate from the general plan, an attachment of, or reference to, the local hazard mitigation plan or other climate adaptation plan or document.

(ii) Cities or counties that have an adopted hazard mitigation plan, or other climate adaptation plan or document that substantially complies with this section, or have substantially equivalent provisions to this subdivision in their general plans, may use that information in the safety element to comply with this subdivision, and shall summarize and incorporate by reference into the safety element the other general plan provisions, climate adaptation plan or document, specifically showing how each requirement of this subdivision has been met.

The safety element discussion is not the only section of the GPG that should address climate change adaptation and resilience. Nearly every other chapter of the GPG outlines how climate change applies to each respective section. The safety element is the statutory "home" for the discussion; however, it should not preclude discussion of climate adaptation and resilience in other appropriate sections of a jurisdiction's general plan. Specifically, addressing a changing climate may result in the need to consider the end year of the general plan and the environmental changes that may occur through the life of a general plan's applicability. As the climate changes, future environmental conditions at the horizon year of the general plan may be just as important for consideration of long range policy as the base environment setting. As climatic systems shift away from a historically predictable paradigm, planning policy should adapt to better incorporate the associated impacts of these anticipated environmental shifts. Further, all major policy documents in a jurisdiction should discuss climate adaptation and resilience, as both an input to and implementation of the jurisdiction's general plan. This will lead to consistency within a jurisdiction's policy framework and ensure implementations of policies are occurring in an efficient and appropriate manner. Examples and cases studies of how this incorporation might occur will be hosted on OPR's Adaptation Clearinghouse.

In some cases, jurisdictions have chosen to address climate change in their community through a climate action plan or adaptation plan. Additional guidance on how a jurisdiction might treat these two types of documents in relationship to the general plan is included in Chapter 8, Climate Change. Many jurisdictions have chosen to address greenhouse gas (GHG) emissions reductions and climate change adaptation together in the same document. The guidance here does not require bifurcating the GHG emissions and adaptation discussions, rather the intent of the policy maker should be to look at the whole of the policy framework to both meet statutory requirements while also maximizing co-benefits of policy initiatives. An outline of a climate action plan that could address both GHG emissions and adaptation is included in Chapter 8, Climate Change and in OPR's Adaptation Clearinghouse.

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Timing of Updates

For those jurisdictions that have an adopted local hazard mitigation plan (LHMP), the next update of their LHMP triggers an update to the safety element of the general plan to address climate adaptation and resilience. If a jurisdiction does not have an LHMP, the safety element of the general plan must be reviewed and updated on or before January 1, 2022 to address climate adaptation and resilience. Internal consistency and disclosure of impacts to a community may become problematic if the document is not updated regularly. A jurisdiction may choose to review and update the safety element each time the housing element is updated, as is required for flood and fire hazards. The housing element's five to eight year update cycle may be adequate to regularly review and update the safety element climate change discussions. Jurisdictions that have an LHMP may also choose to review and update their climate change analysis in the LHMP concurrently or as preparation for the next LHMP update to create consistency and efficiency in the review and update cycle for both general plans and LHMPs.

Fulfilling the Objectives of This Section

Some jurisdictions have already completed climate change adaptation analysis. In recognition of this, a city or county may use an existing LHMP or climate adaptation plan to satisfy the requirements of this section. The key to using these stand-alone documents is to both satisfy the requirements of this chapter and to adequately incorporate contents of the plan into the general plan. Likewise, a city or county may use a general plan that currently includes adaptation to satisfy the requirements of this section. If a separate plan is used, it must be incorporated by reference into the safety element and summarized to specifically show how each requirement of this subdivision has been met.

To the extent that a county's safety element is sufficiently detailed and contains appropriate policies and programs for adoption by a city, a city may adopt that portion of the county's safety element that pertains to the city's planning area in satisfaction of the requirement imposed by this subdivision.

Process for Analysis

The requirements of SB 379 have five distinct steps (outlined below). The first and last steps focus on the relationship of the analysis and policy efforts of the larger general plan. Steps 2, 3, and 4 focus on how to conduct the recommended analysis, goal setting, and policy development. This process can also be found at the OPR Adaptation Clearinghouse. The five steps require that the jurisdiction:

1. Review the existing LHMP, climate action plan (CAP), adaptation plan and other relevant documents to ensure it meets the requirements of Government Code section 65302(g)(4) as outlined in this chapter. If the LHMP, or plan to address climate adaptation, does not meet the requirements of this chapter, proceed to Step 2. Proceed to step 5 if these requirements have already been satisfied.
2. Conduct a vulnerability assessment.
3. Develop adaptation goals.
4. Create implementation measures.

Complete Adaptation Planning Guide (APG) Process to satisfy these steps

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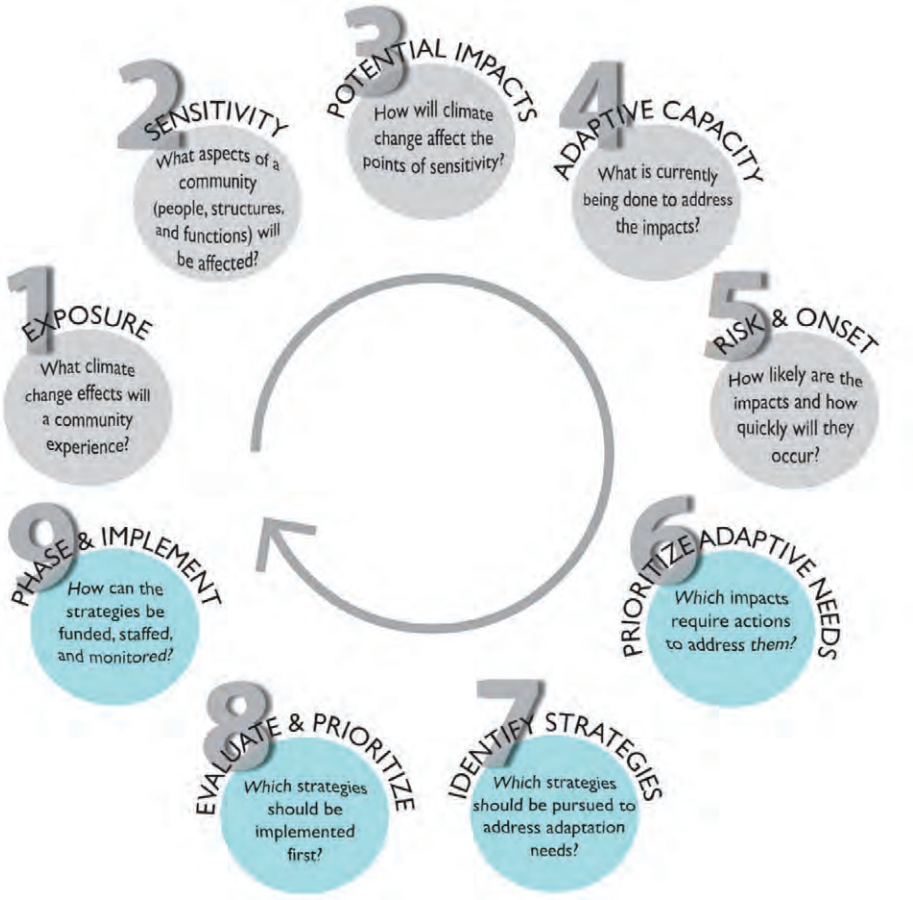
5. Update the safety element with adaptation and resilience considerations consistent with this chapter. This update can be done through incorporation by reference of a plan that meets the requirements of this chapter, through incorporation in entirety of language that meets the requirements, or other appropriate mechanism. When updating the safety element to address climate change, it is important to review other elements of the general plan to ensure consistency.

Steps 2, 3, and 4 respond to the nine step process outlined in the Adaptation Planning Guide (APG).



Source: Adaptation Planning Guide, 2012

The APG is periodically updated in conjunction with updates of the Safeguarding California Plan and State Hazard Mitigation Plan. The next APG update will include updates to address the requirements of Government Code section 65302(g)(4). You can review further detail for each step in the APG in the document.

1. Exposure: What climate change effects will a community experience?
2. Sensitivity: What aspects of a community (people, structures and functions) will be affected?
3. Potential Impacts: How will climate change affect the points of sensitivity?

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4. Adaptive Capacity: What is currently being done to address the impacts?
5. Risks and Onset: How likely are the impacts and how quickly will they occur?
6. Prioritize Adaptive Needs: Which impacts require actions to address them?
7. Identify Strategies: Identify the strategies that should be pursued to address adaptation needs?
8. Evaluate and Prioritize: Which strategies should be implemented first?
9. Phase and Implement: How can the strategies be funded, staffed and monitored?

Senate Bill 1000, adopted in 2016, requires local governments to incorporate environmental justice (EJ) policies into their general plans, either in a separate EJ element or by integrating related goals, policies, and objectives throughout the other elements. This update, or revision if the local government already has EJ goals, policies, and objectives, must happen "upon the adoption or next revision of two or more elements concurrently on or after January 1, 2018." Environmental justice should be considered when making decisions about climate change adaptation and resiliency. For additional information on how the new requirement applies to this and other elements in the general plan guidelines, refer to the environmental justice element discussion.

Complete a vulnerability assessment (steps 1-5 of the Adaptation Planning Guide)

As outlined in Government Code section 65302(g)(4) and the APG, the vulnerability analysis should incorporate information from multiple sources. Case studies can also be quite helpful in order to inform a jurisdiction's efforts. Although much of climate adaptation related policy work is an emerging practice, a number of examples are available to provide context. Case studies are available through OPR's Integrated Climate Adaptation Resilience Program (ICARP) "Case Studies" webpage. The results of the Annual Planning Survey and the awareness of efforts occurring in surrounding communities can also be helpful. External resources such as the Climate Resilience Toolkit, Climate Adaptation Knowledge Exchange (CAKEx) and the Georgetown University Adaptation Clearinghouse can also be helpful.

Numerous tools are available to support climate change analysis, such as those referenced in the table in Chapter 8, Climate Change. Specific tools to address climate change adaptation include the following.

TOOLS TO ADDRESS CLIMATE ADAPTATION

Guidelines for CEQA compliance	CEQA Guidelines
Comprehensive framework for addressing adaptation at the local level	APG
Visualization tool for the impacts of climate change and links to resources	Cal-Adapt
Federal resource for visualizing impacts, case studies, decision support	Climate Resilience Toolkit
Guide to developing adaptation policy at the local level in California	Adaptation Planning Guide
Georgetown University Climate Center Adaptation Clearinghouse	Adaptation Clearinghouse
The State's approach to addressing climate impacts	Safeguarding California Plan
The State's framework for climate hazards	State Hazard Mitigation Plan
See also: Chapter 7, Climate Change of the General Plan Guidelines	Chapter 8, Climate
See also: OPR Adaptation Clearinghouse	ICARP

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Including the following information will help a jurisdiction satisfy the minimum requirements of Government Code section 65302(g)(4). A deeper level of analysis is encouraged as data, policy and implementation methods continue to improve over time. In all cases, reviewing the information and process guidance in the California Adaptation Planning Guide (APG) should be the first step, in parallel with reviewing data and information in the Cal-Adapt tool. In some cases, working through a regional collaborative such as those working through the Alliance of Regional Collaboratives for Climate Adaptation (ARCCA), to identify partnering opportunities in analysis and implementation may provide value, and in some cases, resources. Regional guidance may differ from guidance provided in this chapter, and may be appropriate as long as it meets the minimum requirements as shown in the safety element checklist. Staff at the ICARP can also answer questions about the available tools and help jurisdictions choose the appropriate resources. New tools and sources of data will be added to the ICARP Adaptation Clearinghouse as they become available. Other important data sources include:

Assessing vulnerability and risk can help a community plan infrastructure in more resilient areas



Image by Urban Advantage, SANDAG

1. Local agency data on the types of assets, resources, and populations that will be sensitive to various climate change exposures. This can be obtained through overlaying Cal-Adapt outputs with the General Plan Mapping Tool (GPMT) and augmenting with locally relevant data. This service will be provided in updates to both tools.

2. Local agency data on current status of climate change preparedness, including institutional capacity, redundancy limitations, critical assets inventory, exposure risk and vulnerability of disadvantaged communities. Sources include municipal service reviews developed by LAFCOs, Metropolitan Planning Organization (MPO) data, other regionally available data, local hazard mitigation planning documents and data in the General Plan Mapping Tool, Cal-Adapt and MyPlan.

3. Historical data on natural events and hazards, including locally prepared risk and vulnerability maps, and sites that have been repeatedly damaged. This information can be obtained by visiting the General Plan Mapping Tool, MyPlan, Cal-Adapt and the Climate Resilience Toolkit in addition to locally available data that may provide more specificity, detail and context.

4. Existing and planned development in identified at-risk areas, including structures, roads, utilities, and essential public

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facilities. Much of this data will only be available at the local level. These can be meshed with downloaded data from the General Plan Mapping Tool, MyPlan and Cal-Adapt.

5. Coordination with federal, state, regional, and local data and information related to protection of public health and safety and the environment, including data from special districts and local offices of emergency services. Through the OPR Adaptation Clearinghouse jurisdictions can access contact information for local, regional, State and federal offices that can assist with this work.

Developing goals and measures for climate change adaptation and resilience (steps 6-9 of the Adaptation Planning Guide)

Jurisdictions must identify a set of adaptation and resilience goals, policies, and objectives, based on the information analyzed in the vulnerability assessment outlined above, for the protection of the community. The "Identifying Adaptation Strategies" chapter of the APG provides a start to this process, and links to other resources. CalAdapt, the OPR Adaptation Clearinghouse and other relevant local, regional, state and federal resources are appropriate to use. In particular, as mentioned in the vulnerability assessment section, regional collaboratives can play a useful role in both identifying policies and coordinating on implementation of those policies. See www.arccacalifornia.org for more information on regional collaboratives and potential partners in your area.

As outlined in the APG, feasible implementation measures must also be developed to ensure the goals, policies, and objectives in the plan are supported through implementing actions. This can be done through the general plan implementation matrix or other mechanism that allows monitoring of progress over time. The structure of the implementation matrix or program may shift depending on whether the climate change discussion is captured in a climate action plan, adaptation plan, or incorporated in the general plan. As with the vulnerability assessment section above, a jurisdiction should start with the APG, then review local or regionally relevant resources, and then review other statewide or national guides as outlined in the table above.

Whenever possible, cities and counties should work with neighboring jurisdictions to develop joint policies and coordinate on joint implementation of policy. Not only does this type of coordination increase policy consistency in a region, but it also may reduce staff and financial cost of implementation. Specific contents required in the climate adaptation discussion include:

1. Feasible methods to avoid or minimize climate change impacts associated with new uses of land. These include, but are not limited to, flooding, fire, extreme heat, sea level rise, runoff, risk, etc.). This should not just capture new risks, but also risks exacerbated by climate change.

2. The location, when feasible, of new essential public facilities outside of at-risk areas, including, but not limited to, hospitals and health care facilities, emergency shelters, emergency command centers, and emergency communications facilities, or identifying construction methods or other methods to minimize damage if these facilities are located in at-risk areas.

3. The designation of adequate and feasible infrastructure located in an at-risk area. Meaning, any new infrastructure should be built to withstand the identified risk.

4. An approach (guidelines) to working cooperatively with relevant local, regional, state, and federal agencies. The APG includes examples of outreach and coordination measures that can be taken to develop these guidelines.

5. The identification of natural infrastructure that may be used in adaptation projects. Where feasible, the plan shall use existing natural features and ecosystem processes, or the restoration of natural features and ecosystem processes, when

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developing alternatives for consideration. Additional guidance on natural infrastructure data and resources can be found at the OPR Adaptation Clearinghouse.

Seismic Hazards

Requirement Description:

The safety element must establish policies to minimize the loss of property and life as a result of earthquakes. The general geology and seismic history of the region and the planning area can be addressed with a map of known seismic and geologic hazards. The element should determine the location of active fault zones designated by the State Geologist under the Alquist-Priolo Earthquake Fault Zoning Act. Next, a geologic evaluation can evaluate the potential for displacement along active and potentially active faults in the planning area. Active and potentially active faults in the region should be identified with historical data on seismic ground shaking within the planning area. A geotechnical evaluation based on the state probabilistic earthquake hazard map can determine the potential for localized ground shaking, landslides, and tsunamis. Hazardous or substandard structures that may be subject to collapse in the event of an earthquake, including, but not limited to, unreinforced masonry buildings could be identified.

The geotechnical evaluation can also identify the potential for earthquake-triggered landslide, mudslide, liquefaction, and soil compaction. It should also determine the location of zones of required investigation for liquefaction. Areas that would be inundated in the event of a dam failure should also be identified. Dam inundation maps are available from the California Office of Emergency Services (OES). The development, facilities, and people potentially at risk in areas subject to potential inundation should be identified as well.

The safety element should include historical data on landslides and mudslides and identify areas that are landslide-prone by using, among other sources, landslide features maps, seismic hazard zone maps, and geology maps produced by Department of Conservation. The local potential for landslides and mudslides should also be identified in a geotechnical evaluation.

Historical data on land subsidence resulting from extraction of groundwater, natural gas, oil, and geothermal resources and from hydrocompaction can be used to identify areas of known risk from liquefaction, subsidence, or ground shaking. The potential risks associated with other known geologic hazards, such as volcanic activity, avalanche, or cliff erosion may also be analyzed.

Flood Protection

Requirement Description:

Flooding is a natural function of every river, alluvial fan, and coastal area. In riverine systems, floodwaters enrich bottomlands and provide spawning habitats for native fish. There are ecological benefits to maintaining connections between the river and its floodplain.

Land use decisions directly influence the function of floodplains and may either reduce or increase potential flood hazards. The functions of floodplains include, but are not limited to, water supply, water quality, flood and erosion control, and fish and wildlife habitat. Development within floodplains may not only expose people and property to floods, but also increase the potential for flooding elsewhere and negatively impact floodplain ecosystems. Land use regulations, such as zoning and subdivision ordinances,

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are the primary means of implementing general plan policies established to minimize flood hazards. In addition to including floodplain management policies in the general plan, making related changes to zoning and subdivision ordinances is crucial to the success of a floodplain management program.

In the process of preparing a flood management element, the city or county will have to collect a substantial amount of information concerning its floodplains and its watershed. There are a variety of sources for this information. Federal Emergency Management Agency (FEMA) maps are available for most communities. The U.S. Army Corps of Engineers will do floodplain delineation on a cost-sharing basis and has information on floodplains and project levees. The Department of Water Resources (DWR) also has floodplain information and a floodplain management program, as does the Central Valley Flood Protection Board. The OES and DWR have information on past flooding and flood levels based on awareness mapping. Local levee districts and resource conservation districts may also have information to share.

The Central Valley Flood Protection Plan (adopted pursuant to SB 5, the Central Valley Flood Protection Act of 2008) aims to revamp insufficient levee, bypass, and other flood defense mechanisms to create a more integrated and hazard-averse flood management system. Carrying implications for Central Valley land use, conservation, and safety planning in floodplain zones, the 2012 Central Valley Flood Protection Plan (CVFPP) documents the condition of all of the region's state and federal flood management facilities and guides improvements to flood hazard prevention along the Sacramento River and San Joaquin Rivers. All cities and counties within the Sacramento-San Joaquin Valley were required to amend their general plans by July 2015 to contain the data and analysis in the Central Valley Flood Protection Plan and include goals, policies, and objectives based on that plan, as well as relevant implementation measures (Gov. Code § 65302.9).

Key Terms

Flood management is defined as the overarching term that encompasses both floodwater management and floodplain management.

Floodwater Management

Floodwater management includes actions to modify the natural flow of floodwaters to reduce losses to human resources and/or to protect benefits to natural resources associated with flooding. Examples of floodwater management actions include containing flows in reservoirs, dams, and natural basins; conveying flows via levees, channels, and natural corridors; managing flows through reservoir reoperation; and managing watersheds by decreasing rainfall runoff and providing headwater stream protection.

Floodplain Management

Floodplain management includes actions to the floodplain to reduce losses to human resources within the floodplain and/or to protect benefits to natural resources associated with flooding. Examples of floodplain management actions include minimizing impacts of flows (e.g., flood-proofing, insurance); maintaining or restoring natural floodplain processes (e.g., riparian restoration, meander corridors, etc.); removing obstacles within the floodplain voluntarily or with just compensation (e.g., relocating at-risk structures); keeping obstacles out of the floodplain (through subdivision and zoning decisions); education and emergency preparedness planning (e.g., emergency response plans, data collection, outreach, insurance requirements, etc.); and ensuring that operations of floodwater management systems are not compromised by activities in the floodplain.

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Fire Hazards

Requirement Description:

There are many opportunities to address fire protection, fire prevention and hazard mitigation in the general plan, most obviously in the safety element which deals with all manner of natural and man-made hazards to life and property. California's increasing population and expansion of development into previously undeveloped areas is creating more "wildland-urban interface" with a corresponding risk of economic loss caused by wildland fire. The changing climate, specifically the rising temperatures and increasing temporal variability of water availability, continues to increase wildfire risk in many areas. Meanwhile, drought episodes with greater frequency and severity effectively lower fuel moisture conditions to create longer fire seasons, and combined with overstocked vegetation vulnerable to insects and diseases, produce an abundance of dead woody matter prime for intense burning.

Mitigating Hazards through Drought Resiliency Plans

The onset of severe droughts in California poses considerable threats to public safety and wellbeing by increasing fire hazard susceptibility and straining already scarce water resources. Drought's toll on crop yields, livestock production, and local community water sources create food and water security concerns, in addition to economic considerations, that showcase the importance of proper preparedness plans. Climate change will likely foster more consecutive disasters – for example, droughts followed by fires, or floods followed by drought – prolonging recovery of natural resources and compounding total recovery costs.

Government Code 65302(g):

(3) Upon the next revision of the housing element on or after January 1, 2014, the safety element shall be reviewed and updated as necessary to address the risk of fire for land classified as state responsibility areas, as defined in Section 4102 of the Public Resources Code, and land classified as very high fire hazard severity zones, as defined in Section 51177. This review shall consider the advice included in the Office of Planning and Research's most recent publication of "Fire Hazard Planning, General Technical Advice Series" and shall also include all of the following:

(A) Information regarding fire hazards, including, but not limited to, all of the following:

(i) Fire hazard severity zone maps available from the Department of Forestry and Fire Protection.

(ii) Any historical data on wildfires available from local agencies or a reference to where the data can be found.

(iii) Information about wildfire hazard areas that may be available from the United States Geological Survey.

(iv) General location and distribution of existing and planned uses of land in very high fire hazard severity zones and in state responsibility areas, including structures, roads, utilities, and essential public facilities. The location and distribution of planned uses of land shall not require defensible space compliance measures required by state law or local ordinance to occur on publicly owned lands or open space designations of homeowner associations

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(v) Local, state, and federal agencies with responsibility for fire protection, including special districts and local office of emergency services.

(B) A set of goals, policies, and objectives based on the information identified pursuant to subparagraph (A) for the protection of the community from the unreasonable risk of wildfire.

(C) A set of feasible implementation measures designed to carry out the goals, policies, and objectives based on the information identified pursuant to subparagraph (B) including, but not limited to, all of the following:

(i) Avoiding or minimizing the wildfire hazards associated with new uses of land.

(ii) Locating, when feasible, new essential public facilities outside of high fire risk areas, including, but not limited to, hospitals and health care facilities, emergency shelters, emergency command centers, and emergency communications facilities, or identifying construction methods or other methods to minimize damage if these facilities are located in a state responsibility area or very high fire hazard severity zone.

(iii) Designing adequate infrastructure if a new development is located in a state responsibility area or in a very high fire hazard severity zone, including safe access for emergency response vehicles, visible street signs, and water supplies for structural fire suppression.

(iv) Working cooperatively with public agencies with responsibility for fire protection.

(D) If a city or county has adopted a fire safety plan or document separate from the general plan, an attachment of, or reference to, a city or county's adopted fire safety plan or document that fulfills commensurate goals and objectives and contains information required pursuant to this paragraph.

In response, many local governments are choosing to strengthen water management and drought prevention efforts by adding a separate water element to their general plan, but drought preparedness strategies could also be incorporated into the safety element as part of fire or flood hazard mitigation tactics. Structural and nonstructural flood management methods that enhance water storage and groundwater recharge work to mitigate drought impacts, and promoting greater water efficiency through land use and development policies can minimize capital damage from droughts as well as fires. As opposed to solely relying on local hazard mitigation plans, existing urban and agricultural water management plans, or expecting state or federal disaster aid after severe drought impacts, local governments can use the general plan as a tool to encourage water conservation policies, drought-tolerant parks and landscaping, water audits, and dual plumbing with recycled water. For more resources on how local governments can plan for droughts, see:

- California's 2010 State Drought Contingency Plan
- OPR's 2014 Local Government Drought Toolkit
- 2011 Climate Change Handbook for Regional Water Planning

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- California's 2009 State Water Plan for integrated water management
- Local Government Commission's guidebook for regional water sustainability

Aside from local fire plans and hazard mitigation plans, the general plan's safety element can provide a framework for inserting fire protection and prevention policy requirements in zoning, subdivision, and strategic fire defense ordinances. To safeguard the increasing "wildland-urban interface," communities with State Responsibility Area (SRA) or Very High Fire Hazard Severity Zone Local Responsibility Area (LRA) must update their safety element following the next revision of the housing element on or after January 1, 2014 to address the risk of wildland fire. In order to develop viable plans for fire protection, wildfire risk reduction, evacuation needs, and consistency between general plan elements and other local plans, the safety element shall incorporate information such as fire hazard maps and assessments, implementation goals and actionable policies, as well as any appropriate references to local fire safety plans.

As a guiding resource, OPR's Fire Hazard Planning Technical Advisory includes a detailed discussion about how to incorporate and comply with the fire hazard requirements in a general plan.

Other Considerations

Additional Requirements

The safety element must also address additional, interrelated considerations in the context of fire and geological hazards. These include evacuation routes, military installations, peakload water supply requirements, and minimum road widths and clearances around structures. The relationships between these considerations interplays throughout the required contents of the safety element, and should be analyzed in the context of safety and disasters, including climate change, drought, fire, flood, or seismic activity, as appropriate.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies for flood risk, fire risk, and climate change can be found in the guidance and technical advisories referenced throughout this chapter.

Sample Policy	Example of Application	Relationship to Other Elements
[City/county] shall promote the strengthening of planned utilities, the retrofit and rehabilitation of existing weak structures and lifeline utilities, and the relocation or strengthening of certain critical facilities to increase public safety and minimize potential damage from seismic and geologic hazards.	City of Rancho Cucamonga	Circulation, climate change, equitable and resilient communities
[City/county] shall site critical public facilities—including hospital and healthcare facilities, emergency shelters, police and fire stations, and emergency communications facilities—outside of the tsunami evacuation zone and 100-year flood plains.	Pacifica	Environmental justice, equitable and resilient communities, healthy communities
[City/county] shall identify and establish specific travel routes for the transport of hazardous materials and wastes, with key considerations being capacity to safely accommodate additional truck traffic, avoidance of residential areas, and use of interstate or state divided highways as preferred routes.	City of Rialto	Circulation, environmental justice, noise, healthy communities
[City/county] shall work to achieve consistency between general plan land use and related policies and the Airport Comprehensive Land Use Plan, as is appropriate for the community. Measures may include restrictions on permitted land uses and development criteria, including height restrictions.	Redwood City	Land use, circulation

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Air Quality

Introduction

Chronic exposure to air pollutants is a serious health risk to millions of California residents, particularly the young, elderly, and people with heart disease and respiratory problems. Safeguarding public health has been the primary focus of federal and state air quality legislation and activities for many years. Air pollution also impacts local economies by damaging agricultural crops, natural vegetation, buildings, and other exposed materials. In addition, the economic health of an area may be affected adversely if insufficient air quality improvement triggers more stringent federally mandated air pollution controls. Air pollution also can impair visibility and obscure views. Cities and counties should strive to reduce emissions for the benefit of both their own residents and those of other communities in their region and the state as a whole. Air quality can be greatly improved through a multi-prong approach.

Local jurisdictions have responsibility for land use planning and can also significantly affect the design, creation, and management of development and the local circulation system. While air pollution is a regional issue, local governments have an opportunity to address air quality issues through general plans, development ordinances, local circulation systems, transportation services, and other plans and programs. As such, they are uniquely positioned to contribute to the local air district's efforts to achieve and maintain compliance with state and federal air quality standards. Supporting mode shift through improved bicycle and pedestrian facilities and support for transit, building infrastructure for zero emission vehicles, reducing parking, and promoting infill development can help reduce emissions and improve air quality. Cities and counties within the San Joaquin Valley Air Pollution Control District (SJVAPCD) jurisdiction are required by state law to include air quality measures in their general plans. The SJVAPCD developed the *Air Quality Guidelines for General Plans* to assist these cities and counties in meeting these requirements. The document provides additional goals, policies, and programs for adoption in general plans that will reduce vehicle miles traveled and improve air quality. In addition to statutory requirements for air quality measures in the San Joaquin Valley, cities and counties that have identified disadvantaged communities, as defined by SB 1000, must also incorporate air quality into their general plans. For more information on the environmental justice requirements, see the EJ section. Regardless of statutory requirements, the benefits of adopting an air quality element or implementing air quality policies throughout a general plan are universal.

Government Code 65302.1(c):

The adoption of air quality amendments to a general plan to comply with the requirements of subdivision (d) shall include all of the following:

(1) A report describing local air quality conditions including air quality monitoring data, emission inventories, lists of significant source categories, attainment status and designations, and applicable state and federal air quality plans and transportation plans.

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CORRELATIONS AMONG ELEMENTS

	Land Use	Circulation	Housing	Conservation	OPen Space	Safety	Noise	EJ
Air Quality	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	-	IN STATUTE

■ Identified in statute ■ Closely related to statutory requirements

San Joaquin Valley Completeness Checklist

Statutory Citation	Brief Description of Requirement
§ 65302.1(c)(1)	Background report on local air quality conditions, including: • Air quality monitoring data, • Emission inventories, • Lists of significant source categories, • Attainment status and designations, and • Applicable state and federal air quality plans and transportation plans
§ 65302.1(c)(2)	Summary of government policies, programs, and regulations that may improve air quality, including • Local • District • State • Federal
§ 65302.1(c)(3)	Goals, Policies and Objectives, consistent with the following: • Mitigate project level and cumulative air quality impacts under CEQA • Integrate land use plans, transportation plans, and air quality plans. • Plan land uses in ways that support a multimodal transportation system (i.e., dense and compact). • Local action to support programs that reduce congestion and vehicle trips. • Plan land uses to minimize exposure to toxic air pollutant emissions from industrial and other sources. • Reduce particulate matter emissions from sources under local jurisdiction. • Support district and public utility programs to reduce emissions from energy consumption and area sources.
§ 65302.1(c)(4)	Feasible implementation tools
§ 65302.1(d)	Consider Air District comments on the draft plan

Required Contents in San Joaquin Valley

Pursuant to Government Code section 65302.1, the legislative body of each city and county within the jurisdictional boundaries of the San Joaquin Valley Air Pollution Control District (SJVAPCD) was required to amend the appropriate elements of its general plan, including, but not limited to, the required elements dealing with land use, circulation, housing, conservation, and open space, to include data and analysis, goals, policies, and objectives, and feasible implementation strategies to improve air quality.

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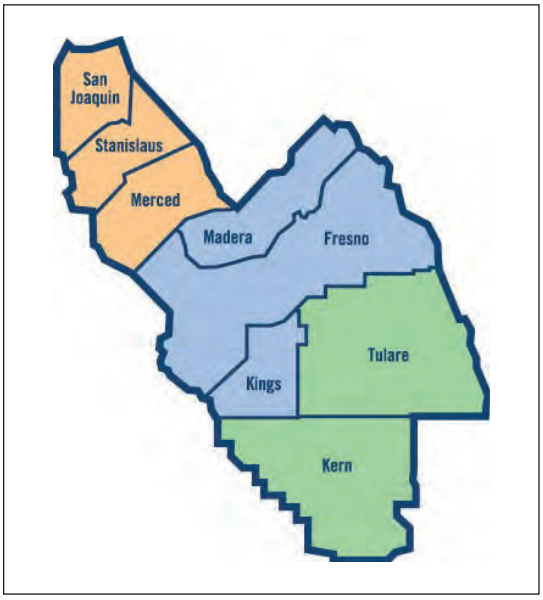
The adoption of air quality amendments to a general plan includes all of the following:

- A report describing local air quality conditions including:
  - » Air quality monitoring data
  - » Emission inventories
  - » Lists of significant source categories
  - » Attainment status and designations
  - » Applicable state and federal air quality plans and transportation plans
- A summary of local, district, state, and federal policies, programs, and regulations that may improve air quality in the city or county.
- A comprehensive set of goals, policies, and objectives that may improve air quality.

San Joaquin Valley Air Pollution Control District Boundaries



A set of feasible implementation measures designed to carry out those goals, policies, and objectives.

Federal, State, Regional and Local Air Quality

Federal Air Quality Standards – The Federal Clean Air Act (CAA) requires the U. S. Environmental Protection Agency (U.S. EPA) to set and periodically review national air quality standards (NAAQS) for six air pollutants: carbon monoxide (CO), ozone (O3), particulate matter (currently in two size ranges: less than 10 microns in diameter, PM10; and less than 2.5 microns in diameter, PM2.5, also called fine particles), nitrogen oxides (NOX), sulfur oxides (SOX), and lead (Pb). Primary standards are based only on health considerations, and secondary standards also take into account welfare considerations. When U.S. EPA revises a NAAQS, states are required to attain the NAAQS by target dates specified in the CAA. A state's NAAQS attainment or non-attainment status is determined by U.S. EPA. States that do not attain the NAAQS are required to develop and implement air pollution control plans to achieve the NAAQS (state implementation plans, SIPs) by the target date. U.S. EPA provides guidance interpreting the SIP requirements in the CAA that the states must follow to develop an approvable SIP. If U.S. EPA deems a SIP is not approvable or if a state fails to develop a SIP, U.S. EPA can develop a Federal Implementation Plan that can be imposed on the state.

State Air Quality Standards – The California Air Resources Board (ARB) was established in 1968 to address air quality problems in California. Since formation of U.S. EPA in 1970, ARB has been designated as the State agency responsible for carrying out the State's responsibilities under the CAA. Because California was already regulating air quality before formation of U.S. EPA and passage of the CAA, California was granted several

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privileges that are not allowed to any other state, including the unique authority to regulate mobile sources.

The California Clean Air Act (CCAA) also directs ARB to set state ambient air quality standards (CAAQS), as well as directing ARB to identify nonattainment areas of the State. In contrast to NAAQS, CAAQS do not have attainment date targets, however, areas that are nonattainment for the CAAQS must make annual progress to reduce air pollution levels. ARB monitors air quality statewide through an extensive monitoring network that is jointly operated with local air pollution control districts (APCDs) and air quality management districts (AQMDs). ARB also promulgates regulations that reduce air pollution emissions from motor vehicles and consumer products that improve air quality throughout the State. ARB has oversight responsibilities related to local air district activities.

Regional Air Quality Management –California is divided into geographic areas which share common airsheds, called air basins. Each part of California falls under the authority of a county air pollution control district (APCD) or a multi-county air quality management district (AQMD). These local districts have the main responsibility of controlling air pollution emissions from stationary sources within their jurisdictions, including sources such as factories, power plants, gas stations, and dry cleaners. The districts adopt and implement rules and regulations related to the stationary sources under their jurisdiction to reach ambient air quality standards in their air basin, and to enforce relevant State and federal laws.

Local Air Quality –Local government air quality responsibility includes four main areas: land use planning, review and mitigation of the environmental impacts of development projects, development and maintenance of transportation infrastructures; including transit systems, and implementation of local air quality programs.

At least 45 days prior to the adoption of air quality amendments to a general plan pursuant to this section, each city and county shall send a copy of its draft document to the SJVAPCD (Gov. Code § 65302.1(d)). The SJVAPCD may review the draft amendments to determine whether they may improve air quality consistent with the strategies. The legislative body of the city or county shall consider the district's comments and advice prior to the final adoption of air quality amendments to the general plan. The SJVAPCD's comments are advisory to the city or county

Statutory Requirements in San Joaquin Valley

The SJVUAPCD prepared the Guide for Assessing and Mitigating Air Quality Impacts (GAMAQI), which can be found on the San Joaquin Valley Air Pollution Control District website. This document, GAMAQI 2015, which has undergone subsequent revisions to ensure its applicability over time, provides guidance for addressing air quality in environmental documents within the District. This includes methods of determining local air quality and suggested policies for improving air quality.

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Considerations for Communities Beyond San Joaquin Valley

The general plan, as the foundation for local planning and development, can be an important tool for implementing policies and programs beneficial to air quality. Communities may choose to adopt a separate air quality element or to integrate air quality-beneficial objectives, policies, and strategies in other elements of the plan, such as the land use, circulation, conservation, and community design elements. Whichever method is selected, consistency among elements and policies within the plan is essential for successful implementation.

Required Contents for Disadvantaged Communities

Cities and counties whose general plan must include an environmental justice element, or related goals, policies, and objectives in other elements, must include ways to reduce the unique or compounded health risks in disadvantaged communities by reducing pollution exposure, including the improvement of air quality. For more information on disadvantaged communities and air quality requirements, see the environmental justice element section.

Communities with a Port of Entry

According to the Air Resources Board,

> "The diesel equipment operating in and around freight hubs, such as seaports, railyards, and warehouse and distribution centers, is a significant source of diesel [particulate matter] PM, a toxic air contaminant that can cause cancer and other health problems, including respiratory illnesses, increased risk of heart disease, and premature death. Exposure to diesel PM is a health hazard, particularly to children whose lungs are still developing and the elderly, who may have other serious health problems. The diesel PM emissions from freight operations impact communities located adjacent to those operations, as well as residents living miles away" (Sustainable Freight: Pathways to Zero and Near-Zero Emissions, 2015).

Port of entry communities may experience extensive exposure to air pollutants, and should have a comprehensive set of goals, policies, and objectives that can improve air quality. Sample policies may be found at the end of this chapter, and in greater detail in Appendix A.

Considerations in Land Uses Near High-Volume Roadways[4]

A general plan update is the opportune time to address issues that require thoughtful cross-sector analysis and discussion. Land use decisions near or adjacent to high volume roadways often present conflicts between economic, health, and environmental benefits from the development and the potential health impacts of vehicle emissions on nearby residents, businesses, schools, and other uses. Mitigating existing near-roadway land use conflicts and planning to avoid such conflicts in new projects requires coordination of several general plan elements, including land use, housing, circulation, environmental justice, and health.

Infill development along primary transportation corridors can help to achieve multiple policy objectives (good access to destinations, low VMT, environmental, heath, and economic benefits, fiscal savings for governments and transportation cost savings for citizens),

[4] High volume roadway is defined as: Roadways that, on an average day, have traffic in excess of 50,000 vehicles in a rural area and 100,000 vehicles in an urban area

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but may also involve residential and commercial development adjacent to high-volume and other roadways elevated levels of air pollution or air toxics. Studies show that exposure to traffic pollution is associated with health issues including worsening of asthma and other respiratory health impacts. The foremost strategy for reducing pollution exposure near high-volume roadways is to minimize creation of traffic pollution in the first place. There are many efforts to do this:

- Federal and state emissions standards for cars, trucks, and buses
- State regulations for zero emission vehicle adoption
- SB 375, SB 743, regional, and local policies that reduce driving
- California's Sustainable Freight Transport Initiative
- Community- and government-led efforts to increase alternative transportation modes including public transit, biking, and walking

From a land use perspective, other strategies such as removing car lanes, having dedicated transit lanes, adding in separate bike lanes, and widening sidewalks are all practical strategies that can reduce emissions since they minimize traffic. Some areas have started Ciclavias, closing down a road for one day to cars to promote the use of the space by walkers, bikers, and other forms of activity.[xxvi] The land use and circulation sections discuss these options in more depth. Capping – by covering and building atop—or removing freeways is another strategy employed by some areas as appropriate.[xxvii] Eliminating the high frequency road altogether, and providing alternate modes of efficient transportation, as San Francisco did when removing the Embarcadero Freeway, may create co-benefits in the community, including increased health and economic vitality.

Some policies and regulations will go into effect in the next few years and will lead to substantial emissions reductions before development guided by current general plan updates will occur, while others have compliance dates that extend well into the future. Other policies, such as travel demand management, vary at the local level. Fleet turnover and changes in the built environment to increase non-auto travel will also take time. As these policies are realized, there is a need for local governments to consider other mitigation options to protect sensitive populations from near-roadway pollution exposure and to reduce the health impacts associated with living or working near busy roadways.

Deciding where to site a project is not a simple task. The pollutant levels and air quality near a freeway can vary significantly based on air-flow patterns, temperature, time of day, season, presence of sound barriers, vegetation, height of structures and other variables. The variation of near-roadway pollution levels means that development plans must consider reducing both peak and long-term pollution exposures. Cross-sector discussion and analysis are of utmost importance to determine adequate sites for future development and balance multiple policy objectives.

Research has begun to evaluate measures to avoid, minimize, and mitigate air pollution exposure near roadways. Simultaneously, new research shows health benefits from reducing GHGs; improving housing stock; preserving agricultural spaces, habitats, and recreational spaces; and engaging in the active transportation and mass transit made possible through infill development.

A comprehensive discussion around process strategies and mitigation strategies to address near roadway land use has the potential to improve air quality and reduce exposure to toxics. Furthermore, a holistic examination allows for weighing benefits related to

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equity, health, economics, resource protection, and overall sustainability goals.

The Atlanta, Georgia Summer Olympic games of 1996 provides an example of a holistic approach to improve air quality through temporary mitigation strategies. Recognizing there would be an influx of people, Atlanta implemented a suite of policies to accommodate the additional visitors in a clean and travel efficient manner. These included a 24-hour public transit system, additional buses, modified work place policies such as telecommuting, and even adjustments to delivery schedules. Researchers were able to evaluate the impact of these short-term policies and showed decreased ozone, traffic counts, and acute care asthma visits. Although these were temporary measures, they reflect of what a more comprehensive suite of policy objectives could achieve through mode shift from car dependency to alternative forms of transit.

Just as in the Atlanta games example, the suite of strategies to address near roadway land use must be considered as it applies to the local context. Potential strategies to address near-roadway land use are identified below. Process strategies are listed to consider during the general plan update process. Additionally, mitigation strategies are identified for cases when they are needed. The mitigation measures listed are based on a review of the literature conducted by the Air Resources Board and published in the Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways.

Potential strategies to avoid and mitigate health impacts near roadways

Process Strategies

Aimed at identifying, mitigating, and avoiding—if possible—exposure to air pollution.

- Consult with regional air district during early stages of the general plan update when prioritizing areas for infill development to identify stationary and mobile sources of toxic air contaminants
- Consult with regional air district, community, and other stakeholders during identification of potential infill sites and create an inventory
- Engage with local community members early in the general plan update process to discuss vision, local priorities, and concerns
- Engage with local community groups working on related issues early in the general plan update

Infill development and active transportation create numerous co-benefits



Image by Urban Advantage, Dover Kohl & Partners

- Incorporate air pollution reduction goals and exposure reduction goals into the general plan language
- Prioritize discussion of policy goals that have the potential to reduce emissions overall to be incorporated into the general plan policy language, such as reduction of lanes in roads
- Prioritize discussion of policy goals that support mode shift from single occupancy vehicles to transit and/or active transit to be incorporated into the general plan policy language

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Mitigation Strategies

Mitigation strategies are aimed at identifying various potential strategies that cities and counties can incorporate as needed to reduce exposure to near-roadway pollution.

Locating potential infill development sites near a high volume roadway may yield an array of benefits, which should be balanced with drawbacks associated with near roadway pollution. Additionally, many communities already have sensitive land uses near which can not be easily relocated, and thus need mitigation strategies to reduce health impacts. Research over the last decade has identified mitigation strategies that reduce pollution concentrations, emissions, or improve air flow. Site-specific factors should be carefully considered as local jurisdictions, in conjunction with their regional air district, assess and select mitigation strategies that make the most sense for the local context. Also, as illustrated with the 1996 Atlanta games example, a combination of mitigation strategies is likely to have a greater impact than implementing one stand-alone measure.

The research on mitigation measures tends to fall into one of several categories including:

1. Strategies to reduce traffic emissions
2. Strategies to increase dispersion of traffic pollution
3. Strategies to remove pollution from the air breathed by people

A full discussion of mitigation strategies and the background research is available in the Air Resources Board Technical Advisory: Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways. The table below is a high level summary of the description of the strategy, the research findings, and appropriate context and other considerations. Please consult the full publication for a more in-depth discussion.

Strategy	Description of research findings	Appropriate context & other considerations
I. Strategies that reduce traffic emissions		
1. Speed Reduction Mechanisms, including roundabouts	Vehicle speed reduction mechanisms change the design and operating speed of the road by altering the physical characteristics of the road. These features can reduce stop-and-go driving and hard accelerations and thereby reduce emissions rates. Some of these features, like the roundabout intersection, can be used as an alternative to stop-controlled and signalized intersections. Studies show that roundabouts can reduce localized pollutant concentrations compared to intersections with stop and signal control by 20% or more (depending on context and site-specific conditions).	Transportation planners and engineers should carefully consider the potential direct and indirect effects of implementing speed reduction mechanisms to determine if they will reduce vehicle emissions and other impacts to the environment as well as to traveler safety and delay. When guidance is needed to estimate emissions and air quality-related effects, planners and engineers may consult with MPOs or traffic modeling experts.
2. Traffic Signal Management	Traffic signal management systems can reduce stop-and-go driving and vehicle idling, resulting in reduced localized pollutant concentrations of up to 50% compared to corridors that do not implement these systems. Studies show that site-specific conditions dictate the magnitude of reductions.	Many different types of signal management are available, and planners should identify what is best for air quality, vulnerable road user safety, and transit and active mode throughput and comfort.
3. Speed limit reductions on high-speed roadways (>55 mph)	Research studies have identified an optimal average speed range of ~35-55 mph within which per-mile traffic emissions and fuel consumption are minimized. Generally, speed limit reductions on high-speed roadways can reduce tailpipe emission rates up to 30%, depending on the change in speed, the pollutant measured or modeled, and the roadway characteristics.	Speed limit reductions are appropriate on roadways where speed limit and design speeds exceed 55 mph.

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Strategy	Description of research findings	Appropriate context & other considerations
II. Strategies that increase dispersion of traffic pollution		
4. Design that promotes ventilation along street corridors	The physical layout of urban streetscapes influences air flow and pollution movement. Research studies show that street corridors characterized by buildings with varying shapes and heights, building articulations (street frontage design elements like edges and corners that help break up building mass), and spaces that encourage air flow (e.g., parks) benefit from better pollutant dispersion and air quality. For example, buildings of varying heights can result in significant increases in turbulence (e.g., up to doubling), and adding bike lanes and sidewalks not only reduces car traffic, but also creates space for more dispersion (up to a 45% reduction in particulate concentrations).	Wider sidewalks, bicycle lanes, and other features benefitting pedestrians can also create space for better air flow and pollutant dispersion along with increasing active transportation and mode shift. This strategy should be considered in the context of the overall need to increase development density.
5. Solid barriers and walls	Measurement and modeling studies consistently find that solid barriers reduce near-road downwind concentrations by increasing vertical dispersion of pollutants emitted by vehicles. The magnitude of the reduction and its spatial extent depend on the height of the barrier, the width of the road, and micrometeorology. As reference, studies have consistently found that pollution concentrations downwind of the barrier, ranging from 10% to 50% reduction compared to concentrations measured on or directly adjacent to high-volume roadways.	Solid barriers should only be considered for installation along freeways, because they have the negative effect of dividing neighborhoods and obscuring sightlines.
6. Vegetation for pollutant dispersion	Studies indicate that vegetation has the potential to alter pollutant transport and dispersion. In some studies, specific locations and conditions translated to air quality benefits (e.g., pollution concentrations of up to 20% on the leeward side of the tree line). It should be noted that most studies were conducted on the East Coast and in Europe where vegetation types and densities differ from what is found in California.	Online tools are available to assist with the selection of appropriate vegetation considering allergen impacts, watering needs, and other factors. Maximum benefits have been shown to occur when vegetation is combined with solid barriers.
III. Strategies that remove pollution from the air breathed by people		
7. Indoor high efficiency filtration	Studies show that particle filtration systems and devices, specifically high-efficiency filtration with mechanical ventilation or portable high efficiency air cleaners, can be highly effective for reducing indoor pollution concentrations. High efficiency filters in ventilation systems can remove from 50-99% of particles in the air. However, research shows that filtration technologies for gaseous pollutants (VOCs) are variable in their effectiveness; some remove certain VOCs well, but not others.	Planners should be aware of current state and local building codes and their respective air filtration requirements, including requirements for amending code standards. Regular operation and maintenance is necessary for highest filter and ventilation efficiency, and is required by regulation in commercial buildings.

Near roadway siting considerations and strategies will continue to evolve. For example, vehicles will continue to become cleaner over the coming years, changing the balance in benefits and drawbacks of near roadway development. A general plan update provides a platform on which to consider multiple policy options simultaneously, and the opportunity to create holistic, internally consistent solutions.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Sample Policy	Example of Application	Relationship to Other Elements
[City, county] shall require that new multi-family residential buildings and other sensitive land uses in areas with high levels of localized air pollution be designed to achieve good indoor air quality through landscaping, ventilation systems, or other measures.	City of Murrieta	Land use, housing, healthy communities
[City, county] shall provide incentives to promote air pollution reductions, including incentives for developers who go above and beyond applicable requirements and mitigate pollution for facilities and operations that are not otherwise regulated.	City of Chula Vista	Land use, healthy communities, environmental justice
[City, county] shall require uses such as smog check stations, automotive painting and repair facilities conduct such activities in enclosed and filtered spaces to prevent odors and emissions from affecting passers-by, nearby residents, and building occupants	National City	Healthy communities, environmental justice
[City, county] shall employ strategies in the Community Design Element that reduce driving rates and improve air quality through land use and urban design will be implemented by the City and other responsible parties. These strategies include transit-oriented development, compact development, an appropriate mix of land uses, a jobs/housing balance, transit oriented development, and walkable streets.	City of Southgate	Circulation, land use, economic development, healthy communities
[City, county] shall minimize exposure to air pollution and hazardous substances	County of Ventura	Climate change, environmental justice, healthy communities
[City, county] shall encourage non-polluting industry and clean green technology companies to locate to the City.	City of Murrietta	Climate change, environmental justice, economic development, healthy communities

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5

Equitable & Resilient Communities

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

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"The future is not someplace we are going to, but a place we are creating. The paths to it are not found, they are made."

—Jane Garvey

Introduction

Addressing social equity in policy decisions is vital for the economy, the health of the population, community well-being, and climate policies that support all residents. In addition to investments in infrastructure, services, and amenities, policies to support community engagement and to foster human capital in local communities are vital to creating more thriving, healthy, resilient, and equitable places. Additionally, there are significant demographic shifts taking place across California including more aging seniors, increasing ethnic diversity, and changing household structures. [xxviii, xxix]

Cities, counties, regions, and states have increasingly been integrating equity principles into their policies and frameworks to increase opportunities for all to thrive. Disciplines such as transportation, housing, agriculture, energy, economic development, land use, health, and education are utilizing an equity framework to inform policy. [xxx, xxxi, xxxii, xxxiii] In the late 1960s, the urban planning equity movement recognized that through expanding choices and services to those with limited options, local jurisdictions could work towards improved planning outcomes and equity. [xxxiv] Equity is also one of the three key pillars in sustainable development and is recognized by the American Planning Association in its official policy on smart growth. Despite the growth and interest in advancing social equity and the recognition of its importance, one common definition has not emerged. [xxxv]

A few definitions include:

The National Academy of Public Administration defines social equity as:

> "The fair, just, and equitable management of all institutions serving the public directly or by contract; the fair, just and equitable distribution of public services and implementation of public policy; and the commitment to promote fairness, justice, and equity in the formation of public policy."[xxxvi]

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The American Planning Association defines social equity as:

> "The expansion of opportunities for betterment that are available to those communities most in need, creating more choices for those who have few."[xxxvii]

The California Planning Roundtable states that social equity "ensures that all groups enjoy the benefits of a healthy and prosperous community, with access to housing, transportation, jobs and commerce. It enables a variety of businesses to flourish."[xxxviii]

"Health equity" is defined in California law, as "efforts to ensure that all people have full and equal access to opportunities that enable them to lead healthy lives" (Health and Safety Code § 131019.5(a)(2)). "Determinants of equity" are recognized to mean "social, economic, geographic, political, and physical environmental conditions that lead to the creation of a fair and just society" (Health and Safety Code § 131019.5(a)(1)).

Geographic inequity describes a situation in which the burdens of undesirable land uses are concentrated in certain neighborhoods while the benefits are received elsewhere. It also describes a situation in which public amenities are concentrated only in certain areas.

Many communities have used a robust community engagement process to adopt their own working definition of social equity, with agreed upon goals for their equity work in land use and transit planning. This chapter will discuss how social equity is foundational to other planning issues such as environmental justice and healthy communities.

American Planning Association Policy on Smart Growth SOCIAL EQUITY AND COMMUNITY BUILDING

The American Planning Association supports a sustained and focused initiative in federal, state, and local public policy to reverse the general decline of neighborhoods through strategies that promote citizen involvement and reinvestment within core communities.

The American Planning Association supports the application of smart growth principles to expand social equity in rural communities in ways that help preserve and strengthen their character.

The American Planning Association supports increased social, economic, and racial equity in our communities and calls on the federal government to increase community development funds to remedy these inequities and to ensure that planning and land development decisions do not unfairly burden economically disadvantaged groups.

The American Planning Association supports federal, state, and local policies and programs that encourage economically and socially diverse mixed income neighborhoods as the foundation for healthy regions, including encouragement for the provision of workforce housing in all new-growth areas and areas to be redeveloped.

The American Planning Association supports efforts to strengthen public education systems, including pre-K, as essential components of community building in urban, suburban, and rural areas, which help to ensure that children have an opportunity for an excellent education wherever they may live, and which provide a critical element for reinvestment in urban core communities.

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The American Planning Association supports planning that identifies the transportation, housing, employment, education, recreation and health needs of our changing population, both with respect to the total number of people expected to reside in an area and also with respect to population groups with special needs such as the elderly, school children, or people of diverse cultures.

The American Planning Association supports public–private partnerships as a means to leverage funds to achieve social equity and community redevelopment.

Source: https://www.planning.org/policy/guides/adopted/smartgrowth.htm

CORRELATIONS BETWEEN ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Safety	Noise	EJ
Social Equity	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED

■ Identified in statute ■ Closely related to statutory requirements

Social Equity and other planning issues

Environmental Justice and Equity

Environmental justice (EJ) is defined in state planning law as the "fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies" (Gov. Code § 65040.12(e)). However, in addition to statute, there are several overlapping definitions and frameworks to contextualize EJ with ongoing robust conversation to define how it is related to social equity. In fact, EJ as a field has undergone tremendous expansion beyond the work that traditionally focused on the disproportionate burden of pollution and contaminants suffered by many communities of color to include access to services, healthy food, and affordable housing.[xxxix, xl] Not only does this expanded framework for EJ overlap with social equity, but it also overlaps with work traditionally associated with healthy community policies. This is evident in new EJ legislation, SB 1000, which requires pollution exposure reduction, including air quality, as well as policies to promote food access, safe and sanitary homes, and physical activities for disadvantaged communities. See the EJ section for more details.

EJ is considered an equity issue.[xli] It is an integral component of equity, but social equity also encompasses a larger framework such as access to jobs and economic opportunity, arts and culture, safety from violence, public administration, management of goods and services, access to education, and complete neighborhoods. Social equity is applied across the age range and various disciplines, and has many other nuances. For instance, an elderly population that has limited mobility could live in a neighborhood without safe, walkable streets or accessible public transit. Although it is not necessarily an EJ issue, the lack of mobility options is an important equity consideration. A low-income community that does not have access to parks – since historically they were not funded for development in lower-income areas – could be considered as having both EJ and equity issues. Equity can be used as the larger framework for ensuring opportunities for all in the community.

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Healthy Communities and Equity

Healthy community work is also directly related to social equity. For decades, health researchers studied disparities in physical and mental health status among distinct segments of the population, including differences that occur by gender, age, race or ethnicity, sexual orientation, education, income, disability or functional impairment, geographic location, or a combination of any of these factors.[xlii] Decades of research have demonstrated that health outcomes are linked to much more than merely access to health services or underlying genetics. The research uncovered that many social, economic, and environmental factors contribute directly to health outcomes. The increased understanding of these factors has led communities across the nation, with California leading, to work closely with planning departments to improve planning policies and the built environment to better support health. It is important to apply an equity framework to the healthy community work to ensure that efforts do not make health disparities worse. See the Healthy Communities Chapter for more details.

SB 244

SB 244, passed in 2011, specifically recognized that many disadvantaged unincorporated communities lacked adequate investment in infrastructure such as sidewalks, safe drinking water, and adequate waste processing. This lack of adequate investment threatens both health and safety of residents and creates inequity in terms of access to quality services.[xliii] SB 244 created procedural requirements to identify these areas of risk and update general plan policies to improve conditions. See OPR's Technical Advisory on SB244.

General Planning

In the context of creating a general plan, considering distribution of and access to resources within a community may help provide improved services and opportunities to thrive.

Cities and counties can prioritize access to public facilities and services that enhance quality of life, including but not limited to, public transportation options connected to job centers, housing, parks, open space, trails, greenbelts, recreational facilities (including senior and youth centers), community centers, grocery stores, health care facilities, child care centers, libraries, and cultural centers. Considering the number and quality of, and access to facilities is important. Many instances of inequity are not intentional, but manifest themselves in terms of process or results. Therefore, by increasing awareness, jurisdictions can modify processes that lead to inequity. For example, transportation decisions are often informed by commute times. However, commute times are calculated during specified hours. Often, service sector employees engage in "reverse commutes," traveling at later or earlier hours. Regular commuter calculations do not adequately capture service sector needs, so other data should be included.

Common definitions in reference to social equity

In conversations about equity, terms such as underserved, low–income, disadvantaged, or environmental justice community are often interchanged but can potentially have different meanings depending on the context. There are also different statutory definitions and references from various funding sources. It is helpful to clarify terminology. For instance, one could reference a disadvantaged community while referring to an elderly or disabled population that does not have adequate access to transit options. Alternatively, disadvantaged could

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refer to children who do not have access to safe places to play. Several common terms have statutory definitions and others are used more generally. Additionally, many state and federal programs utilize the statutory definitions to determine funding for programs, and that too can vary. Some of the most applicable terms to local planning are below and apply where there is no other prevailing statutory definition.

Statutory definitions

Definitions pertinent to SB 1000

Disadvantaged Community Government Code Section 65302

"Disadvantaged communities means an area identified by the California Environmental Protection Agency Pursuant to Section 39711 of the Health and Safety Code OR an area that is a low-income area that is disproportionately affected by environmental pollution and other hazards that can lead to negative health effects, exposure, or environmental degradation."

Low-Income Area Government Code Section 65302

"Low-income Area means an area with household incomes at or below 80 percent of the statewide median income OR with household incomes at or below the threshold designated as low income by the Department of Housing and Community Development's list of state income limits adopted pursuant to Section 50093."

Definition in the water code

Disadvantaged Community Public Resources Code Section 75005, Water Code Section 79505.5

A "Disadvantaged Community" is a community with a median household income less than 80 percent of the statewide median household income. "Severely disadvantaged community" means a community with a median household income less than 60 percent of the statewide average.

Definitions pertinent to SB 244

Disadvantaged Unincorporated Community as per SB 244 Government Code Section 65302.10 (a)

"Community" means an inhabited area within a city or county that is comprised of no less than 10 dwellings adjacent or in close proximity to one another.

"Disadvantaged unincorporated community" means a fringe, island, or legacy community in which the median household income is 80 percent or less than the statewide median household income.

"Island community" means any inhabited and unincorporated territory that is surrounded or substantially surrounded by one or more cities or by one or more cities and a county boundary or the Pacific Ocean.

"Fringe community" means any inhabited and unincorporated territory that is within a city's sphere of influence.

"Legacy community" means a geographically isolated community that is inhabited and has existed for at least 50 years.

Environmental Justice Government Code Section 65040.12(e)

EJ is defined in state planning law as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.

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Health Equity Health and Safety Code Section 131019.5

Recognizes "determinants of equity" means social, economic, geographic, political, and physical environmental conditions that lead to the creation of a fair and just society. Furthermore, "Health equity" means efforts to ensure that all people have full and equal access to opportunities that enable them to lead healthy lives.

Incorporating social equity into planning: examples and strategies

There is not one way to incorporate equity into a general plan, but there are unifying approaches to integration. A local jurisdiction should consider using an equity framework as the basis to start its planning process.

Vision, Outreach and Engagement

Robust community engagement to capture all voices within the community from the beginning of the general plan update is vital to creating a shared vision with significant community support, resulting in a plan that is more likely to acknowledge community challenges and accurately account for existing community assets. Engaging multiple groups also leverages community expertise. Partnership and engagement with diverse stakeholders also helps create more support for the plan during the approval process. There are many actions a local agency can take to support engagement from all sectors and groups within the local community. Focused outreach efforts to specific groups that work on equity issues, such as local community-based organizations, can be an effective way to incorporate an equity framework. If consultants manage public outreach, it can also be helpful to have a city or county staff assigned to serve as a liaison or oversee the outreach process for continuity after the project ends. This also provides for consistent and ongoing communication after plan adoption and implementation updates with the community.

As emphasized in the second chapter, A Vision for Long-Range Planning, coordinating with local agencies is important when seeking to implement many of the policies that provide more equitable access to resources. The Community Engagement and Outreach chapter provides more detailed guidance on ways to effectively engage with the community. SB 1000 also has statutory language about civil engagement.

Incorporating Data, Mapping, and Other Tools

An important step in the process of incorporating equity considerations is to integrate it into the analysis of existing conditions. Jurisdictions have to collect at least jurisdiction-wide socioeconomic data during the preparation of the housing element, such as income levels and persons with special housing needs (elderly, farmworkers, single heads of households, etc.). However, a more complete socioeconomic picture of the community can be analyzed using smaller geographic data sets, less than jurisdiction-wide, such as census tracts, which allows a comparison of different areas throughout a community. Data sources are mentioned throughout the General Plan Guidelines.

Some examples of local jurisdictions both within and outside of California that have done mapping projects to incorporate equity into policy decision making processes include:

- Denver
- Portland-Vancouver

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- Atlanta
- New York
- Riverside
- Los Angeles

Incorporating Supportive Policies

An analysis of existing conditions combined with robust community input can help bring particular policy issues to the forefront for discussion. As policy priorities are established, formulating strong policy language is a key first step. For example, rather than "consider implementing" use the word "implement." Also, instead of using the phrase "consider the development of," use "develop and implement." Additionally, to create more actionable policy language use "priority on" rather than "emphasis on" to highlight policy areas of particular focus.

Community Resilience

Community resilience refers to the ability of a community to respond, recover, and adapt, and do so dynamically. It is directly related to equity. Incorporating equity considerations from the beginning of the planning process offers the potential to decrease vulnerability in the community in terms of infrastructure and human capital. "Vulnerability is the flip side of resilience: when a social or ecological system loses resilience it becomes vulnerable to change that previously could be absorbed."[xliv] Akin to the circulation of traffic, if power is lost and a traffic light goes out, a bottleneck will occur, slowing traffic down across the entire area, not just the focused area where the light went out. This means the system is vulnerable and not resilient.

When other systems within a community are vulnerable, the effects can ripple throughout the area as well. Incorporating social equity is a key strategy for local governments to create resilient communities.

The Rockefeller Foundation has conducted extensive research on what drivers are important to support resiliency. Using that research, they have implemented lessons learned through practical experience with cities across the globe. Many of the lessons can be modified to apply to land use planning. Adapting their framework to apply to a general plan, local jurisdictions can ask a number of questions during the update and at the end of the process to measure how they are addressing resilience. If resilience was incorporated from the beginning, it is much more likely the series of questions will have affirmative responses and the policies will support resilience community-wide.

Questions informed and adapted from the Rockefeller Foundation Resiliency Framework that could be used by a local jurisdiction as it updates its general plan include: [xlv]

Health and Wellbeing

- How do the policies help community members meet their basic needs?
- How do the policies help create opportunities to support basic needs, such as job training, skills, housing, and job fit?

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- How do the policies ensure access to facilities and services, such as emergency services, mental health, and health care services?

Economy and Society

- How do the policies encourage community engagement in the planning process and strengthen social networks?
- How do the policies strengthen crime prevention and safe places?
- How do the policies foster more economic prosperity?

Infrastructure and Environment

- How do these policies conserve our local environmental assets and preserve natural ecosystems?
- How do these policies help maintain our infrastructure and ecosystems?
- How do these policies support multimodal transit and diverse network options?

Leadership and Strategy

- How has data informed the policy development? Were multiple sectors consulted during policy formation?
- Did this general plan update allow for increased organizational capacity, education, and increased awareness between stakeholders and the local government?
- Did data inform the holistic vision that can be integrated across different land use plans, sectors, and users?

Some examples of local jurisdictions both within and outside of California that have incorporated resiliency as a key framework for planning include:

- Boston – Boston has specifically included social cohesion into their framework and has hosted discussions on race and equity to further resilience locally.
- San Francisco – San Francisco, at high-risk for earthquakes and natural disasters, has made resilience around physical infrastructure a priority.
- Atlanta – Atlanta is looking closely at its transit and aging infrastructure.
- Los Angeles – Los Angeles prioritizes addressing poverty as a key to improving resiliency.

The long-range nature of policies in the general plan, as well as the multi-agency and diverse stakeholder involvement, provides an opportunity to incorporate equity. This creates the potential to create a more resilient community.

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Sample Policy	Example of Application	Relationship to Other Elements
[City, county] shall develop programs to attract and retain industries that can provide a living wage, provide health insurance benefits, and meet existing levels of workforce education.	City of Murrieta	Land use, housing, healthy communities, economic development
[City, county] shall prioritize projects that significantly address social and economic needs of the economically vulnerable populations. Address and reverse the underlying socioeconomic factors and residential social segregation in the community that contributes to crime and violence in the city.	City of Richmond	Environmental justice, safety, economic development
[City, county] shall encourage activities such as block parties and community–wide social events, that strengthen neighborhood cohesion and the overall identity of the City.	City of El Monte	Safety, healthy communities
[City, county] shall enhance low income independent housing for seniors, continue to develop and expand senior housing services.	Marin County	Land use, housing environmental justice healthy communities

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6 Healthy Communities

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

"I thought about it while riding my bicycle."

—Albert Einstein on the Theory of Relativity

Introduction

The health and well-being of California's residents are fundamental to their quality of life and economic vitality. Protection of the public health, safety, and welfare of residents is the legal basis for land use regulation.[xlvi] Homes, streets, work places, retail and services, schools, and neighborhoods influence community health in fundamental ways. Educational and employment opportunities may influence and improve health by ensuring access to the ingredients for a healthy life, including nourishing food, clean water, affordable places to live, safe places to walk, bike, and be active, and clean air indoors and out. The World Health Organization (WHO) defines health as "a complete state of physical, mental, and social well-being, and not merely the absence of disease."[xlvii] Any reference to health in these guidelines refers broadly to health, including mental health. Health outcomes are not evenly distributed across all segments of the community. Research has shown that certain communities, often low-income and people of color disproportionately suffer from poor health.[xlviii] Many factors contribute to these health disparities, including neighborhood and community conditions. Changing demographics across California create an imperative to address these disparities. Planning, programs, and policy to achieve health equity, through ensuring access to opportunities, will benefit the entire community. The policy priorities established in local general plans have tremendous potential to improve community health and make the healthy option the easier option for everyone.

Research shows that while access to health services is important, social, environmental, and economic factors also have a significant impact on health outcomes. The built environment is a key component of those factors and can affect all chronic conditions. Walkable neighborhoods promote physical activity, improving health outcomes.[xlix] Other links between health and environment continue to emerge; for example, the impact of green space on mental and physical health.[i] Many planning policies, such as Complete Streets, promote healthier outcomes by creating safer places to walk with improved connectivity to destinations. Thinking about health in

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the planning process can lead to better health outcomes, and using data to inform policy decisions can help to ensure that changes in the built environment improve health disparities, instead of worsening them. Cross-sectoral work throughout the planning process allows communities to prioritize policies and coordinate with other local government agencies and private or non-profit partners to improve the health of the community. Many of the health-related policies identified in this section also promote economic, equity, and climate resiliency goals.

This chapter provides concepts integrated from promising practices that communities may voluntarily incorporate into their general plans and focuses on data analysis and policy development to further healthy planning. Fortunately, many opportunities are already aligned with existing planning practice and state legislation, such as requirements for incorporating complete streets, addressing climate change, and considering environmental justice. This chapter provides ideas for data analysis, policy development, and implementation. Information was gathered from multiple sources, including health organizations across the state, a review of existing published research literature, a survey of promising practices, and extensive stakeholder engagement. As with all of the voluntary sections, this chapter provides suggestions and resources for use by jurisdictions as they see fit. Some of the discussion on topics such as environmental health, nutrition and food systems, housing, and active living and recreation have been moved to Chapter 4 since SB 1000 was signed into law requiring these issues be addressed for disadvantaged communities.

CORRELATIONS BETWEEN ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Safety	Noise	EJ
Healthy Communitites	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	IN STATUTE

■ Identified in statute ■ Closely related to statutory requirements

Strategies and Approaches

Incorporating Health Considerations into General Plans

Local jurisdictions that have incorporated health considerations into their general plans have opted for one of three formats 1) a separate health element; 2) an integrated approach which has health woven throughout all elements; or 3) a hybrid approach that weaves health throughout the General Plan and uses a health element to frame the importance of health issues. The adoption of a health element is consistent with Government Code section 65303. There are benefits to having a separate health element because it can be easier for the public and decision-makers to see health-related policies in one place. At the same time, an integrated approach puts health-related policies into the elements that address those issues. For example, including active transportation policies in a circulation element may potentially make implementation more actionable, by incorporating them in to larger transportation plans. Additionally, some jurisdictions incorporate specific health considerations into the housing element. Since this element is often updated more frequently, it provides an opportunity for more regular evaluation of policy implementation and progress. Regardless of approach, health-related policies must meet internal consistency rule set forth in Government Code Section 65300.5. Ultimately, the best format will depend on the local context, available funding, and community interest, and should complement the overall general plan update and vision.

Jurisdictions will likely prioritize various health considerations differently depending on the local context. For instance, a rural community could prioritize trail connectivity while an urban area might focus on active transportation, while other communities

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may emphasize clean water access, food systems, or access to health care. Whether the general plan is being adopted by a city or county could also impact which health issues emerge as priority areas. Additionally, policies that work in a rural area might not be as relevant for an urban area and visa versa. The discussion below is not exhaustive, but rather a starting point for further deliberation as to some of the associations between health and planning.

Definitions

Health: A complete state of physical, mental, and social well-being, and not merely the absence of disease.

Health Equity: Means every person, regardless of who they are- the color of their skin, their level of education, their gender or sexual identity, whether or not they have a disability, the job that they have, or the neighborhood that they live in- has an equal opportunity to achieve optimal health.

Health Disparities: Refer to differences in health and mental health status among distinct segments of the population, including differences that occur by gender, age, race or ethnicity, sexual orientation, gender identity, education or income, disability or functional impairment, or geographic location, or the combination of any of these factors.

Sources listed in order:
http://www.who.int/about/mission/en/
HealthEquity: Braveman, PA, et al. (2011) Health Disparities and Health Equity: The issue is Justice. American Journal of Public Health, 101 (S1), S149-S155
Health Disparities: California Health and Safety Code (code sign) 131019.5

Health in All Policies

Health in All Policies (HiAP) is a collaborative, cross-sectoral approach that is being used by jurisdiction across California, the United States, and internationally to address the social and environmental factors that drive health outcomes and health inequities. This includes promoting walking and biking, access to healthy food, healthy housing, violence-free communities, and educational and economic opportunities for all.

There is no one "right" way to implement a HiAP approach, and there is substantial variation in process, structure, scope, and participation in the initiatives. Many HiAP initiatives facilitate health and equity input into general plans. California jurisdictions that use a Health in All Policies approach include:

- The City of Richmond's HiAP Strategy Ordinance
- Ventura County's HiAP Resolution
- Los Angeles Healthy Design Ordinanace and Workgroup
- Salinas HiAP Advisory Council

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- Monterey County HiAP Framework
- Healthy Riverside County Initiative
- Healthy Rancho Cucamonga

Resources:
Health in All Policies: A Guide for State and Local Government: http://www.phi.org/uploads/files/Health_in_All_Policies-A_Guide_for_State_and_Local_Governments.pdf

California Health in All Policies Task Force: http://sgc.ca/gov/Initiatives/Health-In-All-Policies.html

Innovative Partnerships and Collaboration

Planning relies on collaborating with different sectors to accomplish the vision set forth in the general plan. Addressing health in the built environment creates an opportunity to form new partnerships. Several organizations can provide unique health expertise and offer a health perspective during the planning process. Additional models of collaboration are referenced in each Chapter.

Both health and planning have distinct professional terminology. In local jurisdictions that have successfully integrated health considerations, cross-sector groups prioritized learning basic planning and health terms, which is important for professional collaboration as well as for community outreach. The long-term nature of the land use plans, e.g., 20 years or more, is new to many groups outside of the planning community. Particularly for large jurisdictions, general plan updates can be costly and are not undertaken frequently. Therefore, it is important to provide clear expectations in the initial phases of engagement, to clarify the timeline, and set expectations about the planning process. In addition, it may be beneficial for jurisdictions that decide to incorporate explicit health considerations into their general plan to start with a city or county resolution prior to the formal update. This may help raise awareness about the connections between the built environment and healthy planning to achieve improved health outcomes. The "Healthy Eating, Active Living Resolution" is an example of such a resolution. To date, 191 cities across California have enacted resolutions to support health and wellness policies.[li]

Sources of Support and Information for Health Considerations

- **Local County and City Departments of Public Health**: Public health experts have in-depth understanding of local health data as well as strong ties with community organizations.
- **Health related non-profits**: Many organizations are working to improve walkability, bikeability, accessibility for the disabled, and overall health in local communities.
- **Equity or Environmental Justice related non-profits**: Many organizations are working to improve conditions in communities unable to access basic resources like safe water, healthy foods, and clean air.
- **Community groups**: Neighborhood or community organizations, local parent groups, youth groups, faith-based organizations, or topically focused interest groups often work on community health issues.

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- **Academic institutions**: Academic researchers often analyze health data and provide expertise on data analysis, mapping, health impact analysis, and knowledge of local health conditions.
- **Hospitals and/ or clinics**: Health care reform has increased awareness on the social, environmental, and economic issues that affect health beyond clinic walls; non-profit hospitals conduct community health needs assessments (CHNAs) which are often made available online and provide funding for initiatives to improve health.
- **Local and Regional Governments**: Local agencies such as police, water, flood, utility, and air districts manage programs that impact healthy planning processes.
- **Local School Districts**: School districts partner with Safe Routes to School programs to ensure safe access to get to school; districts also participate in school siting of new facilities, have access to forecasted school growth and/or school closing data.
- **Private Sector Partners**: Local business associations, vendors, and local industries are increasingly designing work wellness programs that often have a transit component.

Innovating in Riverside - A Healthy Community Planner

In 2011, through a grant by The California Endowment (TCE), the Riverside County Department of Public Health became the first health department in California to hire a full-time urban/regional planner. This "Healthy Communities Planner" position is designed to provide leadership in bringing public health concerns into municipal planning. The planner is key to bridging the gap between public health and urban/regional planners to help ensure that health is considered as the cities and the county plan for the built environment, future development and population growth. The planner is helping to implement the County's Health Element of the General Plan, actively participates in TCE's Building Healthy Communities Initiative, and works with the county's 28 cities to adopt "Health City Resolutions."

Health Considerations

The health considerations listed in this section were gathered from multiple sources, including health organizations across the state, a review of existing literature and best and promising practices, and an extensive stakeholder engagement process. It is divided by general health consideration; example policies are listed below to address these topics as well as in the Appendix A.

SB 1000, "The Planning for Healthy Communities Act" requires cities and counties with disadvantaged communities to address certain health considerations within an Environmental Justice element or related goals, policies, and objectives.[lii] Since there is now a statutory requirement to address some of these health considerations including environmental health, food access, access to safe and sanitary homes, and access to physical activity, a full discussion is in Chapter 4 in the Environmental Justice Section.

Economics and Health

Increasingly, health is recognized as a vital component of human capital. Several measures of health and wellbeing are factored into the World Economic Forum Human Capital Report.[liii] Communities that have access to a wide array of resources have more

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opportunities to experience healthier outcomes and attain their fullest potential. Disinvestment in communities may have the opposite result, worsening health and safety outcomes. Land use planning can influence commute patterns and access to jobs, while development projects may create job opportunities. General plan policies can impact the presence of anchor institutions, such as universities, schools, medical facilities and/or clinics, and have a stabilizing effect on the local economy. Recently, the San Francisco Federal Reserve Bank launched a nation-wide Healthy Communities Cross-sector Initiative to facilitate discussion between community development partners and the health sector, seeking to improve investment in low-income communities and improve health at the community level. New models, with a more integrated approach, continue to emerge and focus on measureable and scalable results. Many of the models for economic development recognize the role of transit-oriented and infill development to leverage resources and increase access to services and amenities to support healthy lifestyles for local community members that work, live, and play in the surrounding areas.

Concurrently, land use patterns that promote healthier lifestyles can generate economic value. A synthesis of peer-reviewed literature showed that open space for recreation and walkable communities create positive economic impacts.[liv] Recognizing the power of healthy planning, the Urban Land Institute created a building healthy places initiative and recently published a series of case studies from developments around the world featuring wellness factors including support of bicycling, built amenities to support physical activity, and design to increase social interaction.[lv]

With changes in health policy, new incentives have emerged for workplace wellness programs, including opportunities to site businesses near multi-modal transportation in a manner that encourages walking, increases activity through design, and improves health in conjunction with workplace programs.[lvi]

A Changing Climate & Resiliency

The natural environment supports human life. Humans, in turn, impact the natural environment. The most prominent example is climate change caused by greenhouse gases (GHGs). Climate change can have devastating consequences on health due to physical or mental harm or displacement from increased frequency or severity of disasters like flooding, drought, fire, and landslides. Climate change may not only increase existing risks but will also pose new threats to human health. The California Department of Public Health provides recommendations and publications dealing with health and climate change. While climate change will be one of the biggest threats to public health for decades to come, land use planning can help communities prepare, adapt, and reduce GHGs that cause climate change. The safety element already requires consideration of natural hazard areas, to avoid or mitigate for potential hazards including fires, flood zones, earthquakes, and landslides. Explicit consideration of health issues provides an opportunity to improve resilience of local communities, especially vulnerable populations.

Some health effects of climate change are already occurring due to increasing temperature. Temperature records continue to be broken with increasing temperatures on record.[lvii] Temperatures in urban areas can exacerbate already warm conditions due to materials, such as asphalt absorbing heat and then releasing it, causing urban heat islands. Increased exposure to heat puts children, elderly, and people with pre-existing health conditions at more serious risk to suffer from heat stroke and heat-related complications. Studies show increased mortality during times of high heat.[lviii] In fact, according to the Center for Disease Control, between 1979 and 2003, more people prematurely died from extreme heat-related illness than the total combined deaths from other natural disasters including tornadoes, floods, earthquakes, hurricanes, and lightning.[lix]

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Land use planning to reduce urban heat island effects is essential to creating more resilient communities. Increased urban greening and cool surfaces, which have a high-albedo effect, reflecting higher portions of radiation and thus absorbing less, can decrease temperatures and lessen the effects of extreme heat. Green roofs can also have health benefits by reducing exposure to heat with the added benefit of better air quality. Healthy tree canopies can also provide shade from heat, help with carbon capture, and improve air quality.[lx] Land use planning can also help to ensure the availability of water resources for cooling purposes.

With climate change, there is a growing recognition of the need to preserve limited resources such as water, fertile ground for agriculture, energy, and clean air. All of these actions are vital for human health.

Street design that promotes walking and social interaction



Photo by Elizabeth Baca

Land use policies to promote efficient circulation, conservation, and recapture of water are needed for water conservation and drought mitigation. Additionally, it is important to control for pools of stagnant water. As water pools, without natural systems such as certain fish populations, there is an increased risk for mosquito reproduction. With higher mosquito populations, strong pesticides- that can affect health- are required to spray to contain mosquito populations. Scientists predict that vector borne diseases will change in the future as a result of climate change. More tropical diseases not previously experienced in California, such as dengue and yellow fever, may emerge. In 2013, the particular mosquito that carries dengue was found in California. Land use policies to conserve water and prevent large-scale stagnant pools will be key in combating and containing such health risks.

Climate change also has the potential to harm agricultural yields. Ensuring adequate food supplies to feed the population and avoid famines will require preservation of agricultural land. Land use policies that identify and avoid development on prime agricultural land are important to protect California's food supply.

Energy conservation programs have potential health co-benefits. When developments are planned to use less energy they can reduce energy bills and allow families to use the savings towards other expenses. Additionally, energy efficiency measures may align with opportunities to improve indoor air quality, which can reduce costs of respiratory illness such as asthma.[lxi]

Policies that continue to improve air quality--such as creating more public transportation options, zero emission vehicles, and bike and walk options for commuting-- are all important to maintain air quality and promote public health for all segments of the community and particularly the most vulnerable.

Social Connection & Safety

The physical environment can have a significant impact on health and wellbeing, but the social structures and how community members engage within the physical space can be equally important. Feeling connected to neighbors, feeling safe in one's home, and having a robust supportive social network affects physical and mental health.[lxii] A neighborhood can be well designed and offer amenities, but if the local residents perceive the area to be unsafe, or there is a great amount of community violence or trauma, it will not be utilized to its full capacity. Design principles can be implemented with this in mind. Crime prevention through environmental

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design (CPTED) examines environmental conditions that have unintended consequences on behavior. This field of research combines evaluations of place and human interaction. CPTED uses design elements to control access, provide more opportunities for passive observation of what is occurring in the area, and encourage civic engagement to maintain properties. An important aspect of implementing CPTED includes a wide, multi-sector-planning approach including law enforcement, for example- community engagement process to define the problems, opportunities, and solutions. Form Based Codes are another planning tool that focuses on design at a scale that incorporates more granular level changes, such as building facades and street level design. This also has potential to design elements to foster more social cohesion. Civic participation and social cohesion can be supported through the design of community spaces that provide engagement, access to learning opportunities, quality interaction of residents, multi-generational connections, public services such as libraries, and cultural and art facilities. Joint use agreements, also known as shared use agreements, with schools allow for another opportunity to collaborate with school districts, maximize resource utilization, and foster more activated spaces that otherwise would be empty during non-work hours.

A safe community with active streets includes protection from criminal activity, as well as from avoidable collisions. Many design elements such as narrower streets; appropriate lighting, improved signage, and slower speed limits can help reduce collisions. Traffic calming measures, complete streets, and improvement of physical infrastructure are important components of injury prevention. In fact, jurisdictions across the US and beyond have adopted Vision Zero efforts to aim for zero collision-related deaths through street design, engineering, and addressing driver related issues. As referenced in the circulation element, the California Complete Streets Act of 2008 (AB 1358) requires local jurisdictions, upon any substantial revision of the circulation element, to plan for a "balanced, multimodal transportation network that meets the needs of all users of streets, roads, and highways for safe and convenient travel in a manner that is suitable to the rural, suburban, or urban context of the general plan."[lxiii] The circulation element provides an excellent opportunity to incorporate design for safety and multimodal use. The National Association of City Transportation Officials (NACTO) Street Design guidelines, formally endorsed by Caltrans in 2014, offer examples and a blueprint to guide complete street policy implementation, particularly around priority sites such as schools and daycare centers.[lxiv]

Health & Human Services

Hospitals and clinics are increasingly recognizing that where patients live, learn, work, go to school, and play affects their health and wellbeing. Through new paradigms and innovation, they are considering what community services are necessary to support health for individuals in their community. Non-profit hospitals conduct community health needs assessments as part of their community tax requirements and can reinvest into the community based on the assessment. Additionally, these reports prioritize key health needs for the catchment area and can provide useful information during the planning process. Increased access to health care, opportunities for physical activity, and healthy foods are key priorities that may be addressed in the general plan to improve community health. In addition, general plan policies may improve access to health services through integrated public transportation and provisions for access to broadband, allowing for telemedicine capacity.

General plan policies authorizing or promoting supportive housing can facilitate the integration of healthcare services into multifamily housing developments, especially for the elderly and disabled. A number of housing developments in major metropolitan areas include health clinics, and community spaces, and tenant services for special needs populations. Supportive services have multiple benefits, for both tenants and property management. Integrated service delivery plays a critical role with populations

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at risk of homelessness or institutionalization. Healthcare providers have started to bring farmer's markets and gardens on clinic and hospital premises to facilitate access to healthy food for their staff and patients.

Clinic locations, particularly federally qualified health centers, serve as important meeting points and service centers in case of a disaster. Having established systems in place to ensure access to routine services allow for a more robust and resilient system during times of emergency.

Health Data and Mapping

Data, Mapping, and Tools

Defining existing conditions is part of the general plan update. Incorporating health data creates an opportunity to conduct a more comprehensive existing condition analysis, while also providing baseline data to track progress, particularly for the social, economic, and environmental factors that can impact health. The housing element section includes analysis of community characteristics related to population characteristics, economic conditions and well-being, housing needs, and special populations. These issues all have health implications. As more and more local jurisdictions have started to incorporate explicit health considerations, geospatial data can be used to analyze health outcomes at a geographic level and to inform how health considerations might be incorporated or targeted. Additional tools such as walk audits, charrettes, community-based visual cataloging, and new crowd sourcing platforms can be an effective means of getting communities involved for more local and qualitative data. There are also resources to help find and utilize data for planning purposes, such as "Neighborhoods by Numbers : An Introduction to Finding and Using Small Area Data".[lxix]

Healthy communities provide safe, accessible spaces for all residents.

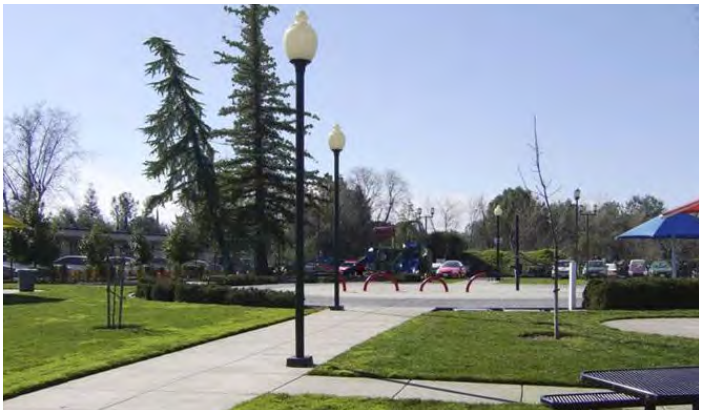





Image by Urban Advantage, SACOG

Data is informing policy in innovative ways. Just as a physician would look at vital signs of a patient, cities and counties have started to look at vital signs or community dashboards that are reflective of the population's health, social, economic, and environmental conditions. An important step in the process of incorporating equity considerations is to assess baseline conditions and acknowledge existing disparities. This type of analytic measurement can be particularly informative when examining areas that are disproportionately burdened by poor health outcomes to help target needed resources towards

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more vulnerable populations. It can also provide a baseline for analytic discussion on location of services, where to prioritize new or update current infrastructure, and provide a means for tracking outcomes of development and infrastructure investments over time. A more in-depth discussion on supporting and engaging vulnerable populations is located in Chapter 4 and Chapter 5.

Additional Health-Related Data Resources

Many health, social, environmental, and economic indicators are available at the census tract level. Health departments also have access to local geospatial data on health outcomes and health determinants, occasionally at a more granular scale. Some health departments may already have reports prepared for their accreditation process that can be applicable to creating a baseline analysis for planning. It is helpful to consider variation within the data and to identify and address differences in health outcomes and the underlying reasons. Data needs and analysis will vary based on population characteristics and whether the area is rural or urban. Local outreach and experts involved in the update are able to help determine what data to prioritize in the analysis. Some additional health data resources include:

- **Community Health Needs Assessment**: This free web-based platform was created to assist community hospitals doing their needs assessment and provides census level data for health, economic, social, environmental, and behavioral data.
- **California Environmental Health Tracking Program**: This program is hosted by the CDPH. The data is more focused on environmental health impacts such as air quality, health, climate change related outcomes, water quality, and cancer prevalence.
- **Envirostor**: the Department of Toxic Substances Control hosts this program. It is a database that provides data in a GIS form to identify contaminated sites as well as facilities that deal with hazardous waste. This resource is important for remediation and siting.
- **CalEnviroscreen**: The Office of Environmental Health Hazard Assessment (OEHHA) in the California Environmental Protection Agency created this online mapping tool. It is a tool that can help identify communities that are burdened with high levels of pollution and/or are highly vulnerable to its effects. The tool also contains socioeconomic data.
- **Healthy Communities Data and Indicators Project (HCI)**: the California Department of Public Health (CDPH) hosts HCI. This indicator list provides evidence for links to health outcomes, data sources, and offers the ability to create maps.
- **California Health Interview Survey (CHIS)**: The largest state health survey in the nation, CHIS is a random phone interview administered by the UCLA Center for Health Policy in conjunction with the State Department of Public Health and the Department of Health Care Services. CHIS recently added new functions, available at the neighborhood level in certain jurisdictions, on health behaviors and conditions of relevance to planning for healthy communities.
- **Transportation Injury Mapping System (TIMS)**: TIMS was created and is maintained by University of California, Berkeley. It hosts data on injury and collision data.
- **Travel Surveys**: Both the California Household Travel Survey and the National Household Travel Survey contain important information on travel-related behavior.

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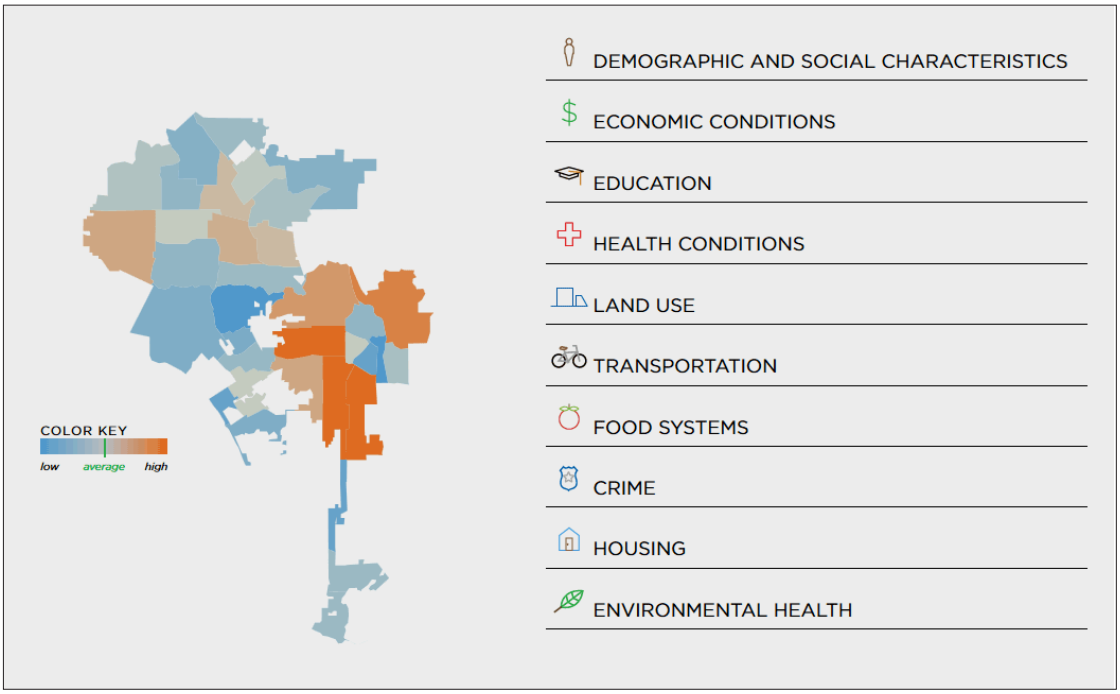
- **California Protected Areas Data Portal**: This data base provides a detailed GIS inventory of all parks and open space owned by agencies and nonprofits in California and serves as a resource to assess access and proximity.
- **Cal Brace Data**: The California Department of Public Health provides climate change and health profile data for counties. Data ranges from covering issues such as food insecurity to vector born illnesses and heat impacts.
- **The California Health Disadvantage Index**: This statewide tool is supported by the Public Health Alliance of Southern California and includes data. The data includes many social, economic, and environmental factors that impact health.

The City of Los Angeles created an interactive geospatial map of built environment and health conditions to inform the update of their general plan. A report was produced to inform community outreach, meetings, and policy formation.



Source: http:/healthyplan.la/the-health-profiles/

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Sample of OPR Recommended Data for Consideration in Analysis of this Element

The health data resources listed above have some of the recommended data below. Other more granular data might be available through the local department of public health, the local air district, the metropolitan planning organization, water district, or business association.

Intent of Analysis	Recommended Data
Life expectancy can be a good proxy for general health and well-being in the community. Many low-income areas suffer from early mortality and morbidity.	Life Expectancy at Birth
Asthma can be worsened by environmental triggers such as poor air quality, poor housing quality, and climate change, examining baseline conditions can help inform siting decisions.	Asthma (Prevalence, ED visits, hospitalizations)
Obesity is caused by many factors, but lack of access to healthy foods and physical activity are significant contributors. Examining baseline status can help with policy decisions around active transportation, recreation priorities, and food system policies.	Obesity (child and adult) prevalence
These diseases, also caused by many factors, are often associated with obesity. Examining baseline status can help with policy decisions around active transportation, recreation priorities, and food system policies.	Secondary diseases from obesity (high blood pressure, high cholesterol, heart disease, type 2 diabetes prevalence)
Many vehicle crashes involving pedestrians and bicycles could be improved through infrastructure, design, and signage. Examining a baseline can inform policy and planning for transit routes, active transportation, and safety.	Unintentional pedestrian and bicycle injury
Walk trips is a behavior that benefits health and is influenced by the environment. Examining a baseline number can help inform active transportation and for climate change and resiliency policy.	Walk trips per capita
Children walking, biking, or rolling to school is a behavior that can improve health and is influenced by the environmental conditions such as distance to school and safety. Examining the baseline condition can inform policy priorities around active transportation, active design, school siting, and housing siting.	Percent of children who walk, bike, roll to school
Commuting decisions are influenced by connectivity, cost and ease of use. Active transportation can have positive health benefits since people are able to achieve higher physical activity. Examining the baseline can inform policy priorities around active transportation, mixed use developments, job locations, and housing locations.	Percent of commuters who use active transportation
Eating more fruits and vegetables is a behavior that can be supported through more access to healthy, affordable options. Examining a baseline condition can inform policy around food systems and location of services.	Consumption of daily fruits and vegetables
Having access to adequate, affordable, and healthy food is important to health. Examining a baseline condition of those suffering from food insecurity can inform policy around food systems and location of services	Self-reported food insecurity
Understanding the poverty conditions can help focus resources and policy development to areas that need additional support. This is important for various issues such as ability to afford healthy food.	Poverty data for population below 200% of the Federal Poverty Level
Income is an important predictor of health outcomes. Access to job opportunities as well as job/housing/work force fit can inform transit lines, housing location, and where jobs are incentivized to locate.	Employment Density (example: Trade Transportation, utility, leisure, hospitality, goods producing, government, education, real estate, finance, health services)
Mapping baseline food retail and access conditions can identify areas that might not have adequate access and inform policy priorities and decisions for siting.	Food retail, community garden, and farmer market location
Creating an inventory of available vacant public and private lands can help identify lands for conversion into community gardens, urban farming, or small parks.	Number of unused or under-utilized property per tax assessor records
This can help identify vulnerable populations, in conjunction with the poverty data above.	Uninsured population data

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Intent of Analysis	Recommended Data
Mapping baseline walk and bike conditions can help create a more connected network for improved use.	Walk and bike maps
Mapping baseline transit conditions can help identify areas that could benefit from improved transportation options	Public transit facilities
Safety in the neighborhood can impact social stress and influence whether people will be active. Establishing a baseline condition can help inform safety policies such as crime prevention through environmental design	Percent of people that feel safe in their neighborhoods
Neighborhood parks contribute important health and community well being benefits, when they are located nearby. Examining the proximity of people to parks can identify areas for future park investment, especially where there is no park within walking distance, or within 1/2 mile.	Inventory of parks and protected open space
This can be assessed to track and analyze risk of displacement	Housing cost burden
Air quality has direct effects on people with respiratory disease. Mapping baseline conditions can help inform policies around transportation, connectivity, siting, and industry.	Air quality (ozone, pm 2.5)
Extreme heat days and heat island effects can cause illness and even death in extreme circumstances. Monitoring heat days and areas with worse heat effects can help inform policies around transit, greening, materials, and programs to mitigate its effects.	Extreme heat days, heat islands effects
Urban tree can have multiple benefits for air quality, shade for easier time spent outdoors for commuting and recreation, and even new research on the benefits of mental health and mood. Establishing a baseline can help inform policy for transit, roadway, recreation, and bike and pedestrian planning.	Urban tree canopy
Health facilities provide daily services and often serve the community in disaster. Establishing a baseline of where services are located can help improve transit decisions, siting, and emergency preparedness planning.	Location of health facilities
Mapping where schools and child facilities are can provide an important baseline. This can inform policies to leverage joint use agreements, ensure they are accessible and free from newly sited environmental hazards.	Location of schools, child care facilities
How much people drive is a proxy to understand how active community members are. New research suggests that the amount of time spent in a vehicle may have potential effects on mental and physical health.	Vehicle Miles Traveled (VMT)
How much the local community is civically engaged can be a measure of how activated the community is	Voting rates

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OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Policy	Example	Relation to other elements
[City, County] shall promote uses that address daily needs within the [city, county] City and close to neighborhoods, reducing the need for residents to travel long distances to access jobs, goods and services.	City of Arvin	Circulation, land use, housing, economic development, equitable and resilient communities, climate change
[City, County] shall encourage development that reduces VMT, decreases distances between jobs and housing, reduces traffic impacts, and improves housing affordability.	County of Sonoma	Economic development, equitable and resilient communities
[City, County] shall plan for the public health implications of climate change, including disease and temperature effects.	County of Marin	Climate change, EJ, equitable and resilient communities, land use
[City, County] shall encourage the development of complete neighborhoods that provide for the basic needs of daily life and for the health, safety, and mental well-being of residents.	County of Riverside	Circulation, land use, equitable and resilient communities
[City, County] shall implement policies and programs that encourage bicycling and walking as alternatives to driving and as a means of increasing levels of physical activity. Encourage bicycle and pedestrian safety through education and incentive programs.	City of El Monte	Circulation, land use, housing, economic development, climate change, EJ, equitable and resilient communities
[City, County] shall invest in community planning efforts that aim to reverse trends of community deterioration and blight which lead toward the decline of personal and property safety within the [city, county] community districts.	County of Kings	Economic development, equitable and resilient communities, land use
The attraction and retention of high quality grocery stores and other healthy food purveyors should be pursued as an economic development strategy for the [city, county]. Healthy food outlets include full-service grocery stores, regularly-held farmer's markets, fruit and vegetable markets, and convenience stores or corner stores that sell a significant proportion of healthy food.	The City of South Gate	Economic development, EJ, equitable and resilient communities, land use

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7

Economic Development and the General Plan

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

"World class communities come in all shapes and sizes, they are not determined by geography, and/or natural resources so much as by the mindset of their local leadership."

—Don Allen Holbrook, The Little Black Book of Economic Development

Introduction

The resilience of an economy both shapes and is shaped by its physical development. It strongly influences how a jurisdiction governs. Cities and counties may include a distinct economic development element, or highlight economic development as a primary theme or goal throughout their general plan. Most communities set forth goals of economic health and sustainable funding for public services for current and future residents, as part of support for a thriving business environment, job growth and retention, and, as appropriate, community revitalization.

CORRELATIONS BETWEEN ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Safety	Noise	EJ
Economic Development	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	-	RELATED

■ Identified in statute ■ Closely related to statutory requirements

Decisions regarding land use and circulation can promote businesses and increase property values.[lxv] Planning effective transportation access to centers of employment, education, and services can help a city or county build and maintain a strong economy. Ensuring an appropriate jobs-housing balance provides residents with nearby employment choices. And fostering public health will have a direct effect on improvements in labor productivity and increased personal income.[lxvi]

Businesses and Employment

Cities and counties can use general plan policies to promote business development and retention, job training and workforce

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development, partnerships with educational institutions and private and non-profit organizations, incentives for targeted business investments, and marketing and communications programs. Economic development policies should be based on goals identified through community engagement, which should include targeted outreach to the business community. Involving potential employees, developers, and business leaders early in the planning process will help ensure policies grounded in the community vision.

Economic development is strongly related to the circulation element; particularly through the movement of goods, services, and people. Resident and visitor access to employment centers and commercial centers is critical. Assessing and addressing the needs for current and future accessibility through multiple modes, including transit, pedestrians, and bicycles will provide employees and customers access to new and existing businesses and help support economic growth and vitality. Proximity to transit options increases property value as well as economic activity. Promoting connected systems of walkways, bikeways, and transit lines leading to economic centers provides easy, affordable access to retail, employment, and services. Including additional infrastructure around retail centers, such as bikeshare stations, pedestrian rest areas, and covered transit stops, may help economic stimulation.

Economic Development and Displacement

As cities and counties grow and prosper, consideration must be given to ensuring equitable development and minimizing displacement. While figures vary by geography and demographics, overall, low and middle income housing availability in California is shrinking. For every 100 extremely low income (ELI) renter households, there are just 34 affordable and available units.[lxvii]

Revitalizing communities, building strong economies, embracing sustainable, coordinated development, and improving infrastructure are all positive policies with a wide range of benefits for communities. An efficient economy relies on housing options that are affordable to a range of workers and accessible to jobs. HCD has created recommendations to combat displacement

Revenue Share Agreements

At times, when potential development straddles geographic boundaries between jurisdictions, projects can be delayed or terminated due to conflict over revenue. Shared sales tax agreements, such as the one between the cities of Oakland and Emeryville, can ensure each city or county receives a share of the benefits of economic growth.

Waterford, Wisconsin. Main Street





Image by Urban Advantage, Lakes Area Realtors

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in planning and implementation in their Statewide Housing Assessment. Additionally, numerous organizations and academics are working to identify potential tools for planners, advocates, and local governments. Some of these tools include:

- Community benefits funds
- Value Capture
- Inclusionary zone

Healthy Communities and the Economy

Public health outcomes correlate directly to economic vitality. Increased investment in communities can lead to improved public health outcomes, through greater opportunities for active transportation and outdoor activity, increased access to nutritious food, and improved economic opportunities. Planning for employment and business centers that are accessible through transit and active transportation can be especially beneficial to public health outcomes, and improve equity in communities.

Ensuring all residents of a city or county are included in economic development planning - through distribution of infrastructure, retail, employment, transit and active transportation networks, housing, and other considerations - can ensure improved health outcomes for the full community.

Economic Development and Climate Change

The impacts of climate change present an increasing threat to local economies throughout California. Planning for climate resiliency and adaptation can help support and maintain a strong local economy. By incorporating climate impacts into long term planning, cities and counties can help local businesses, and their economy, recover more rapidly from climate events, increasing community resiliency. Additionally, promoting adaptation and resilience creates more secure fiscal environments for investment, promoting development and job growth.

Cities and counties can explore the Cal-Adapt tool to examine potential climate impacts in their community. By implementing policies to promote adaptation and resiliency, local communities can help reduce the likelihood of economic disruption from natural disasters and extreme weather events. Planning and policies for climate change can also improve economic recovery after climate events, increasing business resiliency and fiscal stability.

Community Assets and Fiscal Stability

Community assets such as schools, parks, open space, universities, and cultural amenities, as well as infrastructure such as sidewalks, transit systems, and utilities, help create cities and counties that attract residents and businesses. The creation, maintenance, and promotion of

Revenue Share Agreements

At times, when potential development straddles geographic boundaries between jurisdictions, projects can be delayed or terminated due to conflict over revenue.

The neighboring cities of Oakland and Emeryville recognized this issue warly on, and developed a revenue share agreement in 1994 to address it. In 2011, when a large Target opened on the border of both cities, the existing agreement helped them share the additional $550,000 in sales tax revenue.

Shared sales tax agreements, such as the one between the cities of Oakland and Emeryville, can ensure each city or county receives a share of the benefits of economic growth.

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assets and infrastructure should be addressed throughout the general plan. Infrastructure and community assets must align with economic development goals, as they attract, retain, and support the workforce and commercial base that new and existing businesses require.

Ultimately, businesses will invest in and support communities that offer a strong workforce, a stable fiscal climate, and policies to support their growth. General plans create an opportunity for cities and counties to implement policies that can spur economic development, revenue generation, and shared benefits for all community members. Additionally, equity should be considered in all economic development decisions, to ensure all community members benefit from policies and investments.

Engagement with the Business Community

A strong general plan will benefit from outreach and input from all community members. It is important to engage business community members in any economic development plan, as their input and support is vital to its success. Direct outreach, including visiting existing businesses, surveys, and small, targeted meetings, will help ensure engagement with the business community. Additionally, working with business organizations such as chambers of commerce, Business Improvement Districts, and Economic Development Corporations; partnering with service clubs such as Rotary or Kiwanis; and connecting with colleges and universities and Workforce Investment Boards will create a robust pool of information from community members invested in economic development. Such outreach could even lead to public private partnerships, shared benefit programs, or increased investment in the community.

SAMPLE OF OPR-RECOMMENDED DATA FOR CONSIDERATION IN ANALYSIS OF THIS ELEMENT

Intent of Analysis	Recommended Data
Inventory of current business establishments	Local lists, local chambers of commerce, or commercial sources such as InfoUSA.
Inventory of current jobs by industry and business	See above
Estimated wages by industry and occupation	Bureau of Labor Statistics Metropolitan Area Occupational Employment and Wage Estimates
Cost of living data	City-data.com and other sources
Population Characteristics	U.S. Census and City-data.com
Workforce Characteristics	U.S. Census and City-data.com

OPR Recommended Policies

These policies are an example of recommended policies adopted by varying jurisdictions, to be modified and used as appropriate. A full list of recommended policies can be found here.

Policy	Example	Relation to other elements
Encourage a balance between job type, the workforce, and housing development to reduce the negative impacts of long commutes and provide a range of employment opportunities for all (city/county) residents.	Sacramento	Circulation, healthy communities, equitable and resilient communities, economic development, climate change
[City, county] shall require the provision of bicycle parking and related facilities in new employment-generating development to facilitate multi-modal commute choices.	San Pablo	Land use, circulation, healthy communities, equitable and resilient communities, climate change
[City, county] shall establish a list of "ready-to-go" or "shovel-ready" sites in consultation with property owners, and provide the list to interested developers and businesses seeking sites in the city.	Fresno	Land use, circulation

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Climate Change

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

"California, as it does in many areas, must show the way. We must demonstrate that reducing carbon is compatible with an abundant economy and human well-being. So far, we have been able to do that."

—Governor Jerry Brown

Introduction

The impacts of climate change pose an immediate and growing threat to California's economy, environment, and to public health. Cities and counties will continue to experience effects of climate change in various ways, including increased likelihood of droughts, flooding, wildfires, heat waves and severe weather. California communities need to respond to climate change both through policies that promote adaptation and resilience and by significantly reducing greenhouse gas (GHG) emissions. For requirements related to climate adaptation please see the Safety Element.

While climate change is global, the effects and responses occur substantially at the local level, and impacts and policies will affect the ways cities and counties function in almost every aspect. Cities and counties have the authority to reduce (GHG) emissions, particularly those associated with land use and development, and to incorporate resilience and adaptation strategies into planning. For example, the interplay of general plans and CEQA requirements is particularly critical in evaluation of GHG emissions and mitigation. For this reason, specific guidance is provided on how to create a plan to reduce GHG emissions that meets the goals of both CEQA and general plans. To this end, this chapter summarizes how a general plan or climate action plan can be consistent with CEQA Guidelines section 15183.5 (b), entitled Plans for the Reduction of Greenhouse Gas Emissions. This chapter can also be used to update older plans so they comply with the criteria in Section 15183.5 (b) and associated CEQA streamlining opportunities.

This guidance, however detailed, should not be considered the only approach to addressing GHG emissions at the local level. Local governments have substantial discretion in choice of methodology and may identify appropriate methods to address this important issue. This chapter also provides recommended approaches to consistency with other documents that may be related to the general plan such as climate action plans (CAPs), climate adaptation plans, and plans to reduce GHG emissions. Other chapters have more specific guidance for addressing climate change in the context of that element/chapter.

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Throughout this chapter, greenhouse gas emissions is referred to as "GHG emissions" and taking measures to address the impacts of climate change is referred to "adaptation." For more in depth definitions of GHG emissions and resilience refer respectively to the California Air Resources Board Climate Change Scoping Plan and the California Natural Resources Agency Safeguarding California Plan. For requirements related to climate adaptation please see the Safety Element.

CORRELATIONS BETWEEN ELEMENTS

	Land Use	Circulation	Housing	Conservation	Open Space	Safety	Noise	EJ
Climate Change	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED	RELATED

■ Identified in statute ■ Closely related to statutory requirements

Reducing Greenhouse Gas Emissions

Local governments play a critical role in reducing GHG emissions. In California, local governments regulate many activities that contribute to GHG emissions and air pollutants, including industrial permitting, land use and transportation planning, zoning and urban growth decisions, implementation of building codes and other standards, and control of municipal operations.

Since the Legislature expressly recognized climate change as a consideration in CEQA in 2007, local governments have typically addressed climate change either in policies in the general plan itself, or through adoption of a CAP. Doing so, among other things, allows for consistency with GHG discussions and related mitigation measures in the General Plan EIR and mitigation monitoring and reporting program.

The CEQA Guidelines recognize the important role of Climate Action Plans in the CEQA process (CEQA Guidelines § 15183.5, Tiering and Streamlining the Analysis of Greenhouse Gas Emissions). The Guidelines set forth a basic framework for developing a plan to reduce GHG emissions and acknowledges the role CEQA plays in ensuring the impacts of climate change are addressed (CEQA Guidelines § 15183.5(b), Plans for the Reduction of Greenhouse Gas Emissions).

The SEEC ClearPath California tool, supported by the state and available without charge, provides a "five milestone" process for GHG inventory, planning, implementation, and monitoring. While ClearPath is not the only approach, it includes support from state agencies and can be used as a starting point for local governments addressing GHG emissions. The Governor's Office of Planning and Research (OPR) and the California Air Resources Board (ARB) serve on the advisory committee for management of the ClearPath California tool to ensure its ongoing improvement and consistency with California climate policy. ClearPath and most proprietary tools also correspond to the Community Protocol for Addressing Community Scale Emissions and the Local Government Operations Protocol, which also have state support.

Plans to Reduce Greenhouse Gas Emissions

The GHG emissions reduction plan can be either a stand-alone CAP or directly part of the general plan. The CEQA Guidelines recognize either approach. Regardless of approach, local governments should inventory and mitigate GHG emissions "within a defined geographical area"—typically the city or unincorporated county over which they have land use authority.

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Additionally, regardless of approach, it is preferable to create the plan to reduce GHG emissions concurrently with or closely following a general plan update. There are a number of benefits of aligning a GHG reduction strategy, such as a CAP, with a general plan update including:

1. Allowing local governments to include a wider range of mitigation measures in the GHG reduction strategy, especially those that are related to land use and transportation;
2. Allowing projects to take advantage of a wider range of CEQA streamlining measures;
3. Streamlining environmental review for the GHG reduction strategy itself; and
4. Ensuring that the CAP and general plan use a consistent set of baseline conditions and growth assumptions, which can save effort for planners.

SEEC ClearPath California "Five Milestone" Process for Addressing Community GHG Emissions



Source: www.californiaseec.org

The Role of CEQA Guidelines in Supporting GHG Emissions Reductions in General Plans

The CEQA Guidelines acknowledge the role of long-range plans, such as general plans, in addressing cumulative impacts (CEQA Guidelines § 15183.5(a)-(b)). This approach applies to greenhouse gas emissions (GHGs). Because GHGs can be evaluated in different types of plans, such as general plans, facilities plans, and CAPs, CEQA Guidelines section 15183.5(b) sets forth minimum criteria that a plan should satisfy to allow streamlining a cumulative impacts analysis under CEQA. For additional background, see pages 90 and 91 in the Natural Resources Agency's Final Statement of Reasons. For Regulatory Action: Amendments to the State CEQA Guidelines Addressing Analysis and Mitigation of Greenhouse Gas Emissions pursuant to SB97 (Dec. 2009).

Under CEQA, lead agencies should analyze the GHG emissions of proposed projects, and should reach a conclusion regarding the significance of those emissions (CEQA Guidelines § 15064.4, Determining the Significance of Impacts from Greenhouse Gas Emissions).

Lead agencies should also undertake an analysis of a proposed project's potential energy use (including transportation-related energy), sources of energy supply, and ways to reduce energy demand, including through the use of efficient transportation alternatives (Pub. Resources Code § 21100(b)(3); CEQA Guidelines, Appendix F). As with other environmental impacts, when a project's GHG emissions may be significant, lead agencies should consider a range of potential mitigation measures to reduce those emissions. (CEQA Guidelines § 15126.4(c)). Lead agencies should analyze potentially significant direct, indirect, and cumulative environmental impacts that a project may cause by placing projects in hazardous locations, including locations potentially affected by hazards that result from climate change. Agencies should also analyze impacts to the project where the project risks exacerbating those hazards. (California Building Industry Association v. Bay Area Air Quality Management District (2015) 62 Cal. 4th 369; CEQA Guidelines § 15126.2(a)).

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As explained below, lead agencies may significantly streamline the analysis of GHG on a project level by using a programmatic greenhouse GHG emissions reduction plan meeting certain criteria (CEQA Guidelines § 15183.5(b)). As a result, the CAP and EIR, or general plan and EIR, with a robust discussion of climate impacts and mitigation, can be used to streamline project-level evaluation of climate impacts under CEQA.

CEQA Streamlining

CEQA requires analysis of a project's GHG emissions, a determination of whether those emissions are significant, and if so, mitigation of those emissions. On a project-by-project basis, such analysis can be complicated and costly. CEQA provides several ways for a project-level evaluation to rely on programmatic environmental review of climate impacts, including "tiering" (see CEQA Guidelines § 15385, tiering), use of master EIRs, and incorporation by reference (CEQA Guidelines § 15183.5(a)). While there are specific rules for using such tools, this chapter uses the term "streamlining" as a blanket term for relying on a certified plan-level environmental document, such as a general plan EIR, in analyzing the impacts of a specific project. Streamlining is a way for lead agencies to reduce project-level environmental review by ensuring robust evaluation at the programmatic level. Projects that are consistent with the CAP, for example, may be found to cause a less than significant impact under CEQA. (CEQA Guidelines § 15064(h)(3)).

1. Cumulative Impacts (Section 15064(h)(3))

CEQA Guidelines Section 15064(h)(3) provides that "[a] lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project will comply with the requirements in a previously approved plan or mitigation program," that meets certain criteria. However, providing substantial evidence showing how the cumulative effect (in this case of GHG emissions) is addressed is essential to a well-functioning plan or mitigation program that is addressing climate change. A general plan or CAP can lay the foundation for this substantial evidence.

2. Developing a General Plan or Climate Action Plan for CEQA Streamlining related to GHG Emissions (CEQA Guidelines § 15183.5(b))

When a project is consistent with a general plan or CAP that satisfies the criteria in subdivision (b) of Section 15183.5, a lead agency may also presume that the project's GHG emissions are less than significant. Section 15183.5(b) does not require public agencies develop plans for the reduction of GHG emissions, nor does it prohibit public agencies from developing individual ordinances and regulations to address individual sources of GHG emissions. However, a plan satisfying the criteria in that section can be used to streamline the CEQA analysis of future projects and can make it easier to manage both implementation and consistency discussions as required in general plans and general plan EIRs.

As technology improves to support the development of spatial accounting for GHG reduction strategies, CAPs should also be modified to reflect this more integrated approach. Tools such as Urban Footprint, General Plan Mapping Tool and the California GeoPortal can help support decision making by local officials through a data rich, geospatially-referenced environment while also retaining the substantial evidence to support a CEQA analysis.

CEQA Guidelines Section 15183.5, *Tiering and Streamlining the Analysis of Greenhouse Gas Emissions* outlines six "Plan Elements" that should be included in a plan to reduce GHG emissions. This general plan guidelines chapter provides additional guidance on how to implement this section in a general plan, or a CAP that is incorporated by reference into a general plan.

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Further Guidance on the Six "Plan Elements" and Other Considerations

STEP 1: Section 15183.5(b)(1)(A) Inventory *("Quantify greenhouse gas emissions, both existing and projected over a specified time period, resulting from activities within a defined geographic area")*

An essential component of a community scale CAP is the GHG emissions inventory. The Local Government Operations Protocol provides an approach for GHG inventories for municipal operations. The United States Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions provides an approach for community scale GHG emissions inventories in California and nationwide. OPR recommends use of these protocols in local government planning efforts. The Community Protocol does a good job of providing standards for quantifying emissions from different sources; however, individual jurisdictions may choose to do more detailed or different types of analysis depending on community needs.

Consumption-Based Greenhouse Gas Emissions Inventories

Consumption-based emissions inventories (CBEI's) combines emissions from transportation and heating fuels used by households with emissions embodied in the life cycle of energy, food, goods and services they consume, regardless of where those emissions were produced in global supply chains. In contrast, production-based inventories traditionally used in CEQA and general plan discussions count emissions where they physically enter the atmosphere.

The CBEI for cities and counties in California is calculated by U.C Berkeley's CoolClimate Network and CoolCalifornia. Online carbon footprint calculators, maps and downloadable datasets are designed to inform households on their GHG emissions and actions that can be taken to reduce consumer drive GHG emissions.

OPR continues to work with the Statewide Energy Efficiency Collaborative (SEEC), ICLEI, Local Governments for Sustainability, the California Air Resources Board and the Association of Environmental Professionals to ensure the Protocol responds to the needs of California and is effectively integrated into tools, both currently available and under development, for local government use in calculating community scale greenhouse gas emissions. OPR recommends the use of the SEEC tools and templates for development of a general plan or CAP. However, there may be locally appropriate reasons to use other tools and resources such as when additional granularity is desired in specific sectors or when add-on tools achieve better results than the settings in ClearPath. For additional information on available tools and additional resources to complete GHG analysis, please refer to the Cool California website.

STEP 2: Section 15183.5(b)(1)(B) Reduction Target *("Establish a level, based on substantial evidence, below which the contribution to greenhouse gas emissions from activities covered by the plan would not be cumulatively considerable")*

A summary report published by the State Energy Efficiency Collaborative, "State of Local Climate Action: California 2016", found that almost all jurisdictions with a greenhouse gas emissions reduction target include 2020. Many jurisdictions also include a general plan buildout year target. Some are, and increasingly so, including goals for 2050. With a few exceptions, local targets are typically consistent with long-term targets the State has established for 2020 and 2050. Some jurisdictions are preparing updates to include 2030 targets. Nearly all jurisdictions include a "mass emissions" calculation. Some also include "per capita" and "service population" estimates where those metrics may be useful for additional context. Examples are also included in the SEEC document and case studies are available through the Integrated Climate

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Adaptation and Resiliency Program (ICARP) Clearinghouse. Analyzing mass emissions at the community, state, per capita emissions, and service population emeissions may be appropriate to support a full understanding of community emissions.

Reducing GHG emissions on a trajectory consistent with long term State emissions reduction targets, as outlined in Executive Orders S-03-05 and B-30-15, and supported by the International Panel on Climate Change (IPCC), can demonstrate that a plan's emissions will be less than significant for CEQA purposes. Additional recommendations from the California Air Resources Board Scoping Plan for local action should also be considered.

Communities may also consider selecting multiple target years. Selecting a single reduction target year does not typically allow an agency to accurately assess the trajectory of the plan over time. Given the long-term nature of the effects of climate change, understanding the effects of the plan on long-term emissions reductions is necessary to determine whether the plan will reduce emissions to a less than significant level. Examining the long-term trajectory also allows a lead agency to determine whether the emissions reductions in the plan are sustainable, or will be overtaken by population growth, increased driving, or other shifts in emissions.

Community spaces can serve multiple functions, creating places to gather, recreate and generate economic activity





Image by Urban Advantage, Opticos

Take for example, a plan that sets only a near-term target. Such a plan might rely on increasing building energy efficiency to achieve near-term goals. Looking further out, however, might demonstrate that steady increases in vehicle miles traveled will counteract those reductions, and result in an emissions trajectory that increases rather than decreases. Setting targets out to the general plan horizon year or beyond allows a lead agency to consider the full suite of measures that might be necessary to achieve long-term reduction goals.

What Target Years Should the Plan Include?

Once a lead agency commits to looking at a long-term trajectory, the precise points along that trajectory that it chooses to measure may be influenced by practical considerations. The mechanism selected to measure progress towards a target should ensure that it allows the lead agency to meaningfully assess the impacts of a plan. Choosing to measure 2020, 2035 and 2050 emissions may allow a lead agency to compare its progress to projected statewide and region-wide emissions reductions based on work being done under SB 375, AB 32, SB 32, and other State programs. Choosing the year 2030 will align the jurisdiction's efforts with the State's interim target year and link to other air quality regulations. In order to maintain a trajectory towards the statewide 2050 reduction target, local governments should be aiming for more robust reductions in later years. This is due to the phase-in of more significant land use policies and the associated emissions benefits that will achieved by more efficient circulation patterns and resource use. Generally, the target year may reflect horizon years of local planning

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documents, such as general plans, while also ensuring that long term monitoring can be satisfied through the choices made in target years. If a CAP is developed to mitigate the impacts of a general plan, the CAP should also include a target for the horizon year of the general plan.

What Baseline Year is Appropriate?

Typically, a GHG emissions reduction plan baseline year includes the most recent year for which information is available. In the 2006 AB 32 Scoping Plan, the recommended target for local government action was 15% below "current" levels by 2020, generally construed as the baseline years between 2005 – 2008. Newer baseline GHG inventories use years after 2008, which may require some additional calculation to determine consistency with the State's 1990 baseline year. As long as the appropriate narrative and substantial evidence is provided to support a particular baseline year, the specific year chosen is less important than the targets.

STEP 3: Section 15183.5(b)(1)(C) Forecast Projected Emissions for Activities Covered by the Plan *("Identify and analyze the greenhouse gas emissions resulting from specific actions or categories of actions anticipated within the geographic area")*

This step is the long-term forecast and includes trends reflecting existing programs and policies. In the case of a city's general plan, it might address development or infrastructure added by the general plan policies. The forecast might also include implementation of state regulations addressing climate change, such as adopted building codes. In sum, the forecast includes emissions from all activities expected to occur absent any policies in the CAP.

When discussing State programs in a forecast, timing of the baseline year and the start of implementation of State programs are important. Reductions measured towards a reduction target should not include the benefits of State programs already in force; rather these reductions should be reflected in the forecast. Regardless of the role State programs play in local emissions reductions, the focus of local CAPs should be on measures to reduce emissions beyond what the State programs will achieve. The ultimate goal is a plan that identifies strategies to realistically meet longer term State targets as discussed previously.

The same principle applies with respect to existing local reduction measures. For example, a local green building ordinance adopted in 2004 would not be counted as a GHG reduction measure if the plan's inventory base year is 2005. Emission reductions attributed to that ordinance should be reflected in the GHG inventory and forecast – that is, the total amount of GHG emissions from building energy use in the inventory would be lower because the effects of the green building ordinance would already be taking place. Lastly, when accounting for the impacts of existing state or local programs in a local GHG reduction plan, it is important to ensure there is no double-counting of emission reductions.

Mandatory Measures - Nuance

Although mandatory measures are preferred to establish the substantial evidence that a particular emissions reduction measure will have the stated benefit, there are some examples of incentive based measures that could be considered mitigation. One example is proposed to expand an energy efficiency program that has been in place several years and have a proven emissions reduction track record. These types of measures can be included in reductions towards a target, as long as assumptions reflect the proven ability for that program to reduce emissions. In other words, there should be substantial evidence to support the calculations for the measure.

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STEP 4: Section 15183.5(b)(1)(D) Reduction Measures *("Specify measures or a group of measures, including performance standards, that substantial evidence demonstrates, if implemented on a project-by-project basis, would collectively achieve the specified emissions level")*

The heart of a CAP is the suite of reduction measures that will ensure that the plan achieves the selected reduction targets in a transparent and replicable manner. To do so, the lead agency should compare the emissions projected in Step 3 (Forecast) with the targets set in Step 2 (Targets). If forecasted emissions from activities covered by the plan in Step 3 are projected to exceed the reduction targets established in Step 2, additional reduction measures will be needed. See CEQA Guidelines Section 15126.4(c), Mitigation Measures Related to Greenhouse Gas Emissions, for additional information on the appropriate form measures should take. Only GHG emission reduction measures implemented after the baseline year should be counted towards the plan's GHG emissions reduction target.

Feasibility and Enforceability

CEQA Guidelines sections 15168(b)(4) and 15168(c)(3) recognize that programmatic documents like a general plan or CAP provide an opportunity to develop mitigation plans that will apply on a project-specific basis. As a result, a CAP needs to include measures that will achieve the reduction target. How the plan achieves those targets, whether through mandatory or a mix of voluntary and mandatory measures, is up to the lead agency, so long as substantial evidence supports the conclusion.

When addressing greenhouse gas emissions, like all other technical analysis, the methodology and calculations should be transparent and replicable with the goal of providing substantial evidence supporting the assumptions, analysis and conclusions. Measures should also be real and verifiable, through either full enforceability or through substantial evidence in the record supporting an agency's conclusion that mitigation will be effective.

A number of published court cases address the need for feasible and enforceable emission reduction measures. The decision in Communities for a Better Environment v. City of Richmond (2010) 184 Cal. App. 4th 70, provides guidance on the level of detail that is needed. In that case, the city proposed to mitigate the effects of a refinery project by developing an emissions reduction plan after project approval. Specifically, the city pledged to implement measures that would ensure no net increase in emissions from the refinery. The EIR for the refinery suggested several possible measures, including energy efficiency upgrades and carbon sequestration. On appeal, the court held that the city's mitigation plan was inadequate. Specifically, the court found:

> "...The final EIR merely proposes a generalized goal of no net increase in greenhouse gas emissions and then sets out a handful of cursorily described mitigation measures for future consideration that might serve to mitigate the 898,000 metric tons of emissions resulting from the Project. No effort is made to calculate what, if any, reductions in the Project's anticipated greenhouse gas emissions would result from each of these vaguely described future mitigation measures. Indeed, the perfunctory listing of possible mitigation measures ... are nonexclusive, undefined, untested and of unknown efficacy." (Communities for a Better Environment, supra, 184 Cal.App. 4th at 93).

The court observed that to be adequate, a plan should include measures that are "known to be feasible", "coupled with specific and

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mandatory performance standards to ensure that the measures, as implemented, will be effective" (Id. at p. 94).

Finally, when discussing emissions reduction measures in a general plan or CAP, co-benefits from reduction strategies should be considered that may result in better health outcomes, lower energy costs, improved access to transportation options, recreational opportunities, and general resource efficiency.

Existing Local and Regional Plans

Relying on emissions reductions that are achieved at the local level to the detriment of regional emissions is not an appropriate approach to achieving local targets. In the context of GHG emissions, some projects may cause adverse environmental impacts but still provide an overall benefit of reducing GHG emissions on a statewide or regional level. For example, a city may make a policy choice to allow increased housing density within a jobs-rich region in order to reduce region-wide GHG emissions from vehicles and transportation (See, e.g., 2007 Integrated Energy Policy Report (IEPR), at p. 210). Though the introduction of new housing within the jurisdiction may result in near-term or local GHG emissions, doing so may assist the region as a whole in meeting region-wide reduction targets. CEQA Guidelines Section 15093(a) expressly allows a lead agency to consider this type of environmental benefit of a project in a statement of overriding considerations in the environmental document. This ensures that lead agencies may consider regional and statewide benefits along with a project's adverse impacts. Consistent with CEQA Guidelines Section 15021(d), the lead agency may consider environmental benefits to balance a project's significant adverse environmental effects that remain even after the adoption of all available feasible mitigation measures.

Regional transportation plans may contain information regarding transportation-related greenhouse gas emissions that is useful in a cumulative impacts analysis. Sustainable community strategies in regional transportation plans include projections of a region's GHG emissions and related cumulative effects.

Planning inclusive communities creates space for all residents



Image by Urban Advantage, Moule & Polyzoides

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Offsets and sequestration

Offsets and sequestration are emerging as a mechanism to achieve longer term targets that using traditional emission reduction measures will not achieve. CEQA recognizes offsets and sequestration as potential mitigation for GHG emissions. Lead agencies have discretion to choose what is considered feasible and what they are capable of monitoring. Onsite or local offsets and sequestration measures may be more easily monitored and supported with substantial evidence.

In identifying sequestration projects, offsets/offsite mitigation as possible strategies for GHG reductions, cities and counties should keep in mind that achieving long term targets may be challenging and that innovative approaches to addressing emissions locally may be necessary. CAPs should include strategies that address the natural sequestration capabilities within a community, and community-wide efforts that may benefit from project-based funding. Offsets/offsite mitigation should be employed after other measures are generally exhausted, and the proposed measure(s) should be tied to impacts resulting from the project. For example, if a retrofit program is proposed to support GHG reductions within the community covered by the plan, then reductions resulting from the measure are appropriate to count towards achievement of a specific target, assuming the retrofit program is additional to legal requirements (see discussion below).

The lead agency should find, based on substantial evidence, that any measure, including offsets or sequestration measures, is capable of being accomplished successfully within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors (CEQA Guidelines § 15364).

Must be additional

Actions identified as reduction measures in a CAP should not be otherwise required by law or regulation. This is important for measures that apply to new development as well as measures that require funding of offsets/offsite mitigation.

STEP 5: Section 15183.5(b)(1)(e) **Monitoring** *("Establish a mechanism to monitor the plan's progress toward achieving the level and to require amendment if the plan is not achieving specified levels")*

CAPs may be updated every three to five years in order to make adjustments based on the trajectory of emissions under adopted policies. Accordingly, "many plans are on a five year update cycle with tracking of inventories occurring more frequently" (State of Local Climate Action: California 2016). Each update should provide context with regional planning efforts, such as those included in a regional transportation plan (RTP) or sustainable community strategy (SCS).

When incorporated into a general plan, a CAP's policies should also be reflected in the general plan implementation program. This allows for regular monitoring along with other general plan policies in the annual status report submitted to OPR.

Establishing a mechanism to monitor the plan's progress toward achieving the stated target and to require amendment if the plan is not achieving specified levels is an important part of any CAP or general plan. Because GHG reduction strategies tend to be long-term, strategies may become stale, particularly as methods used to quantify GHG emissions evolve and economic growth projections change. Resources are available that allow for efficient monitoring, including through the SEEC ClearPath California tool. Ongoing monitoring of the success of mitigation measures will ensure they are successfully implemented according to the timeline specified within the strategy and that the plan remains eligible for CEQA streamlining. This is also an ideal opportunity to update the decision making body on progress made to date on emissions reductions and implementation of programs in a CAP.

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STEP 6: Section 15183.5(b)(1)(F) Environmental Review *(Plan must "be adopted in a public process following environmental review")*

Local governments adopting CAPs and general plans that incorporate GHG emissions reduction policies are required to analyze the impacts of the policies on the environment. CEQA requires analysis and mitigation of a project's significant adverse environmental impacts. While the overall effect of a CAP may be beneficial, a robust CAP may entail environmental tradeoffs. For example, a CAP that calls for increased solar development may require analysis of impacts to species or habitat. Increases in density may require analysis of land use impacts. Such impacts should be analyzed and, if necessary, mitigated through an environmental document. Note that the CEQA Guidelines define "environmental documents" to include "Initial Studies, Negative Declarations, draft and final EIRs, documents prepared as substitutes for EIRs and Negative Declarations under a program certified pursuant to Public Resources Code Section 21080.5, and documents prepared under NEPA and used by a state or local agency in the place of an Initial Study, Negative Declaration, or an EIR" (CEQA Guidelines § 15361).

Subsequent Projects

A lead agency may rely on the analysis in the CAP or general plan to forego further CEQA analysis of greenhouse gas emissions if a project is consistent with the analysis in the plan.

CEQA Guidelines section 15064.4 together with section 15064(h)(3) provides a lead agency the ability to demonstrate consistency with an existing GHG reduction plan, but it should show that the plan actually addresses the emissions that would result from the project. One way to establish clear compliance with a CAP is a project checklist whereby applicants for new projects identify which CAP measures apply to the project, and include those measures in the application for project review. This is similar in nature to a general plan consistency analysis or zoning code compliance review.

A plan that includes a compliance checklist, discussed in Step 5 above, can simplify this evaluation for later projects. In the absence of such a checklist, a lead agency should demonstrate that the project is consistent with the development assumptions that underlie the plan and verify that relevant measures in the plan are incorporated into the later project. Thus, instead of performing a full GHG analysis (including quantification of emissions and development of mitigation) for the individual project, the initial study or EIR for the later project may just include the evaluation described above.

Climate Adaptation Planning

Emergency managers, planning agencies, private companies, and communities affected by climate change need to plan for the increase in the type, extent, and intensity of natural hazards. As outlined in more detail in the safety element, a jurisdiction can start the process of understanding these hazards by using the resources in Cal-Adapt, the State's visualization tool for climate impacts. Cal-Adapt can be used in conjunction with California's climate change adaptation decision support tool called the Adaptation Planning Guide. Together they can guide creation of an adaptation plan or a general plan that meets minimum requirements for addressing climate adaptation, as required in the safety element. The safety element may be the "home" for adaptation discussions in the general plan, but climate change adaptation should be integrated throughout the elements of a general plan to create internal consistency and support holistic consideration of this important issue. A general plan should also provide context for changes in the environmental setting that will occur over time. For additional information on requirements and recommendations for addressing climate risk, including policy recommendations, please visit the safety element discussion.

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Many local governments find it difficult to address climate change risk and adaptation policy alone. Increasingly, they are choosing to create or join collaborative partnerships that address climate adaptation at a multijurisdictional level. Regional collaboratives can be a coordination point for policy and program development and implementation. The Alliance of Regional Collaboratives for Climate Adaptation (ARRCA) (see www.arccacalifornia.org) is one example. ARCCA was established in 2012 to help various regions of the state prepare for climate change related extreme events such as flooding, heat waves, fires, and others.

Tools and Resources for Addressing Climate Change at the Local Level

Some of the more useful climate change tools and resources referenced throughout this section and in other parts of the GPG are included in the table below. This, and additional resources, such as case studies, executive orders, legislation, and regulatory underpinnings of this discussion are located on the OPR Integrated Climate Adaptation and Resiliency Program website.

Process Guidance and Vulnerability/Impact Tools	Comprehensive free resource supported by the State of California to reduce GHG emissions at the community scale	California State Energy Efficiency Collaborative (SEEC) ClearPath California
	Guidelines for California Environmental Quality Act compliance	CEQA Guidelines
	Decision making framework supported by the State of California for addressing adaptation at the local level	Adaptation Planning Guide
	Tool supported by the State of California for visualizing the impacts of climate change and links to resourcese	Cal-Adapt
	Federal resource for visualizing impacts, historical trends, case studies, decision support.	Climate Resilience Toolkit
Greenhouse Gas Emissions Tools	State of California supported online resource that hosts links to various tools and case studies	Cool California
	Outlines the steps to reduce GHG emissions and includes templates supported by the State of California	California State Energy Efficiency Collaborative
	Outlines examples of policies and programs to reduce GHG emissions	California Air Pollution Control Officers Association (CAPCOA)
	Provides state priorities, targets and the narrative regarding the importance of local planning on climate change. Also included recommended local targets and measures to reduce GHG emissions	California Air Resources Board Scoping Plan
	California Energy Commission Planning Guide	Energy Aware Planning Guide
Climate Adaptation and Resilience	The state supported decision support framework and guide to developing adaptation policy at the local level in California	Adaptation Planning Guide
	The State's approach to addressing climate impacts, including context to how the State should work in coordination with regional and local efforts.	Safeguarding California Plan
	The State's framework for hazard mitigation, including climate risk in the context of emergency services.	State Hazard Mitigation Plan

OPR Recommended Policies

Numerous element specific climate change policy recommendations are included throughout the general plan guidelines. Further policy guidance is included in the resources outlined in the table above. Addittional recommended policies can be found in the Air Resource Board Scoping Plan. A partial list of recommended policies can be found in the general plan guidelines Appendix A.

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Implementation

Preparing, Integrating, and Implementing the General Plan

"I have been impressed with the urgency of doing. Knowing is not enough; we must apply. Being willing is not enough; we must do"

—Leonardo da Vinci

Introduction

All statutory references are to the California Government Code unless otherwise noted

The implementation of a general plan is particularly important to consider even before the general plan update process is started. Determining how goals, policies, and actions may work in practice can help define how best to approach the general plan update and content. Additionally, with the proliferation of regional planning initiatives, grant programs promoting particular policies, and focused and related companion documents such as climate action plans, the general plan serves the function of integrating and synthesizing the various interrelated documents and programs that make a community function affectively.

A general plan is ineffective if not well implemented. Implementation relies on specific plans, zoning ordinances, subdivision ordinances, and public project consistency requirements, among other mechanisms. State law requires cities and counties to have subdivision and building regulations and open-space zoning, while many of the other measures described in this chapter are adopted at the discretion of the city or county. To effectively implement the objectives, policies, and proposals of the general plan, implementing measures must be carefully chosen, reflective of local needs, and carried out as an integrated program of complementary and mutually reinforcing actions. Measures should be specific enough to implement the goals of the general plan, while maintaining enough adaptability to allow flexibility in implementation throughout the timeline of the general plan.

It is important to remember that implementation measures identified in the general plan (and the mitigation measures identified in its EIR) must be fiscally and technically feasible to be valid. Cities and counties should consider collaborating with regional public and private sector partners to develop multi-party fair share impact fee programs for financing infrastructure improvements. For transportation components, jurisdictions should consider impact fee programs focusing on multi-modal system improvements that reduce the VMT generated by new development.

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Some cities and counties have implemented metrics to track their progress towards reaching the outcomes highlighted in their general plans. The City of Sunnyvale incorporated implementation strategies and a system of trackers available annually to the community. The City of Sacramento uses metrics to create reports on the implementation of its general plan annually, and completes a thorough review every five years, looping the information back into regular general plan updates. Implementing metrics to track progress and inform reviews can improve transparency and ease the update process.

Zoning

Zoning is one of the primary means of implementing a general plan. In contrast to the long-term outlook of the general plan, zoning classifies the specific, immediate uses of land. The success of a general plan, and in particular the land use element, rests in part upon the effectiveness of a consistent zoning ordinance in translating the long-term objectives and policies contained in the plan into everyday decisions.

The typical zoning ordinance regulates land use by dividing the community into districts or "zones" and specifying the uses that are to be permitted, conditionally permitted, and prohibited within each zone. Text and map(s) describe the distribution and intensity of land uses in such categories as residential, commercial, industrial, and open space. Trade-offs and considerations related to sustainable development, infill, climate risk, environmental justice, and equity, among other issues, should be considered when designating zoning maps. Written regulations establish procedures for considering projects, standards for minimum lot size, building height and setback limits, fence heights, parking, and other development parameters within each land use zone.

Form based codes (FBC) have also emerged as a resource for planning the "feel" of a community. FBCs are typically accomplished through overlays on a base zoning designation but can also be stand alone. More information on FBCs can be found here.

In counties, general law cities, and charter cities with a population of more than two million, zoning provisions must be consistent with the general plan (Gov. Code § 65860). Charter cities with a population of under two million are exempt from the zoning consistency requirement unless their charters provide otherwise; however, these charter cities should see consistency between the general plan and zoning as a common-sense approach to planning and transparency. An in-depth discussion of zoning consistency can be found later in this chapter under the heading "Consistency in Implementation."

Zoning Tools

Zoning must be consistent with the general plan. The following are some common examples of zoning provisions that can be used to further general plan objectives and policies.

- **Cluster zoning**: A district that allows the clustering of structures upon a given site in the interest of preserving open space. Cluster zones typically have a low standard for gross residential density and a high minimum open-space requirement to encourage the clustering of structures.
- **Conditional use permit (CUP)**: A discretionary permit that enables a city or county to consider, on an individual basis, specific land uses that might otherwise have undesirable effects upon an area and to approve such uses when conditions can be placed on them that would avoid those effects.

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- **Design review**: Required review of project design and/or architectural features for the purpose of ensuring compatibility with established standards. It is often used in historic districts or areas that have a distinct character worthy of protection. Design review is a means of enforcing aesthetic standards.
- **Floating zone**: A district described in the zoning ordinance but not given a specific location on the zoning maps until a property owner or developer applies for it. Planned Unit Development (PUD) zoning is a common example of a floating zone. Floating zones can implement development standards established in the general plan.
- **Floodplain zone**: A district that restricts development within delineated floodplains in order to avoid placing people and structures in harm's way and obstructing flood flows. The zone may allow for agricultural, open-space or similar low-intensity uses that account for current and future flood risk.
- **Hillside development ordinance**: Provisions regulating development on steep slopes, often by establishing a direct relationship between the degree of slope and minimum lot size. This can implement specific policies and standards that may be found in the land use, open-space, and safety elements.
- **Mixed-use zoning**: An ordinance provision that authorizes several land uses to be combined in a single structure, area, or project. It is being widely used in a variety of communities from urban to rural in nature. It is often used for office/commercial/high-density residential and for urban projects that combine ground floor retail/commercial with residential units above.
- **Open-space zoning**: Government Code section 65910 specifically requires the adoption of open-space zoning to implement the open-space element. Similarly, the Timberland Productivity Act requires local governments with qualifying timberlands to adopt Timberland Productivity Zoning (TPZ) for qualifying timberlands (Id. at §§ 51100, et seq.).

Creating walkable, transit friendly communities can revitalize an economic district



Image by Urban Advantage, SANDAG

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- **Overlay zone**: Additional regulations superimposed upon existing zoning in specified areas. Subsequent development must comply with the requirements of both the overlay zone and the base district. Overlay zones commonly establish historic districts, airport height restrictions, and floodplain regulations.
- **Planned unit development (PUD) zoning**: A type of floating zone designed to provide flexibility in project design and standards. It is usually characterized by comprehensive site planning, clustering of structures, and a mixture of land uses. A PUD can implement specific density, open-space, community design, and hazard mitigation standards contained in the general plan.
- **Specific plan zone**: A district that mandates the preparation of a specific plan prior to development. The specific plan establishes zoning regulations tailored to that site, consistent with the general plan.
- **Transfer of development rights (TDR)**: A device by which the development potential of a site is severed from its title and made available for transfer to another location. The owner of a site within a transfer area retains property ownership but not approval to develop. The owner of a site within a receiving area may purchase transferable development credits, allowing a receptor site to be developed at a greater density. The California Coastal Commission has used this technique to "retire" antiquated subdivision lots in environmentally sensitive areas.

Zoning-Related Statutes

Although local governments have broad discretion in zoning matters, there are a number of state-mandated zoning requirements that directly relate to the general plan. The following summarizes most of the requirements that apply to general law cities, charter cities with a population above two million, and counties:

- **Surplus school sites**: School districts may request the rezoning of certain surplus school sites (Gov. Code § 65852.9). The city or county must then zone the site consistently with the general plan. The local government may not rezone surplus school sites to open-space, recreational, or park uses unless surrounding lands are similarly zoned or the school district agrees to the rezoning. If a surplus school site is located on the periphery of a community, rezoning should be compatible with the nature of the development on surrounding parcels.
- **Prezoning**: Government Code section 65859 allows a city to prezone adjacent unincorporated territory. The prezoning action is subject to the requirements applicable to zoning in the city, including the requirement for consistency with the general plan. Prezoning has no regulatory effect until the property is annexed to the city. Local agency formation commission (LAFCO) law requires prezoning as part of the annexation process. Prezoning properties should be considered in context to growth occurring in the city and whether infill development may address similar growth accommodating needs without requiring annexation of undeveloped property.
- **Interim ordinance**: Cities and counties may enact interim ordinances prohibiting uses that may conflict with a contemplated general plan, specific plan, or zoning proposal if they find that the use would result in a threat to public health, safety or welfare (Gov. Code § 65858). Interim zoning may be imposed for an initial period of 45 days and extended for up to two years. It can be used effectively when a general plan revision or major rezoning is underway in order to achieve general plan consistency. Local governments should exercise caution when imposing land use controls or moratoriums, even if they are only temporary. Excessive restrictions may give rise

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to a claim of regulatory taking that entitles affected landowners to just compensation. City and county officials should consult with their legal counsel to determine what degree of interim development control is reasonable.

- **Regional housing needs**: Local governments must consider the effects of proposed ordinances on regional housing needs and balance them against the availability of public services, fiscal resources, and environmentally suitable sites. A zoning ordinance limiting the number of new housing units must contain findings regarding the public health, safety, and welfare that justify reducing regional housing opportunities (Gov. Code § 65863.6). Pursuant to Government Code section 65913.1, the local government must zone a sufficient amount of vacant land for residential use to maintain a balance with land zoned for nonresidential use and to meet the community's housing needs as projected in the housing element. In addition, Government Code section 65863 restricts the ability of a city or county to reduce, through administrative, quasi-judicial, or legislative action, the residential density of any parcel to a density lower than that used by the Department of Housing and Community Development (HCD) in determining compliance with housing element law. Allocation of housing and determination of suitable sites should also consider how new housing may be impacted by a changing climate.
- **Housing development projects**: Government Code Section 65589.5 restricts cities and counties from disapproving a housing development project affordable to very low-, low- or moderate-income households except under certain circumstances. These circumstances include inconsistency with both the applicable zoning and the general plan land use designation, and specific unavoidable adverse impacts on the public health and safety, among others. This code section further restricts the ability of cities and counties to lower the density of a housing development project that is consistent with general plan and zoning standards unless there is a specific, adverse impact on public health and safety that cannot otherwise be mitigated.
- **Density bonus**: Local governments must provide incentives to developers of specified housing developments. A density bonus and at least one other regulatory incentive must be provided when a developer pledges to set aside specific percentages of the total amount of housing for low- or very low-income residents, seniors, or—for condominium projects only—moderate-income residents (Gov. Code § 65915). In return, the developer must reserve these units for this purpose for a certain number of years. Incentives may include a reduction in site development standards or approval of mixed-use zoning. A density bonus must exceed the maximum allowable general plan or zoning density by at least 25 percent.
- **Accessory Dwelling Units**: Local governments may, by ordinance, provide for the creation of accessory dwelling units, also known as "second units", in single family and multifamily zoning districts (Gov. Code § 65852.2). The ordinance may designate areas where accessory dwelling units are permitted, subject to certain zoning and design conditions as set forth in the statute. Second unit applications must be considered ministerially; without discretionary review a local government cannot adopt an ordinance totally precluding second units. In the absence of any local ordinance, state law provides for the approval of accessory dwelling units that meet certain statutory standards. Government Code Section 65583 allows a city or county to identify sites for second units based on the number of second units developed in the prior housing element planning period whether or not the units are permitted by right, the need for these units in the community, the resources or incentives available for their development, and any other relevant factors, as determined by the department.

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Specific Plans

A specific plan is a helpful tool for systematically implementing the general plan within all or a portion of the planning area (Gov. Code §§ 65450, et seq.). Any interested party may request the adoption, amendment, or repeal of a specific plan. Either the public or private sector may prepare a plan. However, responsibility for its adoption, amendment, and repeal lies with the city council or county board of supervisors. As a legislative act, a specific plan can also be adopted by voter initiative and is subject to referendum.

At a minimum, a specific plan must include a statement of its relationship to the general plan (Gov. Code § 65451(b)) and text and diagram(s) specifying all of the following in detail:

- The distribution, location, and extent of the uses of land, including open space, within the area covered by the plan (Id. at § 65451(a)).
- The proposed distribution, location, extent, and intensity of major components of public and private transportation, sewage, water, drainage, solid waste disposal, energy, and other essential facilities proposed to be located within the area covered by the plan and needed to support the land uses described in the plan (Ibid.).
- Standards and criteria by which development will proceed and standards for the conservation, development, and utilization of natural resources, where applicable (Ibid.).
- A program of implementation measures, including regulations, programs, public works projects, and financing measures necessary to carry out the provisions of the preceding three paragraphs (Ibid.).
- Any other subjects that, in the judgment of the planning agency, are necessary or desirable for general plan implementation (Gov. Code § 65452).

A specific plan is especially useful for large projects, as well as for sites with environmental and fiscal constraints. A specific plan may be adopted by resolution (like a general plan) or ordinance (like a zoning ordinance). Some jurisdictions have chosen to adopt the policy portions of their specific plans by resolution and the regulatory portions by ordinance. This enables a city or county to assemble, in one package, a set of land use specifications and implementation programs tailored to the unique characteristics of a particular site.

A regulatory specific plan often has advantages over zoning. A community's control of development phasing provides a good example. The regulatory effects of zoning are immediate, while the provisions of a general plan are long term. If a general plan's implementation is limited to zoning, phasing a long-term development so that it meets the general plan's objectives can be difficult. The one-time adoption of a specific plan that stipulates development timing or schedules infrastructure installation can solve the problem.

Statutory provisions allow streamlined permitting once a specific plan is in place. For example, residential development projects are exempt from CEQA if they implement and are consistent with a specific plan for which an EIR or supplemental EIR has been prepared (Gov. Code § 65457).

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A specific plan can reduce development costs. For example, the specific plan's land use specifications, in combination with its capital improvements program, can eliminate uncertainties as to future utility capacities and help avoid costly oversizing. CEQA exempts certain transit oriented development projects that are consistent with a Specific Plan (Pub. Resources Code §21155.4). The exemption applies if a project meets all of the following criteria:

1. It is a residential, employment center, or mixed use project;
2. It is located within a transit priority area;
3. The project is consistent with a specific plan for which an environmental impact report was certified; and
4. It is consistent with an adopted sustainable communities strategy or alternative planning strategy.

The exemption can be used if the project would cause no new or worse significant impacts compared to what was analyzed in the environmental impact report for the specific plan. If new or worse impacts would result, supplemental environmental review would need to be prepared.

A specific plan must be consistent with the jurisdiction's general plan (Gov. Code § 65454). In turn, zoning ordinances, subdivisions (including tentative tract and parcel maps), public works projects, development agreements, and land projects (as defined in Business and Professions Code section 11004.5) must be consistent with any applicable specific plan (Gov. Code §§ 65455, 66473.5, 66474(a), and 65867.5). Furthermore, a special district, school district, or joint powers authority may not carry out its capital improvements program (prepared pursuant to Government Code section 65403) if the affected city or county's planning agency finds the program or any part inconsistent with a specific plan, unless the district or local agency explicitly overrules the city or county's finding (Id. at § 65403(c)).

A specific plan is prepared, adopted, and amended in the same manner as a general plan, except that it may be adopted by resolution or ordinance and it may be amended as often as the local legislature deems necessary (Gov. Code § 65453(a)). A specific plan is repealed in the same manner as it is amended (Id. at § 65453(b)). To defray the cost of specific plan preparation, a city or county may impose a fee upon persons whose projects must be consistent with the plan. The fee must be prorated according to the benefit a person receives from the specific plan (Id. at § 65456).

For more information about specific plans, see OPR's publication The Planner's Guide to Specific Plans.

Subdivision Regulations

Land cannot be subdivided for sale, lease, or financing in California without local government approval. The Subdivision Map Act establishes statewide uniformity in local subdivision procedures while giving cities and counties the authority to regulate the design and improvement of subdivisions, require dedications of public improvements or related impact fees, and require compliance with the objectives and policies of the general plan (Gov. Code §§ 66410, et seq.). This includes the authority to approve and design street alignments, street grades and widths, drainage and sanitary facilities, lot size and configuration, traffic access, and other measures that are "necessary to ensure consistency with, or implementation of, the general plan or any applicable specific plan" (Id. at § 66418, 66419).

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These regulatory powers can promote the usual array of land use, circulation, open-space, and safety element objectives, policies, and plan proposals. Good subdivision design can encourage pedestrian access, residential street calming, urban forestry, tree preservation, floodplain management, wildland fire safety, and other principles or policies that may be articulated in the general plan.

Subdivisions provide infrastructure that will serve the new lots being created. Local governments can require dedications of public improvements or the payment of in-lieu fees for:

- Streets, alleys, drainage, public utility easements, and public easements (Gov. Code § 66475)
- Local transit facilities, such as bus turnouts, benches, shelters, and landing pads (Gov. Code § 66475.2)
- Bicycle paths (Gov. Code § 66475.1)
- Parks and recreational facilities, if the city's general plan or specific plan contains policies and standards for such facilities (Quimby Act, Gov. Code § 66477)
- Elementary "school sites (Gov. Code § 66478)
- Access to waterways, rivers, and streams (Gov. Code § 66478.4)
- Access to coastline or shoreline (Gov. Code § 66478.11)
- Access to public lakes and reservoirs (Gov. Code § 66478.12)
- Drainage and sanitary sewer facilities (Gov. Code § 66483)
- Bridges and major thoroughfares (Gov. Code § 66484)

No tentative subdivision map or parcel map can be approved unless the city or county finds that the subdivision, together with design and improvement provisions, is consistent with all aspects of the general plan or any applicable specific plan (Gov. Code §§ 66473.5, 66474, and 66474.61). Lot line adjustments must also be consistent with the general plan (Id. at § 66412). The local government must deny a proposed subdivision if it finds that the proposed subdivision map is inconsistent with the general plan or any applicable specific plan; the design or improvement of the subdivision is inconsistent with the general plan or any applicable specific plan; the site is physically ill-suited for either the type or proposed density of development; or the subdivision's design or types of improvements are likely to cause substantial environmental damage, substantially and avoidably injure fish or wildlife or their habitat, or cause public health problems (Id. at § 66474). Local governments should also carefully consider climate risk and environmental justice in approving subdivision and parcel maps in order to be consistent with general plan requirements for the same. Cities and counties must make written findings of fact supported by substantial evidence for each of these matters when deciding upon a subdivision.

The special rules applicable to vesting tentative maps are worth noting, as detailed in Government Code section 66498.1, et seq. When subdividers receive city or county approval of a vesting tentative map, they also obtain a limited right to develop the subdivision in substantial compliance with those ordinances, policies, and standards in effect at the time the application was deemed complete (Id. at § 66498.1(b); Kaufman and Broad v. City of Modesto (1994) 25 Cal.App.4th 1577). If, however, a local agency has initiated formal proceedings to amend applicable plans or regulations prior to the application being deemed complete, the amendments, if adopted, will apply to the

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vesting map (Gov. Code §§ 66498.1(b), 66474.2). The local agency may condition or deny building permits for parcels created under a vesting tentative map if the agency determines that a failure to do so would threaten community health or safety or the condition or denial is required by state or federal law (Id. at § 66498.1(c)). The vesting tentative map law applies to all subdivisions, including commercial and industrial tracts.

Changes in land use and circulation can stimulate economic activity



Image by Urban Advantage, Calthorpe Associates

Capital Facilities

Capital facilities must be consistent with the general plan (Gov. Code § 66473.5; Friends of B Street v. City of Hayward (1980) 106 Cal.App.3d 988). The network of publicly owned facilities, such as streets, water and sewer facilities, public buildings, and parks, forms the framework of a community. Although capital facilities are built to accommodate present and anticipated needs, some (most notably water and sewer facilities and roads) play a major role in determining the location, intensity, and timing of development. For instance, the availability of sewer and water connections can have a profound impact upon the feasibility of preserving agricultural or open-space lands.

The general plan should identify existing capital facilities and the need for additional improvements. The circulation element is the most obvious place to address infrastructure issues, but it is not the only element where capital improvements come into play. For example:

- The housing element must identify adequate sites for various housing types based in part on public services and facilities. Water and sewer providers are required to adopt a procedure to grant priority to development with units affordable to lower income households.
- The safety element must "address evacuation routes, peakload water supply requirements, and minimum road widths...as those items relate to fire and geologic hazards". Climate risk in siting capital facilities should also be considered to ensure long term needs and viability of the investment (Gov. Code § 65302(g)(4)(c)(ii)).
- The land use element must include education-related land uses such as school sites, open-space for recreation, public buildings and grounds (the placement of public buildings may play an important role in urban design), and solid and liquid waste disposal facilities.
- The open-space element may consider "[o]pen-space for outdoor recreation... areas particularly suited for park and recreation purposes" (Gov. Code § 65560(b)(3)). It may also address open-space areas for protecting water quality and for water reservoirs.
- The conservation element can address flood control measures and must be developed "in coordination with any countywide water agency and with all district and city agencies that have developed, served, controlled or conserved water for any purpose in the county or city for which the plan is prepared" (Gov. Code § 65302(b)).

What about timing of improvements for implementation?

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Local governments can underscore their interest in public services and facilities by adopting an optional public facilities element.

Each year, the local planning agency is required to "review the capital improvement program of the city or county and the local public works projects of other local agencies for consistency with the general plan" (Gov. Code § 65103(c)). To fulfill this requirement, all departments within the city or county and all other local governmental agencies (including cities, counties, school districts, and special districts) that construct capital facilities must submit a list of proposed projects to the planning agency (Gov. Code § 65401).

In lieu of considering individual projects or only those projects to be undertaken in a single year, many cities and counties prepare and annually revise a 5- to 7-year capital improvement program (CIP). The CIP projects annual expenditures for acquisition, construction, maintenance, rehabilitation, and replacement of public buildings and facilities, including sewer, water, and street improvements; street lights; traffic signals; parks; and police and fire facilities. In rapidly developing areas, a CIP coordinated with a general plan can help shape and time growth according to adopted policies. In an older city with a declining tax base and deteriorating capital facilities, a CIP can help stimulate private investment or stabilize and rehabilitate older neighborhoods by demonstrating a public commitment to the provision of key public facilities on a predetermined schedule.

Many federal grant programs, including those under the Clean Air Act and the Moving Ahead for Progress in the 21st Century Act (MAP-21) require or promote consistency between federally assisted capital projects and local, regional, and state plans. For example, the Clean Air Act requires that the population projections used in planning capital facilities conform to the assumptions contained in the regional air quality management plan adopted as part of the State Implementation Plan (SIP) when federal funding or approval is sought. The federal government gives priority to implementing those programs that conform to the SIP and will not fund those that do not. The Code of Federal Regulations Title 40, Chapter I, Part 52, Subpart F, Section 52.220 lists all of the items which are included in the California SIP.

Capital improvements also have regional implications. The growing interrelatedness of planning issues among local governments applies directly to local capital improvement projects. The location of major roads, sewer facilities, water trunk lines, and emergency service buildings within the city or county can affect surrounding communities by encouraging or deflecting the direction of growth. Although the LAFCO exists to encourage the orderly provision of services within cities and special districts, it is seldom an effective substitute for every city and the county consulting and cooperating with its neighbors.

Development Agreements

A development agreement is a contractual agreement between a city or county and a developer that identifies vested rights that apply to a specific development project. By its nature, it offers opportunities for a city or county to assure that general plan objectives, policies, and plan proposals will be implemented as development occurs within an area.

A development agreement provides that, for a specified time period, the rules, regulations, and policies that are applicable to a particular development will not change. This gives developers who have otherwise yet to attain a vested right to develop a degree of assurance that their project preparations will not be nullified by some future local policy or regulation change (e.g., the rezoning of a commercial project site to residential), with limited exceptions. In exchange for the privilege of a regulation "freeze," the city or county usually will obtain certain concessions from the developer. For example, the developer might provide extra affordable housing, open space, or public facilities.

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Development agreements must specify the duration of the agreement, the permitted uses of property, the density or intensity of use, the maximum height and size of proposed buildings, and the provisions for reservation or dedication of land for public purposes (Gov. Code § 65865.2). In addition, development agreements may include the conditions, terms, restrictions, and requirements for subsequent discretionary actions; provide that such stipulations shall not prevent development of the land with regard to the uses, densities, and intensities set forth in the agreement; specify the timing of project construction or completion; and set forth the terms and conditions relating to applicant financing of necessary public facilities and subsequent reimbursement over time (Ibid.).

One advantage of development agreements is that the developer may be asked to obligate the project to improvements that exceed the usual legal limits on exactions. The limits do not apply when the developer has voluntarily entered into a contract with the city or county. A disadvantage of development agreements is that a city or county may be unable to respond to a changing market or apply new regulations to a project that is controlled by a long-term development agreement.

A city can enter into a development agreement covering unincorporated territory that is within its sphere of influence (Gov. Code § 65865(b)). This allows for planning in advance of an annexation. Such an agreement is not operative unless annexation proceedings are completed within the period of time specified by the agreement (Ibid.). If territory covered by a county development agreement becomes part of a newly incorporated city or is annexed to a city, the agreement is valid for its original duration or eight years from the date of incorporation, whichever is earlier (Id. at § 65865.3).

Unless otherwise provided in the development agreement, the existing rules, regulations, and policies in effect when the agreement is executed will apply to development of the property (Gov. Code § 65866). This avoids unanticipated consequences for both a developer and a city or county. A detailed specific plan prepared and adopted prior to a development agreement is one way to specify development details for a site, including the regulations and policies that would apply under the development agreement. Specific plan preparation can also facilitate further participation in planning a development.

Building and Housing Codes

State Housing Law delegates the enforcement of state building standards and housing codes to the local building department. Codes and standards are intended to encourage uniformity and establish minimum standards to protect the health, safety and general welfare of the public and occupants of residential buildings statewide. Local land use, housing elements, and additional health or safety elements are established by local ordinances. Building and housing codes have their greatest effect on new construction and rehabilitation, but certain parts of the codes apply to the use, maintenance, change in occupancy, and public health and safety hazards of existing buildings.

State Housing Law (Health & Saf. Code §§ 17910, et seq.) requires cities and counties to enforce state building standards and other regulations adopted by the Department of Housing and Community Development. Local ordinances may modify state building standards to impose substantially the same requirements as those contained in the various industry codes: the Uniform Housing Code, the International Building Code, The International Residential Code, The International Existing Building Code, the Uniform Plumbing Code, the National Electrical Code, and the Uniform Mechanical Code. The State Housing Law applies to buildings such as apartments, hotels, motels, lodging houses, manufactured housing, and dwellings but not to mobile homes (Id. at § 17911). In addition

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to meeting the requirements of state housing law, local codes must also comply with other state requirements related fire safety, noise insulation, soils reports, earthquake protection, energy insulation, and access for the disabled.

State law allows a city or county, when adopting the California Building Standards Code, to make such changes "as it determines ... are reasonably necessary because of local climatic, geological or topographical conditions" (Health & Saf. Code § 17958.5). Further, the local building department can authorize the use of materials and construction methods other than those specified in the California Building Standards Code where the department finds the proposed design satisfactory and the materials or methods at least equivalent to those prescribed by the California Building Standards Code with regard to performance, safety, and the protection of life and health (Id. at § 17951(e)(2)). These provisions can be used to promote the construction of affordable housing and the rehabilitation of substandard housing.

Other provisions are particularly useful where a community intends to encourage historic preservation. Health and Safety Code section 17958.8 allows the use of original materials and construction methods in existing buildings. Health and Safety Code section 17980(c)(2) requires local enforcement agencies to consider needs expressed in the housing element when deciding whether to require abandonment or repair of a substandard dwelling. In the reconstruction of existing buildings that would be hazardous in the event of an earthquake, the law allows cities and counties to use building standards that provide for the protection of the occupants but that are less rigorous in other respects than current building standards (Id. at §§ 19160, et seq.).

Code enforcement and abatement procedures are another means of implementing the general plan, particularly the housing and safety elements. Various state laws and regulations spell out abatement procedures that local government may enforce upon buildings that, because they are substandard or unsafe, constitute a public nuisance. The most common procedures involve citation and misdemeanor action on the part of the city or county to mandate abatement by repair, abandonment, or demolition.

Acquisition

City and county acquisition of real property rights can help to implement the policies of the land use, circulation and open-space elements. In implementing the land use element, cities and counties may acquire land designated for government offices, police and fire stations, parks, access easements, etc., or for public purposes such as urban redevelopment. With regard to the circulation element, local governments may acquire land for public rights-of-way (e.g., streets, sidewalks, bicycle paths, etc.), transit terminals, airports, etc. Cities and counties may advance open-space element policies and proposals through the acquisition of open-space and conservation easements.

Open-space acquisition has some advantages over purely regulatory approaches to implementation, such as zoning. Ownership ensures that the land will be controlled by either the city or county or another public agency. Another option is acquiring an open-space or conservation easement, rather than full ownership. This ensures that development will be limited, while the private landowner who continues to hold the underlying rights is compensated for lost development opportunities. This avoids the question of whether regulatory limitations have unconstitutionally "taken" private property without just compensation.

The primary disadvantage to acquisition is its cost. Land often is expensive, particularly when urbanization is imminent or where the supply of potentially developable land is limited. Funding sources, such as taxes and assessments, are limited

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in this post-Proposition 13 and post-Proposition 218 environment. A successful acquisition program often involves the resourceful blending of several funding sources.

Acquisition can take various forms. An overall program can be tied to general plan consistency or a capital improvements program. A city or county, in consultation with its legal counsel, may wish to consider the following:

- **Fee simple absolute interests**: A fee simple absolute estate in land consists of all the real property interests associated with the land, including the rights to sell, lease, and develop the property. Consequently, fee simple absolute ownership entitles a city or county to develop or not develop the land as it chooses.
- **Easement interests**: An easement consists of a portion of the rights to real property, such as the right to travel over the property or the right to build structures. The seller retains all property rights not stipulated in the easement. Travelways, utilities and open space are some common uses of easements.
- **Leasing**: The lessee possesses and occupies leased real property for a determinable time period, although the landlord retains full ownership. A city or county may lease land from a property owner for access purposes, open-space preservation, etc.
- **Lease-purchase agreements**: A city or county may lease real property and rental payments may be put toward purchasing the property. If a local jurisdiction does not have enough capital to buy the land outright, the lease-purchase method can spread payments over time.
- **Purchase and resale or lease**: Once a city or county has purchased a parcel of land or the parcel's development rights, the jurisdiction may assist in the development of housing affordable to lower income households and preserve open space (or otherwise control land use) by selling the land or the development rights with deed restrictions specifying permitted land uses. A local jurisdiction may also lease property subject to a rental contract specifying permitted uses. These techniques enable the jurisdiction to recover at least a portion of its purchasing expenses.
- **Joint acquisition**: Two or more local governments may combine their funding resources to acquire joint ownership of real property rights. Joint acquisition allows local governments to share the financial burden of purchasing land.
- **Land swapping:** Local governments may exchange some of their land for parcels owned by private landowners or other jurisdictions in order to obtain desirable open space, park sites, etc.
- **Eminent domain**: Eminent domain involves the compensated taking of property for a public use or purpose, such as the acquisition of open space for a city greenbelt. This may include fee simple interest and less-than-fee interests such as easements. An owner whose property is taken is entitled to receive just compensation through the payment of fair market value for the loss (Cal. Const., art. I, § 19). Cities and counties are authorized to exercise the power of eminent domain (Gov. Code §§ 37350.5, 25350.5) in accordance with the Eminent Domain Law (Code Civ. Proc. §§ 1230.010, 1230.020).

Preferential Property Tax Assessments

Preferential assessment programs provide landowners an economic incentive to keep their land in agricultural, timber, open-space, or recreational use. This can help implement the land use, open-space, and conservation elements by protecting areas designated for

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such uses from premature development. State law provides local governments with several preferential assessment programs, the most common of which are discussed below.

Williamson Act

The Legislature enacted the California Land Conservation Act, also known as the Williamson Act (Gov. Code §§ 51200, et seq.) in response to the rapid loss of agricultural land in areas of increasing land values. Typically, as development approaches an agricultural area, the price of land is driven upward by owners and buyers speculating on the future development potential of the land. The increase in prices leads to a corresponding increase in the assessed value of the land and to the owner's property taxes. At some point, the increased tax burden makes it uneconomical to continue farming and encourages the sale of the land for development.

The Williamson Act allows counties and cities to establish agricultural preserves and to assess agricultural and open-space land on the basis of its agricultural, rather than market, value (Gov. Code § 51252). Owners of qualified land located in an agricultural preserve contract with the county or city to continue agricultural or compatible activities for a period of at least ten years (or in some circumstances nine years) (Id. at § 51244). Until 2010, the state annually reimbursed local agencies for a portion of the resultant tax losses pursuant to the Open Space Subvention Act (Id. at §§ 16140 et seq.). However, funding for these payments has not been included in the state budget since 2010. As a result, some counties have stopped entering new Williamson Act contracts; some have also declined to renew existing contracts, generally due to small parcel size or incompatible use.

A Williamson Act contract automatically renews itself each year (Gov. Code § 51244). Termination of the contract may be accomplished by one of three methods. The landowner or local government can file a notice of "nonrenewal" (Id. at § 51245). The notice halts the yearly contract renewal, resulting in its expiration at the end of the ten years (Id. at § 51246). Alternatively, at request of the landowner, a local government may immediately cancel a contract after making certain strict findings. (Id. at § 51282). Such a cancellation requires the owner to pay penalty fees. (Id. at § 51283). A contract may be rescinded without penalty when the city or county has entered into an agreement with the landowner to simultaneously place an equal or greater amount of equally suitable agricultural land into an agricultural conservation easement (Id. at § 51256). The value of the proposed conservation easement must be at least 12.5 percent of the cancellation value of the land subject to the contract being rescinded and other restrictions apply (Ibid.). Nonrenewal is intended to be the normal route for ending a Williamson Act contract. Cancellation is meant to be reserved for special circumstances (Lewis v. City of Hayward (1986) 177 Cal.App.3d 103) and rescission is intended to provide more flexibility.

Williamson Act contracts are voluntary, which is both their greatest strength and weakness. On the positive side, voluntary contracts lessen the potential for litigation over the uncompensated taking of land that is sometimes alleged when land uses are restricted. Also, because the owner is directly involved in entering the program, responsibility is imparted to the landowner for ensuring that the program works. On the other hand, the potential profits anticipated from future development on the urban fringe may outweigh the tax advantages of the contract. Thus, in the very areas where it could be most effective in preventing the premature conversion of farmland, there are strong economic incentives not to join the program.

In 1998, in response to the perceived weaknesses of the Williamson Act program, the Legislature added additional non-regulatory protection in the form of farmland security zones for specific classifications of farmland, including prime farmland, farmland

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of statewide importance, unique farmland, and farmland of local importance. Land can be entered into a farmland security zone contract for a 20-year term rather than the 10-year term of Williamson Act contracts (Gov. Code § 51296.1). During this time, the land is assessed at 65 percent of either its Williamson Act valuation or its Proposition 13 valuation, whichever is lower, rather than on the actual use of the land for agricultural purposes as is required under the Williamson Act (Rev. & Tax Code § 423.4). Cities and special districts that provide non-agricultural services are generally prohibited from annexing land enrolled under a farmland security zone contract, with certain exceptions (Gov. Code §§ 51296.3, 51296.4). Additionally, farmland Security Zone statutes prohibit a school district from using contracted land for school facilities, rendering inapplicable a local zoning ordinance, or even acquiring land, in a farmland security zone (Id. at §§ 51296.5, 51296.6, 51296.7). Farmland security zone contracts also provide that any voter-approved special taxes levied after January 1, 1999, for urban-related services be levied upon the contracted land or the trees, vines, or crops on the land at a reduced rate, unless the urban service directly benefits the land or living improvements (Id. § 51296.2).

For more information on the Williamson Act and farmland security zone contracts, contact the Department of Conservation's Division of Land Resource Protection.

Timberland Productivity Act

The Timberland Productivity Act of 1982 requires all counties and cities with productive private timberland to establish timberland production zones (TPZs) to discourage the premature conversion of timberland to other uses (Gov. Code §§ 51100, et seq.). The land use element must reflect the distribution of existing TPZs and have a land use category that provides for timber production (Id. at 65302(a)(1)). A city or county also may use TPZs to implement the conservation element's timber resource provisions.

Patterned after the Williamson Act, TPZs are subject to rolling 10-year restrictions on use of the land and taxation of the land is based on such restrictions in use (Gov. Code §§ 51110 et seq.). Under this program, assessments on timber are based on the value of harvested timber, rather than on the market value of standing timber, pursuant to the Forest Taxation Reform Act of 1976 (Rev. & Tax Code §§ 434 et seq.) and the Timber Yield Tax Law (Id. at §§ 38101 et seq.).

During the first two years of the Act, local governments could adopt TPZs on qualified parcels without approval of the property owner, provided that statutory procedures were followed (Gov. Code §§ 51110, 51112). Currently, additions to local programs are limited to requests from property owners (Id. at §§ 51113, 51113.5). Subject to approval by the local legislative body, land may be removed from a TPZ by rezoning (Id. at §§ 51120, 51121). The effective date of the new zone generally must be deferred until expiration of the 10-year restriction (Id. at § 51120). However, the local legislative body may, under special circumstances, approve immediate rezonings and a tax recoupment fee will be imposed (Id. at §§ 51133, 51134, 51142).

The Timberland Productivity Act did not rely on voluntary inclusion during its beginning stages. This was advantageous because restrictions could be applied in a more comprehensive manner than Williamson Act contracts and could provide coherent preserves of timberland. The primary disadvantage is that there is greater potential for conflict between property owners and local governments over the designation of lands.

Conservation, Open-Space, and Scenic Easements

State law provides several means of conserving open space through easements. Easements are attractive because they are less expensive than full-fee rights, can be more effective than zoning, do not displace property owners, and may yield property or

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inheritance tax advantages to the grantor. Recording the easement in the office of the County Recorder places future owners on notice of the easement's provisions.

The Conservation Easement Act enables a local government or a non-profit organization to acquire perpetual easements for the conservation of agricultural and open-space lands and for historic preservation (Civ. Code §§ 815, et seq.). Granting of a conservation easement may qualify as a charitable contribution for tax purposes. The easement may also qualify as an enforceable restriction for purposes of preferential assessment.

The Open-Space Easement Act of 1974 authorizes local governments to accept easements granted to them or to non-profit organizations for the purpose of conserving agricultural and open-space lands (Gov. Code §§ 51070 - 51097). These easements are established for a term of not less than ten years and renew annually (Id. at § 51081). They must be consistent with the general plan and are considered enforceable restrictions on land that provides for reduced taxation based on value of the land subject to the restrictions, rather than market value (Cal. Const., art. XIII, § 8). The local government is prohibited from granting building permits for any structures that would violate the easement (Gov. Code § 51086). Procedures for termination by nonrenewal and by abandonment are outlined in Government Code sections 51090 through 51094.

The California Farmland Conservancy Program Act (CFCP) (Pub. Resources Code §§ 10200 - 10277) authorizes the Department of Conservation to provide grants to local governments and qualified non-profit land trusts to assist in the voluntary acquisition of agricultural conservation easements. To be eligible, a parcel be large enough for, and be located in an area that is conducive to, sustained commercial agricultural production (Id. at § 10251(a)). In addition, the local government within whose jurisdiction the parcel is located must have a general plan that demonstrates a long-term commitment to agricultural land conservation, reflected in plan provisions that relate to the area where the easement acquisition is located (Id. at § 10251(b)). Finally, there must be evidence that without protection, the parcel is likely to be converted to a nonagricultural use in the foreseeable future (Id. at § 10251(c)).

There are other noteworthy open-space provisions in the Government Code. The Scenic Easement Deed Act (Gov. Code §§ 6950 - 6954) authorizes a local government to purchase fee rights or scenic easements but does not promote a specific mechanism for obtaining them. Government Code sections 65870 through 65875 enable local governments to adopt an ordinance for the purpose of establishing open-space covenants with property owners. These are deed restrictions regulating land uses.

Land Trusts

A land trust is a private non-profit organization established for the purpose of preserving or conserving natural resource and agricultural lands through acquisition. A city or county may establish cooperative policies with a local land trust or one of the national trusts, such as the Nature Conservancy, the Trust for Public Land, or the American Farmland Trust, to promote the objectives and policies of the land use, open-space, conservation, and safety elements of its general plan.

Land trusts, whether local, statewide, or national, are often funded through membership dues and donations from individuals, businesses, and foundations. Working in cooperation with landowners and governmental agencies but outside of the structure of government, a land trust can quickly, flexibly, and confidentially obtain land or development rights that would otherwise enter the open market. In many cases, particularly where natural lands are being preserved, after obtaining the land or development rights the trust transfers its rights to a governmental agency at below-market rate for the agency to manage.

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Transportation System Management

Transportation system management (TSM) is a means of improving the efficiency of the existing transportation system through more effective utilization of facilities and selective reduction of user demand. TSM strategies, both individually or as a package of supportive programs, attempt to reduce existing traffic congestion and vehicle miles traveled and increase the person-carrying capacity of the transportation system. Other benefits of TSM include improved air quality, conservation of energy resources, reduction of new transportation and parking facility needs, and prolonged life of existing transportation facilities.

Generally, TSM strategies cost less than traditional capacity-increasing capital projects. To achieve the highest degree of success, transportation and planning agencies, transit providers, developers, and employers should all coordinate in the planning and implementation of TSM.

TSM policies can be used to help correlate the land use and circulation elements by assuring that planned street and highway capacities will adequately accommodate traffic generated by planned land uses. TSM programs that discourage single-passenger car commutes and that promote flexible hours at places of employment may improve the levels of service of area streets and highways by reducing peak-hour flows. If a jurisdiction's conservation element includes clean air or energy conservation policies, such provisions may be implemented through TSM programs that reduce motor vehicle trips and thereby air pollution and energy use.

EXAMPLES OF TRANSPORTATION SYSTEM MANAGEMENT TECHNIQUES

Listed below are various transportation system management (TSM) techniques aimed at improving the efficiency of circulation on highway and transit systems by improving flow, reducing congestion, and increasing the carrying capacity of existing facilities. Caltrans has divided these techniques into seven categories, each containing particular measures that may be applied to specific TSM cases.

Programs to Improve Traffic Flow

Signalization

Traffic signal synchronization

One way streets

Changeable message signs

Computerized traffic systems

Integrated single-system traffic operations systems

Reversible lanes

Ramp meters

Preferential Treatment for Transit and Other High-Occupancy Vehicle (HOV) Strategies

Exclusive highway bus or bus/carpool lanes

Contra flow HOV lanes

Reserved lanes or dedicated streets for buses and HOVs

Bus turnouts

Bus-actuated signals

Ramp meter bypass lanes for HOVs

Infrastructure Funding Mechanisms

The timing, type, and quality of development are often directly related to the availability of infrastructure and public services. The principal funding sources for local government infrastructure are taxes, benefit assessments, bonds, and exactions (including impact fees). The following discussion briefly describes each of these.

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It is important to remember that implementation measures identified in the General Plan (and the mitigation measures identified in its EIR) must be feasible to implement to be legally defensible. Cities and counties are advised to collaborate proactively with their regional public and private sector partners in order to develop and adopt multi-party fair share impact fee programs needed to finance planned transportation infrastructure improvements. In light of the legislative trends outlined in Appendix C, cities and counties are advised to base such impact fee programs on multi-modal system improvements with a demonstrated ability to reduce the VMT generated by new development.

Taxes

Taxes are either general or special. A general tax, such as the ad valorem property tax (which is capped at one percent of assessed valuation by Proposition 13), a utility tax, or a hotel tax, is collected and placed in the city's or county's general fund. General taxes are not dedicated to any specific purpose and are usually imposed to pay for capital improvements or services that will used by the entire community.

A special tax is a non-ad valorem tax that is either levied by a city or county and dedicated to a particular use or levied by a special district (e.g., a school district a transit district, etc.) to finance its activities. Special taxes often finance specific projects or services, such as flood control or ambulance service.

The Mello-Roos Community Facilities Act of 1982 authorizes a special tax that is primarily intended and commonly used to finance the infrastructure needs of new development (Gov. Code §§ 53311 - 53368.3). Under the Mello-Roos Act, cities, counties, and special districts create "community facilities districts" and levy special taxes within those districts to finance new public improvements, police and fire protection, and school construction (Id. at §§ 53313, 53313.5). The Mello-Roos Act also authorizes the issuance of bonds (Id. at §§ 53345 et seq.).

The Property Assessed Clean Energy Program (PACE) is an innovative mechanism for financing energy efficiency, water efficiency and renewable energy improvements in multifamily housing and other facilities throughout the state. For more information on PACE, see here.

Proposition 218, approved by voters in November 1996, requires a popular election in order to levy a local general tax (with a simple majority needed for approval) or a special tax (with a two-thirds majority needed for approval) (Cal. Const., art. XIII C; id., art. XIII D). It also requires a simple majority election in order to levy certain service fees, although generally not development impact fees. The effect of Proposition 218 on local financing has been profound. Prior to its passage, an election usually was not required in order to impose or increase taxes, so a jurisdiction could more easily raise needed revenue.

Benefit Assessments

Benefit assessments (also known as special assessments) are among the oldest techniques for financing the construction and maintenance of such physical improvements as sidewalks, sewers, streets, storm drains, lighting, and flood control that benefit distinct areas. Most of the numerous assessment acts authorize the use of bonds, paid for by an assessment.

Unlike general taxes, benefit assessments are not subject to a two-thirds vote requirement. Instead, as a result of Proposition 218 of 1996, a proposed assessment is subject to a ballot procedure that enables property owners to reject the proposal by majority protest among those returning ballots (Cal. Const., art. XIII D, § 4). Property owners' ballots are weighted: those who would pay a larger assessment have a greater vote (Ibid.).

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A benefit assessment cannot be levied on a parcel that does not receive a direct benefit from the improvement or service being financed (Cal. Const., art. XIII D, § 2; id., art. XIII D, §4). The amount assessed to a parcel is strictly limited to the pro-rata share of benefit being received (Cal. Const., art. XIII D, § 4). The improvement must provide a special benefit to each assessed parcel, above and beyond any general benefit that might accrue (Ibid.).

Proposition 218 created important limitations on the use of benefit assessments. Prior to levying any such assessment, OPR recommends reviewing Proposition 218 and any implementing statutes. For more information, see the following sources: Proposition 218 Implementation Guide (League of California Cities, 2007), Understanding Proposition 218 (Office of the Legislative Analyst, 1996), and A Planner's Guide to Financing Public Improvements (OPR, 1997).

Bonds

Cities, counties, school districts, and other districts may issue general obligation (G.O.) bonds for the acquisition or improvement of real property, such as buildings, streets, sewers, water systems, and other infrastructure, upon approval by two-thirds of the voters casting ballots. G.O. bonds are secured by local governments' ability to levy property taxes but may also be repaid from other revenue sources as available. School district (K-12) and community college district bonds may be passed by a 55% vote rather than a two-thirds vote pursuant to Proposition 39 of 2000 (Cal. Const., art. XIII A, § 1; id., art. XVI, § 18).

Revenue bonds are secured by the future revenues of the facility or enterprise they are financing. Wastewater treatment facilities and parking facilities are examples of the types of revenue-producing facilities that are commonly financed by revenue bonds. The Revenue Bond Law of 1941 provides for a source of funds for the construction of hospitals, water facilities, sewer plants, parking facilities, and other such public facilities (Gov. Code §§ 54300, et seq.). Because revenue bonds are secured by the proceeds from the enterprise they fund, they generally carry higher interest rates than general obligation bonds.

Lease revenue bonds are a similar tool. Instead of being issued by the city or county, lease revenue bonds are issued by a non-profit corporation or a special authority that constructs a facility and leases it to the city or county. Lease payments provide the revenue to pay off the bond. When the bond is retired, the facility is turned over to the city or county. Some local agencies have used this method to finance administrative centers and schools.

Exactions

Exactions are dedications of land, improvements, or impact fees imposed on new development to fund the construction of capital facilities. They cannot be used for operations and maintenance. The authority to impose exactions on development derives from the police power and statute. An exaction is levied to finance a specific activity, facility, or service and can only be levied once, at the time of project approval.

Exactions may only be imposed where they will advance a legitimate state interest (e.g., health, safety, and welfare issues, such as smooth traffic flow, availability of recreational facilities, sewer and water service, etc.) and are necessary to mitigate the adverse impact to that interest that would otherwise result from the project (Nollan v. California Coastal Commission (1987) 107 S.Ct. 3141). This principle is reflected in the Mitigation Fee Act, which lays out the ground rules for imposing development impact fees and other exactions (Gov. Code §§ 66000, et seq.).

While the general plan may form a policy basis for exactions, keep in mind that it does not preempt constitutional limits on regulatory "takings" or enable any exaction that would conflict with state law. The Nollan decision established that there must be

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a nexus between the exaction and the state interest being advanced. The U.S. Supreme Court, in Dolan v. City of Tigard (1994) 114 S.Ct. 2309, added a second step to the analysis: there must be a "rough proportionality" between the exaction being imposed and the relative need created by the project. Reducing Dolan to its simplest terms, the court overturned the city's requirements for bicycle path and floodway dedications because they were out of proportion to the impact on flooding and the contribution to bicycle traffic that would have resulted from the proposed expansion of a plumbing supply store, even though Tigard's comprehensive plan contained definitive policies relating to such dedications.

In Koontz v. St. Johns River Water Management District (2013) 133 S. Ct. 2586, 2599, the U.S. Supreme Court held that the "nexus" and "rough proportionality" requirements also apply to mitigation fees (i.e., exactions of money, rather than exactions of property) imposed to obtain a land use approval (accord, Ehrlich v. City of Culver City (1996) 12 Cal.4th 854). In Ehrlich, the California Supreme Court held that while the Mitigation Fee Act is the method for bringing constitutional challenges to a monetary exaction imposed as a condition of development approval in the state, the Court interprets the standards of the Mitigation Fee Act (Gov. Code § 66001) as embodying the requirements established in the Nollan and Dolan opinions (Ehrlich, supra, at pp. 867-868).

In a case decided after Koontz, the California Supreme Court held that the increased scrutiny required by Nollan and Dolan does not apply to allegations that application of an ordinance regulating land use constitutes a taking, if the ordinance does not require the landowner to convey or dedicate a property interest (CA Building Industry Assn. v. City of San Jose (2015) 61 Cal.4th 435).

In some jurisdictions, where development may adversely affect the availability of low- and moderate-income housing, exactions are levied upon developers to finance the construction of sufficient housing to alleviate that impact. San Francisco, for example, has an inclusionary housing program that mandates the construction of affordable housing or payment of in-lieu fees in accordance with a prescribed formula, which links projected employment to the number of housing units, as a condition of new downtown office development. *Public Needs and Private Dollars*, by William Abbott, Marian E. Moe, and Marilee Hansen discusses the legal basis for development exactions and offers practical, California-specific advice about calculating and imposing them.[lxviii]

Privatization

Recent years have seen a growth in the popularity of privatization--the use of private contractors or private ownership--to provide local services, such as garbage collection or street maintenance. Although not strictly a financing measure, privatization is a strategy that can help stretch limited public funds. Privatization has certain advantages: local governments need not purchase and maintain specialized machinery, personnel for specialized or seasonal tasks need not be maintained on salary, and the costs to local governments of providing services may be reduced. It also has disadvantages: special skills are needed to establish and manage the contract with the private-service provider, quality is beyond the direct control of the local government and elected officials, and, if it is necessary to replace the contractor, residents may face a period of interrupted service.

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Transportation Financing Methods

Caltrans' Division of Transportation Planning has provided the following descriptions of general categories and examples of measures to generate additional funds for transportation projects:

- Business license taxes, which are often based upon gross receipts or number of employees, since business activity and employment concentration affect traffic congestion. San Francisco has used this method to provide funds for the operation of its municipal railway.
- Parking regulations, such as neighborhood parking stickers, parking meters, and daily tickets, which can bring in substantial funds in urban areas. These revenues can be used for a variety of local transportation programs.
- Transportation impact fees (also called traffic impact mitigation fees, system development charges, and adequate public facilities fees) based upon the traffic projected to be generated and/or the cost estimates of public transportation facilities necessitated by development. In the Westchester area of Los Angeles, a one-time fee is collected for each p.m. peak-hour trip generated by new commercial and office development to cover needed areawide improvements. In Thousand Oaks, the city requires traffic mitigation fees to pay for signals, the cost of paving adjacent arterials, and off-site improvements, all of which are made necessary by the traffic resulting from new development. To offset development impacts on the local transit system, San Francisco charges a transit impact fee based on building square footage.
- Airspace leasing, which taps the value of public rights-of-way in urban areas. A governmental agency may capitalize on that value by leasing to the private sector unoccupied space over, under, or within the right-of-way. This has been used for a variety of purposes, including parks, parking lots, cellular communications, office buildings, restaurants, and public facilities.
- Public/private partnerships, development agreements, and cost-sharing, which involve developing agreements between the private and public sectors that split responsibilities for the cost of infrastructure provision, operation, and maintenance. This technique tends to be more flexible and less bound by legal constraints than other measures.
- Privatization, which may reduce or eliminate the need for public funds for transportation infrastructure if the prospect of profit exists. California's first modern toll roads were built in Orange County by private funds. Private provision of transit services is becoming more common as it is connected to specific developments. Individual developers and employers have designed and initiated traffic mitigation programs, such as traffic flow improvements, flexible work hours, and bicycle facilities. In addition, recent trends show groups of developers, employers, and businesses banding together in transportation management associations to address mutual traffic concerns in a specific area and developing programs such as those mentioned above. Such measures have been established in the cities of El Segundo, Pleasanton, and Berkeley (in cooperation with the University of California).

Consistency in Implementation

The general plan is largely implemented through zoning and subdivision decisions. In 1971, the Legislature made consistency with the general plan a determinative factor for subdivision approvals. Since then, lawmakers have continued to add consistency requirements to California's planning and land use laws. Other statutes, while not mandating consistency, require findings or a report on whether various

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local actions conform to the general plan. Consistency statutes and legal precedents are detailed below.

In order for zoning and other measures to comply with consistency requirements, the general plan itself must first be complete and adequate (i.e., it must address all required issues and be internally consistent). In 1984, the Court of Appeal ruled that a conditional use permit issued pursuant to existing zoning may be challenged if a city or county general plan does not comply with the statutory requirements that are relevant to the permit in question (Neighborhood Action Group v. County of Calaveras (1984) 156 Cal.App.3d 1176, 1184). More recently, the appeals court ruled that a general plan amendment can only be challenged on the basis of an internal general plan inconsistency when there is a nexus between the particular amendment and the claimed inconsistency in the general plan (Garat v. Riverside (1991) 2 Cal.App.4th 259, 289-90).

The California Attorney General has opined that "the term 'consistent with' is used interchangeably with 'conformity with'" (58 Ops. Cal.Atty.Gen. 21, 25 (1975)). A general rule for consistency determinations can be stated as follows: An action, program, or project is consistent with the general plan if, considering all its aspects, it will further the objectives and policies of the general plan and will not inhibit or obstruct their attainment (see Ibid.).

The city or county is responsible for determining whether an activity is consistent with the general plan. A city council's finding of a project's consistency with the plan would be reversed by a court if, based on the evidence before the council, a reasonable person could not have reached the same conclusion (No Oil, Inc. v. City of Los Angeles (1987) 196 Cal.App.3d 223).

Any given project need not be in perfect conformity with each and every policy of the general plan if those policies are not relevant or leave the city or county room for interpretation (Sequoayah Hills Homeowners Association v. City of Oakland, (1998) 23 Cal.App 4th 704, 719 (1993)). In Families Unafraid to Uphold Rural El Dorado County v. El Dorado County Board of Supervisors (1998) 62 Cal.App.4th 1332, 1341, the court held that "[t] he nature of the policy and the nature of the inconsistency are critical factors to consider." A project is clearly inconsistent when it conflicts with one or more specific, fundamental, and mandatory policies of the general plan (Id. at p. 1342).

Placer County's Online General Plan employs one method to help ensure consistency. Upon receiving a development proposal or other entitlement request, county staff enters distinguishing project features into a computer program. The program analyzes the proposal by checking for general plan and community plan consistency, identifying goals and policies by topic, and preparing a report of its results. The software can compare project characteristics to the goals and policies of the general plan and each of its elements, providing an unbiased consistency analysis.

Zoning Consistency

Counties, general law cities, and charter cities with populations of more than two million are required to maintain consistency between their zoning ordinance and their adopted general plan (Gov. Code § 65860). Charter cities with populations under two million are not subject to this mandate but may choose to enact their own code requirements for consistency (Id. at §§ 65803, 65860(d)).

Where the consistency requirement applies, every zoning action, such as the adoption of new zoning ordinance text or the amendment of a zoning ordinance map, must be consistent with the general plan. A zoning ordinance that conflicts with the general plan at the time it is enacted is "invalid at the time it is passed" (Lesher Communications v. City of Walnut Creek (1990) 52 Cal.3d 531; accord, Sierra Club v. Board of Supervisors (1981) 126 Cal.App.3d 698).

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By the same token, when a general plan amendment makes the zoning inconsistent, the zoning must be changed to re-establish consistency "within a reasonable time" (Gov. Code § 65860(c)). According to the California Supreme Court, "[t] he Planning and Zoning Law does not contemplate that general plans will be amended to conform to zoning ordinances. The tail does not wag the dog." (Lesher Communications v. City of Walnut Creek, supra, at p. 541).

State law does not prescribe what constitutes "a reasonable time" for reconciling the zoning ordinance with the general plan. OPR suggests that when possible, general plan amendments and necessary related zoning changes be heard concurrently (Gov. Code § 65862). When concurrent hearings are not feasible, OPR suggests the following time periods:

- For minor general plan amendments (those involving a relatively small area), six months.
- For extensive amendments to the general plan (such as a revision that results in the inconsistency of large areas), two years.

Zoning-related initiatives and referenda must also maintain general plan consistency. An initiative seeking to impose growth management regulations was invalidated when it was found to be inconsistent with the general plan (Lesher Communications v. City of Walnut Creek, supra). A referendum that sought to overturn a rezoning approval was invalidated because the rezoning was necessary to maintain or achieve consistency with the general plan (deBottari v. City of Norco (1985) 171 Cal.App.3d 1204; City of Irvine v. Irvine Citizens Against Overdevelopment (1994) 25 Cal.App.4th 868).

Zoning can be a useful tool in creating vibrant spaces







Image by Urban Advantage, SANDAG

Assessing and Achieving Zoning Consistency

Zoning consistency can be broken down into three parts: uses and standards, spatial patterns, and timing. These are described below.

The local agency's general plan and zoning ordinance contain text and maps that specify development standards and the proposed location of uses for the community. The development standards and uses specified for all land use categories in the zoning ordinance—density, lot size, height, and the like—must be consistent with the development standards and uses specified in the general plan's text and diagram of proposed land use. This has several implications.

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The zoning scheme, with its range of zoning districts and their associated development standards or regulations, must be broad enough to implement the general plan. For example, if a general plan contains three residential land use designations, each with its own residential intensity and density standard, then the zoning ordinance should typically have at least as many zoning districts with appropriate standards. Similarly, if the general plan identifies seismic hazard areas and calls for zoning measures to implement safety policies, the zoning ordinance must contain appropriate provisions, such as a hazard overlay zone, or specific development standards.

When a new element or major revision to a general plan is adopted, the zoning scheme should be thoroughly reviewed for consistency. It must be amended if necessary to ensure that it is adequate to carry out the new element or revisions.

When rezoning occurs, the newly adopted zoning must be appropriate and consistent with all elements of the general plan. This includes not only the land uses and development standards, but also the transportation, safety, open-space, and other objectives and policies contained in the plan.

Both the general plan diagram of proposed land use and the zoning map should set forth similar patterns of land use distribution. However, the maps need not be identical if the general plan text provides for flexibility of interpretation or for future development (*Las Virgenes Homeowners v. County of Los Angeles* (1986) 177 Cal.App.3d 312). For example, a land use diagram may designate an area for residential development while the zoning map may show the same area as predominantly residential with a few pockets of commercial use. Despite the residential designation, the commercial zoning could be consistent with the general plan if the plan's policies and standards allow for neighborhood commercial development within residential areas. Likewise, more than one zoning classification may be consistent with any one of the general plan's land use categories. For example, both R-1 (residential) and PUD (planned unit development) may be consistent zoning for a low-density residential category in the plan.

The timing of development is closely linked to the question of consistency of spatial patterns. A general plan is long term in nature, while zoning responds to shorter-term needs and conditions. In many cases, zoning will only gradually fulfill the prescriptions of the general plan. Timing may be particularly important in rural areas designated for future urbanization. If the general plan contains policies regarding orderly development, adequate public services, and compact urban growth, rezoning a large area from a low-intensity use (e.g., agriculture) to a more intensive one (e.g., residential) before urban services are available would be inconsistent with the general plan. Conversely, an inconsistency may be created when general plan policies promote high-intensity development in an area but the jurisdiction instead permits low-intensity uses.

Since timing can be a problem, general plans should provide clear guidance for the pace of future development, perhaps by using five-year increments or by establishing a set of conditions to be met before consistent zoning would be considered timely.

Local governments have devised a number of ways to evaluate and achieve zoning consistency. A fairly common approach is to employ a matrix comparing the general plan's land use categories and associated development standards with the zoning districts and their corresponding zoning ordinance development standards. To indicate the degree of zoning consistency with the plan, many matrices feature categories ranging from "highly compatible" to "clearly incompatible." An intermediate category, "conditionally compatible," could reflect zoning that by itself is not compatible but could become compatible if measures such as a PUD overlay were imposed to reduce or eliminate potential conflicts.

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The matrix approach has its limitations. By itself, a matrix cannot answer questions about the zoning's compatibility with the objectives, policies, and programs of the general plan, nor can it answer questions about timing. A number of local governments use a checklist to evaluate the consistency of individual zoning proposals. The checklist repeats the major goals and policies of the general plan and rates the degree to which the proposed zoning conforms to each of them (e.g., "furthers," "deters," "no effect"). A point system that rates development projects by their level of consistency with the goals, objectives, and policies of the general plan is a similar approach.

Subdivision Consistency

Before a city or county may approve a subdivision map (including parcel maps) and its provisions for design and improvement, the city or county must find that the proposed subdivision map is consistent with the general plan and any applicable specific plans (Gov. Code § 66473.5). These findings can only be made when the local agency has officially adopted a general plan and the proposed subdivision is "compatible with the objectives, policies, general land uses and programs specified in such a plan" (Ibid.).

Government Code sections 66474 and 66474.61 require a city or county to deny approval of a tentative map if it makes either of the following findings: the proposed map is not consistent with applicable general and specific plans or the design or improvement of the proposed subdivision is not consistent with applicable general and specific plans.

Enforcement and Remedies

Any resident or property owner may sue to enforce the requirements for the adoption of an adequate general plan (58 Ops.Cal.Atty. Gen. 21 (1975)). The same is true for enforcing the requirements that zoning and subdivisions must be consistent with the general plan (Gov. Code §§ 65860(b), 66499.33). As the state's chief law enforcement officer, the Attorney General may do the same (58 Ops. Cal.Atty.Gen. 21; Cal. Const., art. V, § 13). Additionally, persons living outside a city have standing to sue if the city's zoning practices exclude them from residing in the city or raise their housing costs by adversely affecting the regional housing market (Stocks v. City of Irvine (1981) 114 Cal.App.3d 520).

The courts may impose various remedies for failure to have a complete and adequate general plan (Gov. Code §§ 65750, et seq.). One is a writ of mandate to compel a local government to adopt a legally adequate general plan. The courts also have general authority to issue an injunction to limit approvals of additional subdivision maps, parcel maps, rezonings, and public works projects or (under limited circumstances) the issuance of building permits pending adoption of a complete and adequate general plan (Id., 58 Ops.Cal.Atty.Gen. 21 (1975), Friends of "B" Street v. City of Hayward (1980) 106 Cal.App.3d 988, *Camp v. Mendocino* (1981) 123 Cal.App.3d 334). Where a court finds that specific zoning or subdivision actions or public works projects are inconsistent with the general plan, it may set aside such actions or projects. Under certain circumstances, the court may impose any of these forms of relief prior to a final judicial determination of a general plan's inadequacy (Gov. Code § 65757).

Annual Progress Reports

After the general plan has been adopted, Government Code section 65400(a)(2)(A) requires the planning agency to provide an annual report to their legislative body, OPR, and HCD on the status of the plan and progress in its implementation. The report must detail

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progress in meeting the jurisdiction's share of regional housing needs determined pursuant to Government Code section 65584 and local efforts to remove governmental constraints to the maintenance, improvement, and development of housing pursuant to Government Code section 65583(c)(3) (Id. at § 65400(a)(2)(B)).

The annual progress report must be provided to the legislative body, OPR, and HCD on or before April 1 of each year. Jurisdictions must report on a calendar-year basis (January 1 through December 31). Jurisdictions are able to complete the housing element portion of the annual progress report online through the Department of Housing and Community Development's online portal. While there is a standard format for the housing element portion of the annual report, there is no standardized format for the preparation of the annual progress report for the rest of the general plan. The form and content of the report may vary based on the circumstances, resources, and constraints of each jurisdiction. This section is meant to provide general guidance to cities and counties in the preparation of their annual progress reports.

Purpose of the Report

- To provide enough information to allow local legislative bodies to assess how the general plan is being implemented in accordance with adopted goals, policies, and implementation measures.
- To provide enough information to identify necessary course adjustments or modifications to the general plan as a means to improve local implementation.
- To provide a clear correlation between land use decisions that have been made during the 12-month reporting period and the goals, policies, and implementation measures contained in the general plan.
- To provide information regarding local agency progress in meeting its share of regional housing needs and removing governmental constraints to the development of housing pursuant to Government Code section 65583(c)(3).

Format of the Report (General)

The following describes ways in which various cities and counties have organized and formatted their annual progress reports:

- **Focus on individual policies and implementation measures**: Provide a comprehensive listing of all general plan policies, including those which have been incorporated by reference, categorized by element, with a commentary on how each policy was implemented during the reporting period (i.e., a description of the activities underway or completed for implementation of each policy). This listing can most easily be accomplished by using a table format.
- **Focus on development activities and projects approved**: Provide comprehensive listing of all development applications that the planning agency received and processed with commentary on how the agency's actions on these development applications further the goals, policies, and/or implementation measures of the general plan. Link the major projects, including public projects, to the general plan using policy numbers or by element.
- **Focus on general plan elements**: Provide a general summary of each of the mandatory and optional elements of the general plan with a brief description of various actions taken by the agency (e.g., development application approvals, adoption of ordinances or plans, agency-initiated planning studies, etc.) that advanced specific goals and policies of each element.
- **Broad annual report format**: Incorporate the annual progress report into a broadly focused annual report on all of the

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activities and programs of the jurisdiction, drawing upon data and sources such as an annual performance report on budgeting, processing of land use entitlements, redevelopment activities, housing construction, or other programs or "state of the city/county" reports.

CONSISTENCY PROVISIONS IN STATE LAW AND LEGAL PRECEDENTS

All statutory references are to the California Government Code unless otherwise noted.

Agricultural Preserves

- § 51234 requires that agricultural preserves established under the Williamson Act be consistent with the general plan.
- § 51282 requires a city or county, when approving a Williamson Act contract cancellation, to make a finding that the proposed alternate use is consistent with the general plan.

Capital Improvements

- §§ 65401 and 65402 require planning agencies to review and report on the consistency with the applicable general plan of proposed city, county, and special district capital projects, including land acquisition and disposal.
- § 65103(c) requires planning agencies to review annually their city or county capital improvement programs and other local agencies' public works projects for consistency with the general plan.
- Friends of B Street v. City of Hayward (1980) 106 Cal.App.3d 988 held that a city's capital facilities projects must be consistent with the city's general plan.
- § 53090, et seq., require that most public works projects undertaken by special districts, including school districts, must be consistent with local zoning, which in turn must be consistent with the general plan. A school district board may render a zoning ordinance inapplicable with respect to school classroom facilities (§ 53094). A special district governing board may render the zoning ordinance inapplicable if it makes a finding after a public hearing that there is no feasible alternative to the project (§ 53096). State entities are an exception to this consistency requirement (Rapid Transit Advocates, Inc. v. Southern California Rapid Transit District (1986) 185 Cal.App.3d 996).

Condominium Conversion

- § 66427.2 requires that when the general plan contains objectives and policies addressing the conversion of rental units to condominiums, any conversion must be consistent with those objectives and policies.

Development Agreements

- § 65867.5 requires development agreements to be consistent with the general plan.

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Consistency Provisions in State Law and Legal Precedents, Continued

Housing Authority Projects

- Health and Safety Code § 34326 declares that all housing projects undertaken by housing authorities are subject to local planning and zoning laws.

Integrated Waste Management

- Public Resources Code section 41701 states that if a county determines that the existing capacity of a solid waste facility will be exhausted within 15 years or if the county desires additional capacity, then the countywide siting element of the county's hazardous waste management plan must identify an area or areas, consistent with the applicable general plan, for the location of new solid waste transformation or disposal facilities or for the expansion of existing facilities.
- Public Resources Code section 41702 states that an area is consistent with the city or county general plan if:
    1. The city or county has adopted a general plan.
    2. The area reserved for the new or expanded facility is located in, or coextensive with, a land use area designated or authorized by the applicable general plan for solid waste facilities.
    3. The adjacent or nearby land use authorized by the applicable general plan is compatible with the establishment or expansion of the solid waste facility.

On-Site Wastewater Disposal Zones

- Health and Safety Code section 6965 requires a finding that the operation of an on-site wastewater disposal zone created under Health and Safety Code section 6950, et seq., will not result in land uses that are inconsistent with the applicable general plan.

Park Dedications

- § 66477 enables local governments to require as a condition of subdivision and parcel map approval the dedication of land or the payment of in lieu fees for parks and recreational purposes if the parks and recreational facilities are consistent with adopted general or specific plan policies and standards.

Parking Authority Projects

- Streets and Highway Code section 32503 specifies that parking authorities, in planning and locating any parking facility, are subject to the relationship of the facility to any officially adopted master plan or sections of such master plan for the development of the area in which the authority functions to the same extent as if it were a private entity.

Planning Commission Recommendations

- § 65855 requires that the planning commission's written recommendation to the legislative body on the adoption or amendment of a zoning ordinance include a report on the relationship of the proposed adoption or amendment to the general plan.

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Consistency Provisions in State Law and Legal Precedents, Continued

Reservations of Land Within Subdivisions

- § 66479 specifies that reservations of land for parks, recreational facilities, fire stations, libraries, and other public uses within a subdivision must conform to the general plan.

Special Housing Programs

- Health and Safety Code section 50689.5 specifies that housing and housing programs developed under Health and Safety Code section 50680, et seq., for the developmentally disabled, mentally disordered, and physically disabled must be consistent with the housing element of the general plan.

Specific Plans

- § 65359 requires that a specific plan covering an area affected by a general plan amendment shall be reviewed and amended as necessary to make it consistent with the applicable general plan.
- § 65454 specifies that a specific plan may not be adopted or amended unless the proposed plan is consistent with the general plan.

Format of the Report (Housing Element)

In 2010, the State Department of Housing and Community Development adopted regulations on the preparation of the annual housing element progress report (Cal. Code Regs., tit. 25, §§ 6200, et seq.). All housing element progress reports must conform to these regulations. Forms, instructions, and a copy of the regulations can be found at the HCD's website at http://www.hcd.ca.gov/community-development/housing-element/index.shtml. In general, the following information is required for housing element reporting:

- Listing of building permits issued for the calendar year by income category.
- Demonstration of the progress towards meeting the regional housing need.
- A description of the progress in implementation of the policies and programs in the housing element.
- A city or county that is the successor to a former redevelopment agency shall include financial and housing information specified at Health and Safety Code section 34176.1(f) in its annual report.

The report must be considered at an annual public meeting before the legislative body where members of the public may provide oral testimony and written comments.

Contents of the Report

Each jurisdiction should determine which locally relevant issues are important to include in the annual report. The following items may be useful in the annual progress report:

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- Introduction.
- Table of contents.
- Date of presentation to and acceptance by the local legislative body.
- List of major agency-initiated planning activities that were initiated, in progress, or completed during the reporting period (i.e., master plans, specific plans, master environmental assessments, annexation studies, and other studies or plans carried out in support of specific general plan implementation measures). Include a brief comment on how each of these activities advances the goals, policies, and/or implementation measures contained in the general plan. Provide specific reference to individual elements where applicable.
- List each of the general plan amendments that have been processed, along with a brief description and the action taken (e.g., approval, denial, etc.). This listing should include agency-initiated as well as applicant-driven amendments.
- List each of the development applications that have been processed, along with a brief description, the action taken (e.g., approval, denial, etc.), and a brief comment on how each action furthers the goals, policies, and/or implementation measures of the general plan. Provide specific reference to individual elements where applicable.
- Identify significant projects built within jurisdiction but not approved by jurisdiction, such as large school facilities not approved by city or county, but affecting general plan.
- Identify priorities for land use decision-making that have been established by the local legislative body (e.g., passage of moratoria, emergency ordinances, development of community or specific plans, etc.).
- The annual progress report should identify goals, policies, objectives, standards, or other plan proposals that need to be added, deleted, amended, or otherwise adjusted.

Submitting the Report to OPR and HCD

Annual progress reports can be submitted to OPR in either electronic or paper format. Preference is for electronic reporting. If you wish to submit your annual report to OPR electronically, e-mail it to state.clearinghouse@opr.ca.gov. Word, Excel, PowerPoint or PDF are the only acceptable file formats. Printed copies of the annual report should be sent to Governor's Office of Planning and Research, State Clearinghouse and Planning Unit, P.O. Box 3044, Sacramento, CA 95812-3044.

A copy of the report must also be sent to the Department of Housing and Community Development via their online system, or printed copies to Division of Housing Policy Development, P.O. Box 952053, Sacramento, CA 94252-2053

Coastal Act Compliance for those Jurisdictions Located in the Coastal Zone

CALIFORNIA COASTAL ACT

The California Coastal Act of 1976 (Public Resources Code section 30000 et seq.) was enacted to "[p]rotect, maintain, and, where feasible, enhance and restore the overall quality of the coastal zone environment and its natural and artificial resources" (Id. at § 30001.5). The Coastal Act applies to the coastal zone, defined in section 30103(a) as a strip along the California coast generally "extending seaward to the state's outer limit of jurisdiction, including all offshore islands, and extending inland generally 1,000 yards from the mean high tide line of the sea." In significant coastal estuarine habitat and recreation areas, the zone may extend further inland by as much as five miles, and in developed urban areas the zone may extend inland less than 1000 yards (Ibid.). The legal coastal zone boundary is delineated on a set of maps adopted by the Legislature and located at the Coastal Commission's San

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Francisco office. The coastal zone excludes the area of San Francisco Bay, which is under the jurisdiction of the San Francisco Bay Conservation and Development Commission. The Coastal Act otherwise applies to all those portions of cities (charter and general law) and counties that lie within the coastal zone (70 Ops.Cal.Atty.Gen. 220 (1987)).

The Coastal Commission, in partnership with coastal cities and counties, plans and regulates the use of land and water in the coastal zone. Under the Coastal Act, Local Coastal Program (LCP) planning requirements create a unique partnership between state and local government. The development of an LCP by a local government is the primary mechanism to implement the state's coastal management policies at the local level. The Coastal Act declares that "[t]o achieve maximum responsiveness to local conditions, accountability, and public accessibility, it is necessary to rely heavily on local government and local land use planning procedures and enforcement" in carrying out the state's coastal management objectives and policies (Pub. Resources Code § 30004). To this end, the Act requires each of the 76 local governments (15 counties and 61 cities) lying wholly or partly within the coastal zone to prepare, with maximum public participation, an LCP to guide future development in the coastal zone. While local government develops LCPs, the Coastal Commission must certify that the LCP is consistent with the state Coastal Act before an LCP may be implemented. Once certified, local government assumes responsibility to issue most local coastal development permits pursuant to the certified LCP, with the Commission retaining limited permit and appeal authority.

As defined in the Coastal Act, an LCP means "a local government's (a) land use plans, (b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of the Coastal Act at the local level" (Pub. Resources Code § 30108.6).

An LCP must include a Land Use Plan (LUP) which, by definition, means "the relevant portions of a local government's general plan or local coastal element which are sufficiently detailed to indicate the kinds, location, and intensity of land uses, the applicable resource protection and development policies, and where necessary, a listing of implementing actions" (Pub. Resources Code § 30108.5). Each LCP must include "a specific public access component to assure that maximum public access to the coast and public recreation areas is provided" (Id. at. § 30500(a)).

The implementation plan (IP) portion of an LCP, including zoning, must conform with and be adequate to carry out the LUP (Pub. Resources Code § 30513). This is a distinctive provision of the Coastal Act. The Act does not just merely state that the zoning must be consistent with the land use plan as is the case for general plans; rather, the Act states that zoning must conform with and be adequate to carry out the LUP.

It is possible that a zoning ordinance would be "consistent with" a general plan designation but not conform with and be adequate to carry out the general plan. For example, zoning code requirements establishing height limits and setback requirements may be consistent with LUP policies regarding protection of public views and community character, but may not by themselves be adequate to carry out those policies. Similarly, zoning code provisions establishing maximum density may be consistent with LUP density limits but be inadequate to address other LUP policies regarding the protection of habitat or the adequacy of public services to support new development. Finally, the adequacy to carry out a certified LUP may hinge on the use of mandatory "shall" or "must" language, rather than "should," where required. The development of zoning ordinances to satisfy the Coastal Act, therefore, must begin with precisely drawn policies in the Land Use Plan, which in turn reflect the specific policies of the Coastal Act. The clearer

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the land use plan designations and policy statements are, the easier it will be to develop zoning ordinances that provide clarity for decision makers, property owners, and the public.

The Commission's methodology for preparing LCPs can be found at Title 14, Division 5.5 of the California Code of Regulations, sections 13506 through 13514. Amendments to certified LCPs must be submitted to the Commission for review and, in the case of major amendments, certification (Pub. Resources Code § 30514). LCP amendments that are minor in nature or that require rapid or expeditious action are reviewed by the Commission's Executive Director and become valid if the Commission concurs with the Executive Director's determination (Id. at § 30514; Cal. Code Regs., tit. 14, §§ 13554, 13555).

The Coastal Act has special requirements for the coastal zone portions of the ports of Port Hueneme, Long Beach, Los Angeles, and the San Diego Unified Port District. Rather than preparing LCPs, these ports must prepare master plans and have them certified by the Coastal Commission (Pub. Resources Code §§ 30711, 30714). With certain exceptions, each development within a port requires a development permit and must conform to the port's master plan (Id. at §§ 30715(a), 30715.5). The cities and counties that have these ports within their jurisdictions must, for informational purposes, incorporate the master plan into their LCPs (Id. at § 30711(a)).

The four ports identified above and in Chapter 8 of the Coastal Act all have certified Port Master Plans and intergovernmental coordination was part of the original certification. How LCPs address these Port Master Plans for informational purposes all differ and reflect local conditions. However, recognizing Port Master Plans in LCPs for informational purposes offers an important benefit in that it can make clear the different jurisdictions and standards of review of proposed coastal developments. On occasion, when appropriate and the conditions warrant, the Commission can review both an LCP Amendment and a Port Master Plan Amendment at the same hearing when the development affects both jurisdictions.

With certain exceptions, development within the coastal zone is subject to a coastal development permit issued either by a local government pursuant to a certified LCP or, where no certified LCP exists, by the Coastal Commission (Pub. Resources Code §§ 30519(a), 30600(d)). A city or county that lacks a certified LCP surrenders a good deal of planning authority within the coastal zone.

Some decisions made under an LCP may be appealed to the Commission (PRC, § 30603). Additionally, the Commission retains permanent jurisdiction over development on coastal zone tidelands, submerged lands, and public trust lands (Pub. Resources Code § 30519(b)).

RELATION BETWEEN THE COASTAL ACT AND THE GENERAL PLAN

Coastal cities and counties are subject to both planning and zoning laws and the California Coastal Act. The Coastal Act has specific requirements that in the coastal zone are different than the Government Code provisions that the local government may be more familiar with in developing general plans. Therefore it is important to keep in mind that in the coastal zone, a local government's general plan may have to be modified if it is to be certified as part of an LCP that must meet Coastal Act requirements. The Coastal Act specifies that coastal Land Use Plan (LUP) provisions be "sufficiently detailed to indicate the kind, location, and intensity of land uses . . ." (Pub. Resources Code § 30108.5).

The contents of coastal LUPs overlap some of the required provisions of general plans but not all are duplicative. For instance, the Coastal Act requires policies concerning diking, dredging, filling, and shoreline structures (Pub. Resources Code §§ 30233, 30235), while planning and zoning law usually does not.

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To govern effectively in the coastal zone, a general plan should be consistent with the local government's Local Coastal Program (LCP). Therefore, when developing or amending a general plan, local governments should coordinate closely with the California Coastal Commission to assure that general plan provisions intended to apply in the coastal zone are consistent with the governing LCP and California Coastal Act as relevant.

While there are requirements under the Coastal Act and regulations for the content of LCPs, there is no set format. Some communities have adopted separate coastal elements within their General Plans. Others have incorporated coastal plan policies, plan proposals, and standards directly into the general plan's land use, open-space, and conservation elements and submitted those general plan elements as the LCP for certification. A third option is to adopt a specific plan within the coastal zone. Given the diversity of local coastal jurisdictions there is no "one size fits all" approach, but the requirements of the Coastal Act must be met in completing the LCP. In the Commission's experience, with a few exceptions for local jurisdictions that are wholly within the coastal zone, maintaining the LCP as a separate element of the general plan results in a more clear understanding of the LCP requirements and fewer issues on appeals. In order to encourage general plan amendments necessary to preparing a certified LCP, such actions do not count toward the limit of four general plan amendments per year (Gov. Code § 65358(b), (d)(3)).

Some communities have adopted separate coastal elements. (See for example the LCP for the City of Malibu.) Others have incorporated coastal plan policies, plan proposals, and standards directly into the general plan's land use, open-space, and conservation elements and submitted those general plan elements as the LCP for certification. (For example see the LCP for the Santa Monica Mountains segment of Los Angeles County.) This LUP is a discrete part of the County's general plan that applies just to the Santa Monica Mountains geographic LCP segment within the coastal zone. The subsections of the LUP are organized into elements, matching the applicable general plan elements. The certified Implementation Plan (IP) of the LCP for this segment is similarly a discrete segment of the County's planning and zoning ordinance. The IP contains all of the applicable standards for the geographic area of the LCP segment, without reference to the general zoning ordinance standards.

A third option is to adopt a specific plan within the coastal zone for the Implementation Portion of an LCP. Examples of this are found in the City of Carlsbad LCP (for Carlsbad Ranch), the City of Huntington Beach LCP (for the Downtown Specific Plan) and others.

There is a special situation where a community has a certified coastal LUP but has not prepared the necessary implementing measures to obtain full LCP certification. The Coastal Act requires that the Commission delegate authority to issue permits within 120 days after the effective date of certification of an LUP, and that the local government shall adopt ordinances that set procedures for issuing coastal development permits (Pub. Resources Code § 30600.5(b), (f)). If the local government does not adopt ordinances establishing permitting procedures, permitting authority remains with the Commission. Further, if such communities adopt general plan amendments without updating the LUP (through amendments that must be certified by the Coastal Commission), discrepancies may arise between land uses and densities authorized under the general plan and those authorized in the coastal LUP. If the general plan and coastal LUP diverge significantly, problems may arise when a project applicant applies to the Commission for a coastal development permit. Communities may avoid these problems by reviewing all general plan amendments affecting the coastal zone for consistency with their coastal LUP. Communities may more efficiently control their planning process and obtain the authority to issue coastal development permits locally by completing their LCPs and seeking full certification from the Coastal Commission.

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HOUSING REQUIREMENTS IN THE COASTAL ZONE

LCPs are not required to include housing policies or programs (Pub. Resources Code § 30500.1). The Government Code, however, contains special requirements for the protection and provision of low- and moderate-income housing within the coastal zone (Gov. Code § 65590). Local governments are responsible for implementing those requirements.

Government Code section 65588, subdivisions (c) and (d), state that when coastal jurisdictions update a housing element, they must document the number of low- and moderate-income housing units converted or demolished and the number of replacement units provided, including specific numbers in the coastal zone. This helps the locality determine whether affordable housing stock in the coastal zone is being protected and provided as required by Government Code Section 65590. This analysis should also reflect whether any housing in the coastal zone was converted or demolished for a nonresidential use that is not "coastal dependent" as defined in Public Resources Code section 30101 (Gov. Code § 65590(c)).

In 2003, the Coastal Act was modified to add Public Resources Code section 30604, subdivisions (f) and (g), directing the Commission to "encourage housing opportunities for persons of low and moderate income" and precluding the local government or the Commission from reducing density bonuses below what is otherwise allowable in the Government Code, unless specific findings are made regarding Chapter 3 policies:

(f) The commission shall encourage housing opportunities for persons of low and moderate income. In reviewing residential development applications for low- and moderate-income housing, as defined in paragraph (3) of subdivision (h) of Section 65589.5 of the Government Code, the issuing agency, or the commission, on appeal, may not require measures that reduce residential densities below the density sought by an applicant if the density sought is within the permitted density or range of density established by local zoning plus the additional density permitted under Section 65915 of the Government Code, unless the issuing agency or the commission on appeal makes a finding, based on substantial evidence in the record, that the density sought by the applicant cannot feasibly be accommodated on the site in a manner that is in conformity with Chapter 3 (commencing with Section 30200) or the certified local coastal program.

(g) The Legislature finds and declares that it is important for the commission to encourage the protection of existing and the provision of new affordable housing opportunities for persons of low and moderate income in the coastal zone.

Since that time, the Commission has interpreted these provisions as direction to encourage affordable housing by supporting it, including density bonuses, unless there is a specific inconsistency with the policies of Chapter 3, but not to require authorization of density bonuses beyond what is allowed by the Government Code.

Although the 1981 amendments to the Coastal Act (repealing former Section 30213) repealed the Commission's ability to require affordable housing and Section 30500.1 prohibits the Commission from requiring affordable housing policies in LCPs, nothing precludes local governments from submitting Land Use Plan Amendments with provisions that protect and encourage affordable housing consistent with the Chapter 3 policies of the Coastal Act. Once certified, these Land Use Plan policies become the standard of review for both implementation plan amendments and coastal development permits issued by the local government and the Commission on appeal.

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The Coastal Act includes many policies that support "smart growth," among them: concentrating development (Pub. Resources Code § 30250), establishing urban-rural boundaries (Id. at § 30241), enhancing public access to the coast through facilitation of transit and non-automobile circulation within developments (Id. at § 30252), and minimizing energy use and vehicle miles travelled (Id. at § 30253). Other Coastal Act policies assure that smart growth housing development is undertaken consistent with the protection of public access and coastal natural and scenic resources. An example of this is illustrated in the following LCP Amendment action on the City of Capitola LCP. See reports: Part 1 and Part 2.

The Commission has taken numerous other actions that address provision of accessory dwelling units, reasonable accommodations and density bonuses/inclusionary housing. Some examples of these can be found in the Commission LUP Update Guide.A report on the Commission's housing program history is contained as an Attachment to the Executive Director's report of April 15, 2015.

While the Coastal Act does not define what constitutes "maximum public participation" there are numerous provisions in the Coastal Act and the California Code of Regulations (Title 14) that specify standards for preparation, review and submittal of documents, for required noticing, scheduling and for conduct of hearings. For example, the Coastal Act:

States the Legislature's findings and declarations that the public should fully participate and that the process should include the widest opportunity for public participation (Pub. Resources Code § 30006).

Outlines the Commission's duties to ensure full and adequate public participation (Pub. Resources Code § 30339).

Mandates opportunities for public participation in a LCP program, including requirements that a local government must, prior to submittal of the program, hold a public hearing or hearings on that portion of the program that has not been subjected to public hearings within four years of such submission (Pub. Resources Code §§ 30500, 30503, 30504).

Requires submittal pursuant to a resolution (Pub. Resources Code § 30510(a)).

Requires public participation in port planning and decisions (Pub. Resources Code § 30711).

In addition, the California Code of Regulations (Title 14) includes requirements for public participation in carrying out the Coastal Act provisions.

SEA LEVEL RISE IN THE COASTAL ZONE

As part of an LCP, update, or amendment, local governments should evaluate and plan for sea level rise. Sea level rise potentially increases the risk of coastal hazards as identified in Public Resources Code Section 30253 (geologic flood, and fire), as well as potentially increasing impacts on coastal resources identified throughout the Coastal Act. The analysis can be performed through a vulnerability assessment, climate action plan or other document and is best coordinated with the guidance in the general plan guidelines on how to address climate change risk, vulnerability and adaptation. The Coastal Commission maintains Sea Level Rise Policy Guidance on how to plan for sea level rise within an LCP or permit at http://www.coastal.ca.gov/climate/SLRguidance.html.

Additional information on LCP planning, such as updating certified LCPs and Best Practices for amending LCPs, can be found here: https://www.coastal.ca.gov/rflg/.

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10 CEQA

Designing Healthy, Equitable, Resilient, and Economically Vibrant Places

Introduction

Because general plans govern the type and location of new development, new or amended general plans may lead to significant changes in the environment. The California Environmental Quality Act, also known as "CEQA," requires cities and counties to study those potential environmental impacts as part of the adoption or update process (Pub. Resources Code §§ 21000, et seq.; see also CEQA Guidelines § 15378). Where those impacts may be significant, the city or county must prepare an environmental impact report (EIR). The primary purpose of an EIR is to inform decision-makers and the public of the potential significant environmental effects of a proposal and possible ways to reduce or avoid any significant environmental effects. This information enables environmental considerations to influence policy development, thereby ensuring that the plan's policies will address potential environmental impacts and the means to avoid them. This chapter addresses some key considerations for complying with CEQA in preparing a new general plan, a general plan update, or a general plan amendment. Some of those considerations include:

- Identifying major points of intersection between the general plan and CEQA processes;
- Comparing different types of EIRs to determine which might best suit the needs of the city or county and that would enable use of several streamlining mechanisms for later development approvals, and
- Mitigation Monitoring and General Plan Implementation

Key CEQA Policies to Remember

Before describing specific considerations for CEQA review of general plans, it is useful to first review several key policies underlying CEQA that are relevant to the general plan process.

- **CEQA should be integrated into planning processes and guide development of the plan itself.** (Pub. Resources Code § 21003(a)). Information developed as part of the CEQA process should influence the development of general plan policies. CEQA should not just be a post hoc rationalization of decisions that have already been made. (Laurel *Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal. 3d 376, 395 ("the later the environmental review process begins, the more bureaucratic and financial momentum there is behind a proposed project, thus providing a strong incentive to ignore environmental concerns that could be dealt with more easily at an early stage of the project")).

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- **While the CEQA process should occur early enough to influence development of the general plan, it should not happen until environmental review will produce meaningful information.** (CEQA Guidelines § 15004). For example, an EIR will not provide meaningful information if it is prepared before actual policy language is developed.
- **The CEQA process should be efficient.** (Pub. Resources Code § 21003(f)). "An EIR on a project such as the adoption or amendment of a ... local general plan should focus on the secondary effects that can be expected to follow from the adoption, or amendment, but the EIR need not be as detailed as an EIR on the specific construction projects that might follow." (CEQA Guidelines § 15146(b)). Further, once a general plan EIR has been certified and the general plan adopted, the general plan EIR should be used to inform and streamline CEQA review for later project applications.

These policies can help guide planners as they confront questions about precisely how to conduct environmental review for a general plan process.

Considerations for General Plan EIRs

The procedure for preparing and using an EIR is described in detail in the state CEQA Guidelines (Title 14, California Code of Regulations, §§ 15000, et seq.). A summary of the CEQA process is provided in the California Planning Guide (OPR, Dec. 2005). The following discussion highlights some of the key points that are particularly important when preparing an EIR for a new general plan, an element, or a comprehensive revision.

A general plan for which an EIR is prepared is considered a project of statewide, regional, or areawide significance (CEQA Guidelines § 15206). This means that the lead agency must conduct at least one scoping meeting and the EIR must be circulated through the State Clearinghouse for review by relevant state agencies. In addition, the city or county must consult with transportation planning agencies during the development of the general plan and EIR (Id. at § 15086(a)(5)).

The plan EIR, to a certain extent, can be seen as describing the relationship between the proposed density and intensity of land use described by the plan and potential environmental constraints within the planning area.

Baseline

The EIR must describe the existing local and regional physical environment, as they exist when the notice of preparation of the EIR is published, emphasizing those features that are likely to be affected by the plan and the environmental constraints and resources that are rare or unique to the area (CEQA Guidelines §§ 15125(a), 15125(c)). It should describe existing infrastructure, such as roads, water systems, and sewage treatment facilities, along with their capacities and current levels of use. It should also discuss any inconsistencies between the proposed plan and adopted regional plans as they may relate to environmental issues (Id. at § 15125(d)). For example, cities and counties should discuss any inconsistencies between the proposed general plan and the regional transportation plan including any applicable sustainable communities strategy.

When a new general plan or a revision is being considered, the EIR must evaluate the proposed plans or revision's effects on both the existing physical environment and the environment envisioned by any adopted plan (*Environmental Planning and Information Council v. County of El Dorado* (1982) 131 Cal.App.3d 354; see also CEQA Guidelines § 15125(e)). When a city or county proposes to amend a

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general plan, the environmental analysis should focus on the changes proposed in the amendment. Reanalysis of unchanged portions of the general plan is not required (*Black Property Owners Assn. v. City of Berkeley* (1994) 22 Cal. App. 4th 974).

Level of Detail in Analysis

The general plan EIR need not be as detailed as an EIR for the specific projects that will follow (CEQA Guidelines § 15146). Its level of detail should reflect the level contained in the plan or plan element being considered (*Rio Vista Farm Bureau Center v. County of Solano* (1992) 5 Cal.App.4th 351). However, the lead agency cannot defer its analysis of any significant effect of the general plan to later-tiered EIRs (*Stanislaus Natural Heritage Project v. County of Stanislaus* (1996) 48 Cal.App.4th 182). "With a good and detailed analysis of the [general plan], many subsequent activities could be found to be within the scope of the project described in the [general plan] EIR, and no further environmental documents would be required." (CEQA Guidelines § 15168(c)(5); see also id. at § 15183.3 (streamlining for infill projects)).

Mitigation

The EIR must identify mitigation measures and alternatives to avoid or minimize potential impacts, to the extent feasible. The general plan EIR is a particularly useful tool for identifying measures to mitigate the cumulative effects of new development. For example, a general plan might anticipate a significant increase in industrial employment in the community. If this proposal would lead to increased automobile commuting, the EIR could identify measures to reduce peak-hour traffic volumes, such as new transit routes or improved bicycle facilities. Where other agencies are responsible for mitigating the effects of the general plan, they should be identified in the EIR. Pursuant to Public Resources Code section 21081.6, the general plan must incorporate the approved mitigation measures identified in the EIR into its policies and programs.

Alternatives

The EIR for a general plan must describe a reasonable range of alternatives and analyze each of their effects (CEQA Guidelines § 15126.6). Each of the alternatives should avoid or lessen one or more of the significant effects identified as resulting from the proposed general plan. A reasonable range of alternatives would typically include different levels of density and compactness, different locations and types of uses for future development, and different general plan policies.

The alternatives should not all have the same level of impacts. This discussion of alternatives will enable environmental considerations to influence the ultimate design of the general plan.

The EIR must also evaluate the "no project" alternative (CEQA Guidelines § 15126.6(e)). This would describe what physical changes might reasonably be expected to occur in the foreseeable future if the new or revised general plan were not adopted, based on the existing general plan (if any) and available infrastructure and services. This "no project" alternative must also evaluate how the changing environment, such as through climate change and drought, may affect the community if a new or revised general plan were not adopted.

Cumulative Impacts

The EIR must analyze the cumulative effects of the plan's land use designations, policies and programs on the environment. For example, a general plan authorizing rural residential uses in or near wild lands could cumulatively increase the potential severity of fire damage by hindering wildfire suppression efforts. Increasing reliance on automobile use in a general plan, through dispersed land uses for example, could contribute not only to cumulative air quality impacts in non-attainment areas and increased energy use, but also indirect effects such as increased water pollution (due to runoff from roads) and adverse effects to public health (due to

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decreased physical activity). When cumulative impacts are adequately addressed in a general plan EIR, further analysis should not be needed at the project level (See CEQA Guidelines § 15183(j)).

Growth Inducing Impacts

Growth-inducing impacts must also be analyzed (Pub. Resources Code § 21100(b)(5); CEQA Guidelines § 15126.2(d)). These may include any policies and programs of the general plan likely to stimulate community growth and development. Examples include policies and programs leading to street and highway improvements in undeveloped areas, wastewater treatment plant expansion, or expansion of employment in basic industries, any of which is likely to increase pressure for or facilitate residential and other development.

Irreversible Environmental Changes

The environmental analysis for a general plan must address any irreversible environmental changes. For example, once a general plan designates certain areas for development and that development occurs, such areas are unlikely to ever be returned to a natural condition. Thus, the environmental effects of locking in certain uses for the foreseeable future must be analyzed in a general plan's environmental analysis. "Irretrievable commitments of resources should be evaluated to assure that such current consumption is justified." (CEQA Guidelines § 15126.2(c), see also Pub.

Resources Code §§ 21100.1, 21000(a) ("maintenance of a quality environment for the people of this state now and in the future is a matter of statewide concern") (emphasis added)).

Timing

The purpose of preparing an environmental analysis is not only to inform decision-makers and the public of a general plan's potential adverse environmental impacts, but also to allow environmental considerations to influence the design of the plan itself. To accomplish this purpose, the CEQA analysis should be prepared in coordination with the development of the general plan.

Careful coordination between the CEQA process and the general plan process can also minimize unnecessary duplication of work.

Public Review of the EIR and Consultation

Both CEQA and the Government Code require extensive consultation with the public and other public agencies during the development of a general plan. For example, Government Code section 65352 requires consultation with, among others:

- A city or county, within or abutting the area covered by the proposal.
- Any special district that may be significantly affected by the proposed action.
- An elementary, high school, or unified school district within the area covered by the proposed action.
- The local agency formation commission.
- An areawide planning agency whose operations may be significantly affected by the proposed action.
- A federal agency if its operations or lands within its jurisdiction may be significantly affected by the proposed action.
- The military.

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- Public water systems.
- The Bay Area Air Quality Management District for a proposed action within the boundaries of the district.
- A California Native American tribe that is on the contact list maintained by the Native American Heritage Commission, with traditional lands located within the city or county's jurisdiction.
- The Central Valley Flood Protection Board for a proposed action within the boundaries of the Sacramento and San Joaquin Drainage District.

In addition, the city or county must provide for at least one scoping meeting to receive input on the scope and content of the draft EIR. (Pub. Resources Code § 21083.9). Refer to Chapter 3: Community Engagement and Outreach, for methods to seek meaningful community input.

Adoption and Certification

Before adopting the general plan, element, or revision for which the EIR was prepared, the city council or county board of supervisors must consider the final EIR, certify its adequacy, and make explicit findings explaining how the significant environmental effects identified in the EIR have been or should be mitigated or explain why mitigation measures and identified alternatives are not feasible (CEQA Guidelines § 15091). The city or county cannot approve the general plan unless the approved plan will not result in a significant effect on the environment or, more commonly, the city or county has eliminated or substantially lessened all significant effects where feasible and made a written statement of overriding considerations explaining the reasons why any remaining unavoidable significant effects are acceptable (Id. at §§ 15092, 15093). The jurisdiction must also adopt a mitigation monitoring or reporting program to ensure that the mitigation incorporated into the plan in accordance with the EIR will be implemented (Id. at § 15091(d)).

Program and Master EIRs

In order to minimize the need to reanalyze a series of projects related to the general plan, CEQA and the state CEQA Guidelines encourage using a general plan EIR to address subsequent discretionary projects, such as adopting zoning ordinances and approving specific capital improvement or development projects that are consistent with the general plan. By using a programmatic approach, the environmental review for a subsequent project can be limited to those project-specific significant effects that either were not examined or not examined fully in the general plan EIR.

Later environmental analysis for more specific actions can use analysis from the general plan EIR in several ways. The following paragraphs present a brief discussion of program EIRs, master EIRs, streamlining under Public Resources Code sections 21083.3 and 21094.5, and the use of certain statutory exemptions.

Program EIRs

The program EIR prepared for a general plan examines broad policy alternatives, considers the cumulative effects and alternatives to later individual activities where known, and contains plan-level mitigation measures. Later activities that have been described adequately under the program EIR will not require additional environmental documents (CEQA Guidelines § 15168(c)(2)). When

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necessary, new environmental documents, such as a subsequent or supplemental EIR or a negative declaration, will focus on the project-specific impacts of later activities, filling in the information and analysis missing from the program EIR (Id. at subd. (d)).

The "project" being examined in the program EIR is the general plan, element, or revision. The CEQA Guidelines recommend that program EIRs deal with the potential effects of a general plan, element, or revision "as specifically and comprehensively as possible." The program EIR's level of detail should be commensurate with the level of detail contained in the general plan or element (See *Rio Vista Farm Bureau Center v. County of Solano* (1992) 5 Cal.App.4th 351).

A program EIR should pay particular attention to the following EIR components:

- The significant environmental effects, including cumulative effects of anticipated later activities under the plan or element.
- Mitigation measures, including plan-wide measures.
- Alternatives to the basic policy considerations set forth by the plan or element.

When evaluating a later activity to determine whether it is eligible for consideration under a program EIR, OPR suggests the following sequential approach.

First, the lead agency must determine whether the subsequent activity meets both of the following criteria:

1. It is consistent with the plan or element for which the program EIR was certified. (A general plan amendment obviously would not qualify (See *Sierra Club v. County of Sonoma* (1992) 6 Cal.App.4th 1307).
2. It incorporates the feasible mitigation measures and alternatives developed in the program EIR. (Additional mitigation measures and alternatives may also be applied when a subsequent or supplemental EIR is prepared.)

Second, the lead agency must evaluate the later activity and its location to determine whether the environmental effects of that activity were adequately described in the program EIR. If there are any new effects from the later activity, the lead agency must prepare an initial study to determine the significance of those effects. No subsequent EIR is necessary for a project that is essentially part of the "project" described by the general plan's program EIR unless:

1. The later project would propose substantial changes in the plan that were not described in the program EIR, requiring revisions to the program EIR due to the involvement of a new significant effect or a substantial increase in the severity of a previously identified effect.
2. Substantial changes have occurred in the circumstances under which the general plan was undertaken, requiring revisions to the program EIR due to the involvement of a new significant effect or a substantial increase in the severity of a previously identified effect.
3. New information of substantial importance that was not known and could not have been known at the time the program EIR was certified indicates that significant effects were not adequately analyzed or that mitigation measures or alternatives should be revisited.

(See CEQA Guidelines §§ 15162, 15168(c)). If no subsequent EIR is required, the project is deemed to be within the scope of the program EIR and no additional environmental document would be required.

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Case law provides good examples of when further environmental review may, or may not, be required. For example, the City of San Diego's redevelopment agency was not required to conduct additional environmental review of a hotel project because it had previously prepared a program EIR addressing development in its downtown that adequately examined the hotel's potential environmental effects (See *Citizens for Responsible Equitable Envt'l Dev. v. San Diego Redevelopment Agency (2005)* 134 Cal.App.4th 598). On the other hand, additional environmental review was required for a proposal to use land for mining purposes because it included a new method of reclamation that was not "within the scope" of the program EIR (See *Sierra Club v. County of Sonoma* (1992) 6 Cal.App.4th 1307).

If a subsequent EIR must be prepared, it is subject to the standard EIR content requirements (i.e., project description, environmental setting, significant effects, mitigation measures, etc.). However, the subsequent EIR need not duplicate information and analysis that is already included in the program EIR. This may include such areas as environmental setting, project alternatives, and cumulative impacts. Pertinent discussions from the program EIR, to the extent that it examines regional influences, secondary effects, cumulative effects, broad alternatives, and other factors that apply to the later project, should be incorporated by reference into the subsequent EIR (CEQA Guidelines § 15168(d)).

Master EIRs

Another option for conducting programmatic review is to prepare and certify a master EIR (MEIR) (Pub. Resources Code §§ 21157, et seq. and CEQA Guidelines §§ 15175, et seq.). The MEIR is intended to be the foundation for analyzing the environmental effects of subsequent projects. Those projects that have been described in some detail in the MEIR may avoid the need for a later EIR or negative declaration. Other projects will only require analysis in a focused EIR that examines project-specific impacts while referencing the MEIR's analysis of cumulative and growth-inducing impacts.

Sections 15176(d) and 15177 of the CEQA Guidelines specifically allow later projects that are consistent with the land use designations and the permissible densities and intensities of use described in the general plan to proceed under the MEIR. This avoids the need for another EIR or negative declaration. The OPR publication Focusing on Master EIRs offers detailed technical information about using MEIRs.

In practice, an MEIR is similar to a program EIR. However, there are at least three differences worth noting.

- First, the requirements for preparing and applying an MEIR and its associated focused EIRs are described in detail in both statute and the CEQA Guidelines. Requirements for program EIRs, on the other hand, are less specifically described in the CEQA Guidelines.
- Second, once a subsequent project is determined to be within the scope of the MEIR, a focused EIR must be prepared whenever it can be fairly argued on the basis of substantial evidence in the record that the project may have a significant effect, even if evidence exists to the contrary.
- Third, to use an MEIR for a subsequent project, the MEIR must be re-examined and, if necessary, supplemented at least once every five years. This ensures that the analysis contained in an MEIR remains topical.

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Streamlining in Public Resources Code Section 21083.3

Public Resources Code section 21083.3 contains a specific limitation on CEQA for projects that are consistent with a general plan. When an EIR has been certified for a general plan, the CEQA analysis of later projects can be limited to those significant effects that "are peculiar to the parcel or to the project" and that either were not addressed as significant effects in the plan's EIR or that new information shows will be more significant than when the plan's EIR was certified. The requirements of this option are detailed in CEQA Guidelines § 15183.

Streamlining for Infill Projects in Public Resources Code Section 21094.5

Similar to the provision described above, section 21094.5 of the Public Resources Code limits the CEQA analysis of infill projects. Specific rules on this provision are contained in Section 15183.3 and Appendix M of the CEQA Guidelines. Because the primary criteria for eligibility is proximity to transit, cities can maximize the streamlining benefit of a general plan EIR by carefully analyzing residential, commercial and school uses in transit corridors.

COMPARING EXISTING STREAMLINING MECHANISMS

	Program EIRs	Master EIRs	Section 21083.3	Streamlining Under Section 21094.5
Time Limit on Prior EIR	None	5 Years	None	None
Plan Consistency	General Plan and zoning consistency not explicitly required, but if project is not consistent, it may not be "within the scope" of the PEIR.	Silent	Requires consistency with General Plan and Zoning	Project may include general plan amendments or zoning variances, provided that new effects would need to be analyzed
Project-Level Description	Not required, but a PEIR "will be most helpful in dealing with subsequent activities if it deals with the effects of the program as specifically and comprehensively as possible."	Projects relying on the Master EIR must have been specifically identified	Not required in general plan or zoning EIR	Not required in EIR for a planning level decision
Project Contribution to Significant Effects	Analysis does not need to be repeated at the project level if the project is "within the scope" of the PEIR.	Analysis does not need not be repeated at the project level	Analysis does not need not be repeated at the project level	Analysis does not need not be repeated at the project level
Document Containing Programmatic Analysis	An EIR prepared for a program, plan, policy or ordinance	A Master EIR for specified projects	An EIR for a comprehensive general plan amendment or zoning code	An EIR for a planning level decision, as well as any supplements or addenda thereto
Effect of Development Standards	Can be used as thresholds of significance in an analysis, but not conclusively	Can be used as thresholds of significance in an analysis, but not conclusively	Can be used to address peculiar effects of the project, only if adopted by a city or county with a finding that the standard will substantially mitigate the effects of future projects	Can be used to address either new specific effects or effects that are more significant than previously analyzed, provided the finding is made at project approval

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Integrating Annual Reporting with Mitigation Monitoring and Implementation

When a general plan is enacted or amended based upon an EIR or a mitigated negative declaration, the city council or board of supervisors must also adopt a reporting or monitoring program for ensuring compliance with the adopted mitigation measures (Pub. Resources Code § 21081.6). The city or county should coordinate general plan policies and environmental mitigation measures during the planning process so that the mitigation measures will be reflected in the plan policies and those policies realistically can be implemented.

The city or county must adopt a specific program that will enable it to track compliance with the mitigation measures. One approach is to use the yearly "status of the plan" report prepared for the city council or board of supervisors pursuant to Government Code section 65400(b) as the reporting program for a new general plan. See OPR's publication Tracking Mitigation Measures Under AB 3180 for more information about designing a mitigation monitoring program. Transportation information resulting from the mitigation monitoring program must be submitted to the local transportation planning agency and to Caltrans (Pub. Resources Code § 21081.7; CEQA Guidelines §15097(g)).

A general plan can be measured by how well its goals, policies, and programs are implemented. The same is true for the mitigation measures identified in the plan's EIR. When drafting mitigation measures, consider how they can be reflected in plan goals, policies, and programs and how they will be implemented. The mitigation measures should be an integral part of the plan, not an afterthought.

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Appendix A

Example Model Goals, Objectives, and Policies and Programs

The policies contained in this appendix were selected through a combination of public outreach, stakeholder engagement, expert input, and independent research. They are organized by element, with relevant subheadings and grouped into policies by area consistent with the general plan sections. Many policies could be classified under various elements; for instance, a policy relevant to circulation could also be classified under healthy communities or environmental justice. However, rather than repeat the policies in several areas, the document is searchable for key words. Policies can be used as a reference or as a starting point to meet the needs of different local jurisdictions. As with the entire general plan, the policies need to be consistent across elements.

The goals, objectives, policies, programs, and actions (heretofore referred to as 'policies') listed were gathered through extensive outreach and public comment. Where available, cities and counties that have adopted the policies are listed in parenthesis. Often, these are the exact policies from the listed jurisdictions. Some policies, however, have been modified or combined to be more widely applicable, and have different wording than the general plan(s) from which they were pulled. Where the policy language varies significantly from any cities and counties that have implemented them, the policy is listed as "general." In some instances, numerous jurisdictions have different versions of the same policies, written with slight variations. In such instances, the policy has been modified slightly to be broad, and numerous jurisdictions are listed as examples. The goal in modifying policies is to retain the intent, while making them relevant for a broad range of jurisdictions.

While much research and effort was put into assuring inclusive representation of policies from diverse areas, including rural, urban, agricultural, and suburban, some jurisdictions are listed more prominently than others due to the complexity of their general plans, and the availability of information. As the GPG is updated, additional policies will be added to this document.

Definitions- for more detailed definitions, see Appendix E: Glossary

This appendix combines all items into goals, objectives, and policies and programs. General plans vary in their terminology, and may include other categories such as vision and actions. For this appendix, all items have been consolidated into the following three areas:

Goal

A goal is a general direction-setter. It is an ideal future end related to the public health, safety, or general welfare. A goal is a general expression of community values and, therefore, may be abstract in nature. Consequently, a goal is generally not quantifiable or time-dependent.

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Objective

An objective is a specified end, condition, or state that is an intermediate step toward attaining a goal. It should be achievable and, when possible, measurable and time-specific. An objective may pertain to one particular aspect of a goal or it may be one of several successive steps toward goal achievement. Consequently, there may be more than one objective for each goal.

Policies, Programs, Actions

A policy is a specific statement that guides decision-making. It indicates a commitment of the local legislative body to a particular course of action. A policy is based on and helps implement a general plan's vision. Programs can be short or long term groupings of projects or services that help achieve policy goals. Actions are specific methods to achieve policy goals. In this appendix, policies, programs, and actions are listed together.

Example Policies by Element

Land–Use Planning

- Design for Sustainability and Stability
- Provide for New Development
- Create Economically Vibrant Communities
- Improve Community Life

Circulation

- Transportation Planning
- Parking
- Public Transit
- Biking and Walking
- Preserving Neighborhood Character
- Economics and Transportation

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Housing

- Special Populations and Homelessness
- Affordability
- Housing and Neighborhoods
- Infill Housing

Conservation

- Biological Resources
- Mineral Resources
- Cultural Resources
- Water Resources
- Agricultural Resources

Open Space

- Open Space for Habitat and Conservation
- Open Space for Recreational Uses
- Visual Resources

Safety

Numerous safety element policy recommendations are included throughout the general plan guidelines and in guidance from the office of emergency services (CalOES) in support of local hazard mitigation planning. Rather than relying on this appendix entirely for recommended policies, OPR recommends accessing the resources available by CalOES for local hazard mitigation planning and those outlined in the Safety Element, in addition to those resources listed in the table in Chapter 4, Tools to Address Climate Adaptation. See also: *"Healthy Communities: A Changing Climate and Resiliency"*

- Avoiding and Mitigating Natural Disasters
- Emergency Preparedness and Prevention

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Environmental Justice

- Pollution Exposure
- Food Access
- Safe and Sanitary Homes
- Physical Activity
- Access to Public Amenities

Noise

Air Quality

Healthy Communities

- Economics and Health
- A Changing Climate and Resiliency
- Social Connection and Safety
- Health and Human Services

Economic Development

Equitable and resilient communities

- Community Engagement

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Climate Change

Numerous element specific climate change policy recommendations are included throughout the general plan guidelines. Further policy guidance is included in the resources outlined in the table included in Chapter 8, Climate Change. Goals, policies, and actions to address climate change adaptation and greenhouse gas emissions reductions are constantly evolving. Rather than relying on this appendix entirely for recommended climate related policies, OPR recommends referencing the variety of resources readily available on the *California Air Resources Board Cool California website* and the *Office of Planning and Research's Integrated Climate Adaptation Resiliency Program's (ICARP) Adaptation Clearinghouse.*

Code Changes, Zoning Changes, and/or Policy

- Energy
- Transportation and Land Use
- Natural and Working Lands (NWL)
- Agriculture
- Water
- Waste Management
- Short-Lived Climate Pollutants
- Green Buildings

Mitigation

- Construction
- Operation

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Land–Use Planning

Design for Sustainability and Stability

Provide for New Development

Create Economically Vibrant Communities

Improve Community Life

Design for Sustainability and Stability

Goal: Accommodate the development of a mix of land uses that meet the diverse needs of residents and businesses, with places to live, work, shop, be entertained and culturally enriched, engage in healthy lifestyles, and engage with one's community. (Sacramento, Pasadena, La Habra)

Objective 1: Regulate and Optimize Density (General)

Policies, Programs, Actions:

- Regulate the levels of building intensity and population density consistent with the designations established by the Land Use Diagram. Within these designations, cumulative development shall not exceed (insert number) additional persons (or housing units) and (insert number) additional employees (or non-residential building square feet) by (insert year). (Sacramento, La Habra)
- Review the General Plan's residential and commercial capacities every five years and modify, as necessary, to reflect development that has occurred, its impacts, evolving market and economic conditions, and consistency with community values. (Pasadena)
- Allocate sufficient land at densities sufficient to support the development of businesses offering jobs matched to the education and skills of the city's residents and housing affordable to employees of local businesses, thereby reducing commutes to and from outside of the community. (La Habra)
- Avoid the overconcentration of uses and facilities in any neighborhood or district where their intensities, operations, and/or traffic could adversely impact the character, safety, health, and quality of life. (Pasadena)

Objective 2: Enhance areas at the local level to increase livability and bolster local economy while reducing automobile traffic. (General)

Policies, Programs, Actions & Programs:

- Provide for and encourage the development of a broad range of uses in the city's commercial centers and corridors that reduce the need to travel to adjoining communities and capture a greater share of local spending. (La Habra)

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- Require that development is located and designed to assure compatibility among land uses and districts. (La Habra)
- Encourage school districts and park and recreation districts to locate school sites and parks within or adjacent to existing or planned residential and mixed use neighborhoods. (Butte County)
- Encourage development of local, citywide, and regional mixed-use centers that address different community needs and market sectors, and complement and are well-integrated with surrounding neighborhoods. (Sacramento)
- Facilitate the redevelopment of the city's auto-oriented commercial corridors and suburban centers to create vibrant, mixed-use boulevards by clustering higher density, pedestrian-oriented mixed use on larger parcels at key intersections, while re-using intervening parcels for housing mixed with neighborhood-oriented commercial services and/or public plazas. (Sacramento, La Habra)
- Support uses that meet daily needs such as grocery stores, local-serving restaurants, and other businesses, activities, and community-supportive facilities within walking or biking distance of residences to reduce the frequency and length of vehicle trips. (La Habra)

Objective 3: Incorporate existing buildings into community design. (General)

Policies, Programs, Actions:

- Prevent deteriorating conditions in areas of the city with buildings that are aging and not properly maintained through public and private conservation and rehabilitation programs. (La Habra)
- Encourage the adaptive re-use and application of green technologies of existing buildings as a preference for demolition and replacement to retain the structure's embodied energy, increase energy efficiency, and reduce waste. (Sacramento, Rialto)

Provide for New Development

Goal: Support development projects that provide a diversity of urban and suburban neighborhood opportunities. Ensure that new residential growth areas include neighborhoods that provide a mix of residential types and densities, and appropriate transitional features integrating the area with adjacent existing neighborhoods and development. (Fresno, Sacramento, Citrus Heights)

Objective 1: Plan new development that is high-quality and well-integrated into existing cities and communities. (General)

Policies, Programs, Actions:

- Provide opportunities for interested and affected parties to have input in proposed planning activities as early as possible. (Citrus Heights)
- Encourage the retention and production of diverse types of housing within Urban Service Areas in order to provide adequate housing choices for current and future residents. (Sonoma County)
- Coordinate the development of capital facilities and infrastructure with the timing of growth to ensure adequate and high levels of services for existing and new development. (Pasadena)

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- Provide for a diversity and variation of building types, densities, and scales of development in order to reinforce the identify of individual neighborhoods, foster a variety of market-based options for living and working to suit a large range of income levels, and further affordable housing opportunities. (Fresno)
- Require that new development and reconstruction comply with the California Green Buildings Standards Code with amendments and update periodically to reflect future amendments. (La Habra)
- Require that the scale and massing of new development in higher-density centers and corridors provide appropriate transitions in building height and bulk and are sensitive to the physical and visual character of adjoining lower-density neighborhoods. (Sacramento, Pasadena)
- Require that buildings are designed as a high-quality, long-term addition to the City's urban fabric; exterior design and buildings shall exhibit permanence and quality, minimize maintenance concerns, and extend the life of the building. (Pasadena)

Objective 2: Promote compact development patterns, mixed-use, and higher densities that use land efficiently; reduce automobile dependence and pollution and greenhouse gas emissions, and facilitate walking, bicycling, and transit use, including through mixed-use corridors and activity centers. (Sacramento, Fresno)

Policies, Programs, Actions:

- Target growth and new construction in infill areas by redeveloping underutilized commercial, residential, and industrial properties. (Pasadena)
- Site a mix of housing and jobs in close proximity or through mixed use development so that bicycling, walking and transit use is a viable option for residents and employees. (General)
- Protect and conserve land that is used for agricultural purposes, including cropland and grazing land. (Butte County)
- Encourage new neighborhoods to be designed to locate all housing within ½ mile of a central gathering place that incorporates public spaces, shopping areas, access to transit, and/or community-supportive facilities and services. (Sacramento)
- Encourage the consolidation of small parcels, joint public-private partnerships, and land clearance and re-sale to facilitate the revitalization of underused and obsolete commercial and industrial properties. (La Habra)

Objective 3: Incorporate practices that preserve aesthetics and environments simultaneously. (General)

Policies, Programs, Actions:

- Encourage the renovation, infill, and redevelopment of existing suburban centers that reduces the visual prominence of parking lots, makes the centers more pedestrian friendly, reduces visual clutter associated with signage, and enhances the definition and character of the street frontage and associates streetscape. (Sacramento)

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- Promote and, where appropriate, require sustainable building practices that incorporate a "whole systems" approach for design and construction that consume less energy, water, and other non-renewable resources, facilitate natural ventilation, effectively use daylight, and are healthy, safe, comfortable, and durable. (Sacramento, Long Beach, San Diego County)
- Encourage the strategic selection of street tree species to enhance neighborhood character and identity and preserve the health and diversity of the urban forest. (Sacramento)

Create Economically Vibrant Communities

Goal: Foster a robust local economy that provides high-quality employment for residents and attracts stable businesses. (General)

Objective 1: Use smart planning to create a favorable economic environment. (General)

Policies, Programs, Actions:

- Increase the amount of land properly zoned, consistent with the General Plan, and ready to be expeditiously developed, redeveloped, and/or revitalized for economic development and job creation purposes. (Fresno)
- Ensure that the city has appropriate resources in place to implement its economic development strategy and work in close coordination with other public agencies, private entities, the non-profit sector, and multi-cultural communities to coordinate economic development efforts on a region-wide basis. (Fresno)
- Prioritize the provision of necessary major street infrastructure and utility capacities for properly zoned-land, consistent with the General Plan, so this land can be developed in a timely manner to support economic development. (Fresno)
- Modify and monitor zoning codes to create economic incentives for more intensified forms of land use on previously developed but underutilized parcels.(La Habra)
- Promote, educate, and market the benefits of a "buy local" campaign. (Fresno)
- Support the development of locally-grown and based retail businesses as an alternative to national chain brands. (Pasadena)

Objective 2: Ensure fair financial management. (General)

Policies, Programs, Actions:

- Require new residential and commercial development to pay its fair and proportional share of needed community improvements through impact fees, assessment districts, and other mechanisms. (Fresno)
- Periodically conduct comprehensive fee studies to determine whether impact fees fully account for the recovery of costs, consistent with applicable law.(Fresno)

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Objective 3: Attract and retain long-term, economically sustainable businesses. (Sacramento)

Policies, Programs, Actions:

- Encourage a balance between job type, the workforce, and housing development to reduce the negative impacts of long commutes and provide a range of employment opportunities for all city residents. (Sacramento)
- Explore and identify target industries with well-paying occupations that match or can enhance the skill base and training capacity of local residents. (La Habra)
- Establish a list of "ready-to-go" or "shovel-ready" sites in consultation with property owners, and provide the list to interested developers and businesses seeking sites in the city. (Fresno)
- Cultivate an entrepreneurial and academic environment that fosters innovation.(Pasadena)
- Promote the local workforce as a marketable resource for job placement companies serving the area and target industries. (La Habra)
- Provide incentives to existing small and startup businesses, including minority- and women-owned businesses, to facilitate their expansion and job creation. (Sacramento)
- Work with universities, the local chamber of commerce, and other groups to encourage businesses working with cutting-edge technology to locate in the city. (Sacramento)

Objective 4: Promote the development and retention of a skilled workforce. (General)

Policies, Programs, Actions:

- Reduce barriers to gainful employment such as lack of public transportation, training, job information, and child care.(Pasadena)
- Work with local organizations in developing links between public and private providers of primary, secondary, and post-secondary education and with local businesses and industries to develop and promote educational programs relevant to the needs of the local economy. (Sacramento)
- Work to improve the quality of life in the city to retain existing skilled workers and attract skilled workers from beyond the region. (Sacramento)
- Create a program to provide incentives for local businesses to offer internship, mentoring, and apprenticeship programs to high school and college students in partnership with local educational institutions. (Fresno)

Improve Community Life

Goal: Provide services to promote the health, safety, and well-being of all residents. (General)

Objective 1: Provide a diversity of uses and services supporting the city's residents such as facilities for governance, public safety,

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seniors and youth, community gatherings, and comparable activities. (La Habra)

Policies, Programs, Actions:

- Work with external agencies and non-profit organizations to encourage the provision of services and facilities not subject to city jurisdiction, such as public schools and quasi-public infrastructure. (La Habra)
- Ensure that sufficient parks, open space, and trails are planned throughout the city to ensure adequate facilities are available to existing and future residents. (Sacramento)
- Require higher-density urban neighborhoods and mixed-use districts to incorporate small public spaces and have broad tree-lined sidewalks furnished with appropriate pedestrian amenities providing comfortable and attractive settings for high levels of pedestrian activity. (Sacramento)
- Promote the co-location of parks, schools, police, police and fire facilities, health services, and other community facilities to support community interaction, enhance neighborhood identity, and leverage limited resources. (Sacramento)

Objective 2: Strive to make communities socially equitable. (General)

Policies, Programs, Actions:

- Ensure that parks and recreation facilities, community services, public facilities, and amenities are equitably distributed and accessible throughout the city. (Pasadena, La Habra)
- Discourage features in residential development that tend to isolate residents from the sense of an integrated community, such as walls and gated single-family neighborhoods. (Citrus Heights)
- Promote an equitable distribution of housing types for all income groups throughout the City and promote mixed-income developments rather than concentrations of below market-rate housing in certain areas. (Sacramento)
- Promote the design of neighborhoods, centers, streets, and public spaces that enhances public safety and discourages crime by providing street-fronting uses ("eyes on the street"), adequate lighting and sight lines, and features that cultivate a sense of community ownership. (Sacramento)
- Prohibit or control land uses that pose potential health and environmental hazards to residents of neighborhoods and districts. (Pasadena)

Promote the development of uses providing healthy and locally-grown food choices for the city's residents (i.e., brick and mortar facilities, community gardens, and farmer's markets). (Pasadena)

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Circulation

Transportation Planning

Parking

Public Transit

Biking and Walking

Preserving Neighborhood Character

Economics and Transportation

Transportation Planning

Goal: Develop a transportation system that meets the needs of all segments of the community, including those of residents, businesses, visitors, and the region. (San Pablo, Pasadena)

Objective 1: Design and operate city streets based on a "Complete Streets" concept that enables safe, comfortable, and attractive access and travel for pedestrians, bicyclists, motorists, and transit users. (San Pablo)

Policies, Programs, Actions:

- Include "Complete Streets" considerations in the design of all circulation improvement projects. These new design considerations include, but are not limited to, the following:
- Landscaping (trees, medians, key intersections and gateways) that uses drought-resistant plant species, whenever possible, to conserve water;
- Minimized ingress and egress points, consolidated entries;
- Public transit facilities and improvements;
- Safety criteria such as lighting and traffic calming devices for residential streets;
- Sign design (including commercial signs, street signs, entry signs, directional signs)
- Street furniture;
- Bus stop locations and sidewalk widening, as needed; and
- On and off-street parking management (San Pablo)
- Design intersections and public right-of-ways to include adequate and safe access for all users including pedestrians, bicyclists, and motorists of all ages and abilities. (San Pablo)

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- Encourage connectivity and accessibility to a mix of land uses that meet residents' daily needs within walking distance. (Pasadena)
- Provide an ongoing review of emergency operations plans and provisions to ensure that the City's program for emergency transportation services is coordinated with other local and regional jurisdictions and incorporates updated procedures and programs as appropriate. (Pasadena)
- Coordinate transportation options for major community and commercial events to increase transit access, ridesharing and bicycle access and parking options. (Pasadena)
- Design sidewalks and pedestrian paths to provide defensible space and adequate sight lines between adjoining development to insure safety and security. Sidewalks should feel comfortable and welcoming at all times of the day and night. (Sonoma County)

Objective 2: Improve safety for all modes by developing and coordinating between the Police Department and the Transportation Department the implementation of traffic management, education, and enforcement. Increase options for walking and bicycling to recreate, shop, and services while improving safety for all modes. (Pasadena)

Policies, Programs, Actions:

- Install traffic calming devices, such as signage, road bulbs (also called curb extensions), raised crosswalks, and speed humps, as needed and appropriate in existing neighborhoods. (San Pablo)
- Work with transit providers to implement a Safe Routes to Transit program for bicycle and pedestrian access to transit stops and stations. (Sonoma County)
- Manage traffic speeds on neighborhood streets to reduce cut-through traffic. (Pasadena)
- Promote efficient use of existing transportation facilities through the implementation of transportation demand management concept (San Pablo)
- Establish travel demand management programs to reduce peak-hour traffic congestion and help reduce regional vehicle miles traveled (San Pablo, Pasadena)
- Continuously evaluate the operation of the City's transportation system to manage the speed of travel at or below the speed limit, manage queues at intersections and develop improvements to increase safety of all transportation services. (Pasadena)
- Promote greater linkages between land uses and transit, as well as non-vehicular modes of transportation to reduce vehicular trip related emissions. (Pasadena)
- Promote safe travel in neighborhoods and coordinate with the Pasadena Police Department to enforce traffic regulations with particular attention given to sensitive uses such as schools, senior centers, hospitals, community service facilities, and parks. (Pasadena)

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- Limit the intrusion of commercial truck traffic on City streets, especially residential neighborhoods, by directing truck traffic to the city's designated truck routes and coordinating with the Pasadena Police Department to enforce related regulations on local streets. (San Pablo, Pasadena)
- Collaborate with the business community to encourage truck deliveries to be made in off-peak hours especially in areas where nearby residents would be affected. This policy must be consistent with provisions of the City's noise ordinance. (Pasadena)

Goal: Create a transportation system that encourages health benefits for all community members. (General)

Objective: Improve air quality from transportation sources to protect human and environmental health, and minimize impacts on sensitive populations. (General)

Policies, Programs, Actions:

- Designate truck routes that avoid sensitive land use areas in combination with adequate signage and enforcement. (General)
- Prohibit overnight parking of trucks on secondary streets or publicly habitable space located in residential zones. (General)
- Prohibit idling of on-road and off-road diesel vehicles and equipment for more than 5 minutes. (General)
- Partner with the local air quality management district to establish a program facilitating diesel engine retrofitting or replacement in existing automobiles, trucks, rail, and ships. Identify feasible technologies and funding. (General)
- Collaborate with regional agencies to establish best practices for emissions reduction. (General)
- Create residential and commercial units located along higher density corridors and areas where increased intensity of use may result in higher levels of vehicular traffic on adjacent streets. Identify recommendations for mitigation, including design standards and public transportation (Richmond)
- Balance commercial goods movement with the health and quality of life priorities of the community by routing heavy truck traffic away from residential zones and promoting safety at rail crossings (San Pablo)

Parking

Goal: Foster practical parking solutions to serve community needs while avoiding excessive amounts of surface parking that disrupt the urban fabric of the city. (San Pablo)

Objective: Amend the Zoning Ordinance to establish "green" parking design standards that have multiple benefits, such as shared parking for mixed use projects, photovoltaic panels on parking structures to generate energy for parking lot lighting, landscaping and trees in surface parking, and pervious paving to improve groundwater recharge and promote innovative surface parking design that avoids the appearance of a "sea of asphalt" and reduces environmental impacts. (San Pablo)

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Policies, Programs, Actions:

- Promote the use of time, motion-sensing, and/or solar powered parking lot lights or security lights, wherever feasible (San Pablo)
- Establish specific standards for perimeter landscaping, including the type and coverage required along the edges of surface parking areas adjacent to streets (San Pablo)
- Require a minimum number of trees per parking stall in surface parking areas (e.g. 1 per 8 stalls for double-loaded bays) to provide shade, and reduce urban heat island effects (San Pablo)
- Separate pedestrian pathways from car lanes where possible (San Pablo)
- Promote the use of porous paving and a variety of drainage features according to the site (San Pablo)
- Restrict use of vacant lots as vehicle parking and outdoor storage of commercial equipment, construction equipment, and similar items unless screened from view from adjacent streets (San Pablo)
- Promote use of innovative parking technologies, such as parking lifts and automated parking (San Pablo)
- Require convenient and accessible parking facilities for persons with disabilities, consistent with Americans with Disabilities Act (ADA) requirements (San Pablo, Pasadena)
- Limit parking within the public right of way based upon considerations of safety, street width ,visibility and access to properties (San Pablo)
- Enforce regulations that prohibit parking of commercial, recreational, and non-operable vehicles in residential areas, including the staging of taxi services (Pasadena)
- Plan for the deployment of autonomous vehicles and related smart cities infrastructure through modifications to the jurisdiction's implementing documents such as zoning, parking, bike/ped plans, congestion management plans, etc. (General)
- Maintain and better utilize existing private and public parking structures through shared parking opportunities and advanced traveler information services to direct parkers to available spaces (Pasadena)
- Continue to enforce parking regulations and prevent spillover of parking from commercial areas into residential neighborhoods (San Pablo, Pasadena)

Public Transit

Goal: Plan for transportation modes and strategies that ensure good air quality, reduce greenhouse gas emissions, reduce petroleum consumption and reduce the need to devote additional lands to transportation uses (Butte County)

Objective: Facilitate the use of public transportation in by making it more comfortable and convenient (San Pablo, Pasadena)

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Policies, Programs, Actions:

- Assess ways to improve availability of transit for underserved populations (Pasadena)
- Continue coordination efforts with public transit providers to maintain transit service that is safe and efficient with convenient connections to high use and activity intersections in the city (San Pablo)
- Assess implications of autonomous vehicles on transit and mobility planning infrastructure. (General)
- Where feasible and appropriate, and where non-motorized travel is reasonably expected, the width of existing streets shall be reduced through bulbouts, medians, pedestrian islands and similar methods, and planting shade trees in landscaped areas within and adjacent to streets, while not jeopardizing emergency response and future capacity requirements. (Butte County)
- Seek funding to enhance accessibility by increasing routes, frequency and hours of operation for the transit system throughout the community. (Pasadena)
- Encourage carpooling by providing additional carpool pickup and park-and-ride locations near transit centers and at freeway interchanges. (Butte County)
- Facilitate coordination between transit providers to improve seamless transit service. (Pasadena)
- Promote safety at railroad crossings through the following measures, as necessary:
  - Improvements to pedestrian warning devices at existing railroad crossings to maintain the visibility of warning devices and approaching trains; and
  - Rail safety awareness programs to educate the public about the hazards of at grade crossings.
  - Installation of additional warning signage and/or channelization;
  - Improvements to traffic signaling at intersections adjacent to crossings;
  - Prohibition of parking near crossings to improve the visibility of warning devices and approaching trains (San Pablo)

Biking and Walking

Goal: Develop a safe and comprehensive bicycle and pedestrian network to improve access and public health. (San Pablo, Pasadena)

Objective: Expand and maintain a safe and comprehensive bicycle system that connects the City's neighborhoods to regional bicycle routes. (San Pablo, Pasadena)

Policies, Programs, Actions:

- Require the provision of bicycle parking and related facilities in new employment-generating development and multi-family housing to facilitate multi-modal commute choices. (San Pablo)

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- Develop and maintain a comprehensive and integrated system of reduced stress bikeways and increase bicycle parking at destinations to promote bicycle riding as a mode of transportation. (Pasadena)
- Encourage local and regional transit agencies to provide and maintain convenient and secure bike parking facilities, all-weather shelters, and other amenities at major transit stops and transportation centers. (Sonoma County)
- Explore bicycle share programs or any other bicycle programs (e.g., discounts for bikes, free bikes, inexpensive bike loans or rentals) that will provide greater access to bicycles for visitors and those that may not own a bicycle. (Pasadena)
- Increase walking and bicycling to local destinations and regional transportation services by developing wayfinding signage for pedestrians and bicyclists. (Pasadena)
- Adopt and periodically update a Bicycle Master Plan to enhance bicycle circulation and planning and be coordinated with the Countywide Bicycle and Pedestrian Plan. (San Pablo)
- Use brightly-colored paint or a one-foot buffer strip along bicycle routes to provide a visual signal to drivers to watch out for bicyclists and nurture a "share the lane" ethic. Start with areas of town where automobile-bicycle collisions have occurred in the past, based on data from the Statewide Integrated Traffic Records System maintained by the California Highway Patrol. (San Pablo)
- Develop measures to reduce conflict areas for bicyclist such as driveways and right turn lanes. (Pasadena)
- Amend an existing transportation impact fee to include pedestrian and bicycle improvements. (Pasadena, City of Santa Cruz)
- Develop a schedule and comprehensive funding program for proposed bike system improvements within the Capital Improvements Program. (City of Santa Cruz)
- Implement Safe Routes to School program where funded. (City of Santa Cruz)
- Incorporate projects listed in the Bicycle Transportation Plan in any relevant future area, neighborhood, or similar plans that are prepared. (General)
- Assure that right-of-way acquisition and street design will support pedestrian and bike improvements and transit. (City of Santa Cruz);
- Facilitate bicycling connections to all travel modes. (City of Santa Cruz)
- Encourage all educational facilities to provide for safe and convenient pedestrian and bike access. (City of Santa Cruz)
- Replace or retrofit storm drain grates and channels that are hazardous to bicycles. (General)
- Ensure all traffic control detection systems are designed, adjusted, and marked for bicycle detection and that signals allow enough time for bicycle passage through controlled intersections. (General)
- Provide design guidelines for safe and secure bicycle parking and promote bicycle access for special events. (City of Santa Cruz)

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Goal: Increase the opportunities, where appropriate, for transit systems, pedestrians, bicycling and other alternative modes to reduce the demand for automobile travel. (Sonoma County)

Objective: Increase the viability of walking and biking as a method of transportation (General)

Policies, Programs, Actions:

- Routinely consider the needs of pedestrians and bicyclists and, where possible, accommodate in all roadway construction and renovation projects. (Napa County)
- Collect and analyze bicycle, pedestrian, and transit trip data by establishing routine collection of alternative trip information on collector and arterial roadways and require such information be provided as part of project traffic studies. (Sonoma County)
- Incorporate Americans with Disabilities Act (ADA) requirements throughout the City, but especially in high-volume pedestrian areas. (City of El Monte)
- Require major employment centers and employers to provide facilities and Traffic Demand Management (TDM) programs that support alternative transportation modes, such as bike and shower facilities, telecommuting, flexible schedules, etc. These programs may apply to existing employers as well as to new development (Sonoma County)
- Regularly inspect streets and maintain pavement in a condition that keeps maintenance costs at a minimum, encourages bicycling, and ensures that repairs are acceptable and long-lasting. (City of Santa Cruz)
- Provide regular sweeping, pavement repairs, striping, and signs along bike routes. (City of Santa Cruz)
- Work with appropriate agencies to seek funding for pedestrian and bicycle projects and submit applications to all available regional, state and federal funding sources. (City of Santa Cruz)
- Assure a high level of bicycle user amenities. (City of Santa Cruz)
- Use the City/county's web site to promote walking and cycling and publicize routes and facilities. (General)
- Implement bicycle safety programs and cooperate with other agencies in the enforcement of bicycle safety. (City of Santa Cruz)
- Complete and enhance the pedestrian network with an interconnected system of walkways, continuous sidewalks on both sides of the street, and pedestrian crossings. (San Pablo)
- Support neighborhood walk-to-school efforts. (Pasadena)
- To maintain walkability and pedestrian safety, reduce curb-to-curb road widths and employing roadway design features such as islands, pedestrian refuges, and pedestrian count-down signal. (San Pablo)
- Provide pedestrian facilities that are accessible to persons with disabilities and ensure that roadway improvement projects address accessibility and universal design concept. (San Pablo)

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- In mixed-use areas or other areas with high pedestrian traffic, provide mid-block pedestrian crossings, where feasible, to create more direct walking routes and slow vehicle speeds (San Pablo)

Preserving Neighborhood Character

Objective: Protect the character of local residential streets. (San Pablo)

Policies, Programs, Actions:

- Ensure that public right-of-way improvement designs are consistent with the character of each neighborhood. (San Pablo, Pasadena)
- Minimize street and intersection widening to facilitate pedestrian crossings and protect historic resources and open space. (Pasadena)

Economics and Transportation

Objective: Maintain economic health and viability while making improvements to transportation infrastructure. (General)

Policies, Programs, Actions:

- Ensure that new development pays its fair share of the costs of new and improved transportation facilities. (San Pablo)
- Pursue funding opportunities such as grants, impact fees or fair share contributions from development to implement programs and projects that contribute to the City's Mobility Element objectives. (Pasadena)
- Emphasize transportation projects and programs that will contribute to a reduction in vehicles miles traveled per capita, while maintaining economic vitality and sustainability. (Pasadena)
- Manage curb-space parking to support neighborhood protection and economic vitality. (Pasadena)

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A

Housing

Special Populations and Homelessness

Affordability

Housing and Neighborhoods

Infill Housing

Special Populations and Homelessness

Objective: Support provision of housing to address the needs of the disabled, mentally ill, persons with substance problems, persons with HIV/AIDS, and other groups needing transitional and supportive housing. (Long Beach)

Policies, Programs, Actions:

- Encourage universal design of housing products and environments, making them usable by a wide range people with different physical and mental abilities. (Long Beach)
- Integrate and disperse special needs housing within the community and in close proximity to transit and public services. (Long Beach)
- Adopt a written reasonable accommodation ordinance to provide exception in zoning and land-use for housing for persons with disabilities, for development standards such as building setbacks and parking requirements. (City of Lindsay)

Affordability

Objective: Increase the availability of affordable housing. (General)

Policies, Programs, Actions:

- Where the City provides financial assistance, require the inclusion of affordable units. (Long Beach)
- Support programs and projects which link affordable housing with other community development goals and resources. (Long Beach)
- Utilize development agreements as a tool to achieve a mix of affordability levels in large-scale projects. (Long Beach)
- Expedite the processing of residential development proposals and permits and granting priority queuing to permit applications for affordable housing projects. (Simi Valley)
- Convene a working group made up of building industry and affordable housing experts to explore new funding sources for affordable housing. (City of Sacramento)

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- Conduct a seminar with affordable housing developers to discuss priority sites as well as to promote new development standards and programs that promote affordable housing. (City of Sacramento)

Housing and Neighborhoods

Objective: Plan and maintain housing with a view to creating safe and functional neighborhoods. (General)

Policies, Programs, Actions:

- Promote strong, on-site management of multi-family complexes to ensure the maintenance of housing and neighborhood quality. (Long Beach)
- Support the development of housing that is technology-friendly and designed to meet the housing needs of the emerging information and technology industry workforce. (Long Beach)
- Invest in infrastructure and public facilities to ensure that adequate water, sewer, roads, parks, and other needed services are in place to serve existing and future residential developments. (Kings County)
- Incorporate other community goals with the production, conservation, and protection of housing, including encouraging sustainable development, providing supportive services, increasing walkability and non-motorized forms of transportation, improving and maintaining public safety, and ensuring ongoing public participation efforts. (Santa Monica)
- Encourage and provide incentives for the development of housing in mixed-use zoning districts near transit opportunities. (Santa Monica)
- Ensure that architectural design of new housing development is compatible with the surrounding neighborhood. (Santa Monica)
- Encourage residential projects to utilize a variety of housing types, unit clustering, and special construction techniques, where these will preserve natural topographic, landscape and scenic qualities. (Alameda County)
- Mandate that residential projects be sited, designed and landscaped to: ensure privacy and adequate light, air and ventilation to units and residential open space areas; provide adequate and usable private indoor and outdoor spaces; and ensure adequate visual and acoustical buffering and/or separation between residential units and adjoining nonresidential units and major transportation facilities. (Alameda County)
- Encourage institutions of higher education to build student, staff, and faculty housing to meet the needs of their students and employees. (Long Beach, California State University)

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Infill Housing

Also see the Infill Compendium

Objective: Make use of existing and new policies to encourage compact development and infill. (General)

Policies, Programs, Actions:

- Prepare a study recommending new financing options to provide infrastructure in infill areas. New sources of financing could include state and federal grants, the General Fund, the use of impact fees, bond measures and financing sources. (City of Sacramento)
- Encourage and facilitate transit-oriented development in key locations by maintaining a webpage with a map of sites in transit priority areas, and near services and amenities. (City of Sacramento)
- Revise County ordinances and fees to encourage development of secondary dwellings, and further promote secondary dwellings. For example, the County will consider revising road requirements and public facility fees for secondary dwellings or according to home size. (San Luis Obispo County)
- Explore ways to provide incentives for development of mixed use projects such as reduced or deferred fees and revised ordinance standards for mixed use. The County will consider the relationship between the amount of public benefit (such as reduced traffic and enhanced business viability) and proposed incentives. (San Luis Obispo County)
- Provide assistance for project design (e.g. site planning, engineering, and/or preliminary architectural services) and infrastructure improvements (e.g. cost-sharing and/or fee waivers) for: 1) infill housing development and/or redevelopment projects, especially when located in or near downtown; or 2) housing development projects that promote land or energy conservation. (City of Lindsay)
- Encourage development of residential uses in strategic proximity to employment, recreational facilities, schools, neighborhood commercial areas, and transportation routes (Long Beach)

EEC ORIGINAL PKG

A

Conservation

Biological Resources

Mineral Resources

Cultural Resources

Water Resources

Agricultural Resources

Biological Resources

Goal: Protect and enhance biodiversity and special ecosystems outside of preserves as development occurs according to the underlying land use designation. (San Diego County)

Objective 1: Ensure wildlife populations have sufficient habitat, including habitat corridors, to maintain viable numbers. Particular attention shall be focused on retaining habitat areas that are contiguous with other existing natural areas and/or wildlife movement corridors. (City of Sacramento, Yolo County)

Policies, Programs, Actions:

- Identify existing conservation lands and develop a coordinated biological preserve system that includes Pre-Approved Mitigation Areas, Biological Resource Core Areas, wildlife corridors, and linkages to allow wildlife to travel throughout their habitat ranges. Development should avoid adverse impacts to areas of conservation priority, wildlife movement corridors and nursery sites (e.g., nest sites, dens, spawning areas, breeding ponds). (San Diego County, Yolo County)
- Require that impacts to species listed under the State or federal Endangered Species Acts, or species identified as special-status by the resource agencies, be avoided to the greatest feasible extent. If avoidance is not possible, minimize and fully mitigate impacts consistent with applicable local, State, and Federal requirements. (Yolo County)
- Allow for appropriate public access to open space lands for recreation activities while protecting and restoring the natural ecosystem and minimizing environmental damage, as appropriate. (Redwood City)
- Habitat preserved as a part of any mitigation requirements shall be preserved in perpetuity through deed restrictions, conservation easement restrictions, or other method to ensure that the habitat remains protected. All habitat mitigation must have a secure, ongoing funding source for operation and maintenance. (Yolo County)

Objective 2: Preserve, maintain, and expand the number of trees in the urban forest, on both public and private property. (Redwood City)

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Policies, Programs, Actions:

- Incorporate existing trees into development projects. Avoid adverse effects on health and longevity of native trees or other significant trees through appropriate design measures and construction practices. When tree preservation is not possible, require appropriate tree replacement. (City of Citrus Heights)
- Require the retention of trees of significance (such as heritage trees) by promoting stewardship of such trees and ensuring that the design of development projects provides for the retention of these trees wherever possible. Where tree removal cannot be avoided, the City shall require tree replacement or suitable mitigation (City of Sacramento)

Objective 3: Protect and enhance streams, channels, seasonal and permanent marshland, wetlands, sloughs, riparian habitat and vernal pools in land planning and community design. (Yolo County)

Policies, Programs, Actions:

- Enhance fisheries habitat and restore access for native fishes in creeks. (Redwood City)
- Promote floodplain management techniques that increase the area of naturally inundated floodplains and the frequency of inundated floodplain habitat, restore some natural flooding processes, river meanders, and widen riparian vegetation, where feasible. (Yolo County)
- Ensure ecosystem connectivity and fish passage. (General)
- In conjunction with new development located along existing creeks and streams and where appropriate, incorporate daylighting for culverted portions or other bank naturalizing approaches for channeled sections as a means of creek and stream restoration. (Redwood City)
- Prohibit development within a minimum of 100 feet from the top of banks for all lakes, perennial ponds, rivers, creeks, sloughs, and perennial streams. A larger setback is preferred. The setback will allow for fire and flood protection, a natural riparian corridor (or wetland vegetation), a planned recreational trail where applicable, and vegetated landscape for stormwater to pass through before it enters the water body. (Yolo County)
- Require development to preserve existing natural wetland areas and associated transitional riparian and upland buffers and retain opportunities for enhancement. Require development projects to mitigate any unavoidable losses of wetlands, including its habitat functions and values. (San Diego County)

Mineral Resources

Objective: Encourage the production and conservation of mineral resources, balanced by the consideration of important social values, including recreation, water, wildlife, agriculture, aesthetics, flood control, and other environmental factors. (Yolo County)

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Policies, Programs, Actions:

- Ensure that mineral extraction and reclamation operations are compatible with land uses both on-site and within the surrounding area and are performed in a manner that does not adversely affect the environment. (Yolo County)
- Discourage development or the establishment of other incompatible land uses on or adjacent to areas classified or designated by the State as having important mineral resources (MRZ-2), as well as potential mineral lands identified by other government agencies. The potential for the extraction of substantial mineral resources from lands classified by the State as areas that contain mineral resources (MRZ-3) shall be considered by the County in making land use decisions. (San Diego County)
- Require all mining projects to be conducted in accordance with a reclamation plan that meets the minimum reclamation standards required by the California Surface Mining and Reclamation Act and associated regulations. Require the reclamation plan to include a phasing plan that provides for the completion of the surface mining on each segment of the mined lands so that the reclamation can be initiated at the earliest possible time on those portions of the mined lands that will not be subject to further disturbance by the surface mining operation. (San Diego County)
- Permit plant nurseries, recreational open space, and other temporary uses in State-designated mineral resource sectors prior to and pending their development for mineral extraction. (Rialto)

Cultural Resources

Objective: Encourage the preservation, protection and restoration of historic sites, properties and public works through the coordination of activities of the various City departments, non-profit organizations, and other associations concerning historic preservation. (City of Woodland)

Policies, Programs, Actions:

- Encourage the preservation and/or adaptive reuse of historic sites, structures, and landscapes as a means of protecting important historic resources as part of the discretionary application process, and encourage the preservation of historic structures identified during the ministerial application process. (San Diego County)
- Preserve important archaeological resources from loss or destruction and require development to include appropriate mitigation to protect the quality and integrity of these resources. Require development to avoid archeological resources whenever possible. If complete avoidance is not possible, require development to fully mitigate impacts to archaeological resources. (San Diego County)
- After consultation with local Native American Tribes affected by the plan, determine which areas may be of cultural significance and determine how the areas can be preserved. Consultation with tribes should continue to occur as the general plan is implemented. (General)
- Promote the formation and maintenance of neighborhood organizations to foster neighborhood conservation programs, giving special attention to transitional areas. (City of Woodland)

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- Require archaeological inventories that consist of field survey, record search, and archival research of all proposed developments which have not been surveyed within the last five years. Archaeologists conducting such surveys shall be proficient in identifying both historical and prehistoric sites. (General)

Water Resources

Objective 1: Manage groundwater resources on a sustainable yield basis that can provide water purveyors and individual users with reliable, high quality groundwater to serve existing and planned land uses during prolonged drought periods. (Yolo County)

Policies, Programs, Actions:

- Protect aquifer recharge features and areas of important aquifers from degradation of water quality and reduction of recharge. (City of Riverside)

Objective 2: Preserve and protect surface water through the use of careful and empirically-backed planning. (General)

Policies, Programs, Actions:

- Maximize stormwater filtration and/or infiltration in areas that are not subject to high groundwater by maximizing the natural drainage patterns and the retention of natural vegetation and other pervious surfaces. This policy shall not apply in areas with high groundwater. (San Diego County)
- Coordinate with water purveyors and water users to manage supplies to avoid long-term overdraft, water quality degradation, land subsidence and other potential problems. (Yolo County)
- Conserve and where feasible create or restore areas that provide important water quality benefits such as riparian corridors, buffer zones, wetlands, undeveloped open space areas, levees, and drainage canals. (Sacramento)

Objective 3: Require development to reduce the waste of potable water through use of efficient technology and conservation efforts that minimize the County's dependence on imported water and conserve groundwater resources. (San Diego County)

Policies, Programs, Actions:

- Support projects that provide reliable and sustainable surface water from a variety of energy efficient sources. Sources should be sufficient to serve existing and planned land uses in prolonged drought periods and protect natural resources and surface water flows. (Yolo County)
- Require new development to protect the quality of water bodies and natural drainage systems through site design, source controls, storm water treatment, runoff reduction measures, best management practices (BMPs) and Low Impact Development (LID), and Hydromodification strategies consistent with permits. (Yolo County)
- Require all development to have an adequate water supply. Require significant discretionary projects to demonstrate adequate long-term and sustainable water supplies by preparing a verified water supply assessment. (Yolo County)

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- Require new development to demonstrate that adequate water is available before project approval and to fund its fair-share costs associated with the provision of water service. (Redwood City)
- Require efficient irrigation systems and in new development and encourage the use of native plant species and non-invasive drought tolerant/low water use plants in landscaping. (San Diego County)
- Require development to minimize the use of directly connected impervious surfaces and to retain stormwater run-off caused from the development footprint at or near the site of generation. (San Diego County)
- Continue to develop and implement water conservation programs in response to community input and to keep pace with changing technology. (Redwood City)
- Support the integrated management of surface and groundwater, stormwater treatment and use, the development of highly treated wastewater, and desalinization where feasible. (Yolo County)
- Develop a recommended native, low-water-use, and drought-tolerant plant species list for use with open space and park development. Include this list in the landscape standards for private development. (City of Riverside)
- The City shall require all new development to contribute no net increase in stormwater runoff peak flows over existing conditions associated with a 100-year storm event. (Sacramento County)

Agricultural Resources

Goal: Encourage maintenance of a strong and robust agricultural land base (General)

Objective 1: Strongly discourage the conversion of agricultural land for other uses. (Yolo County)

Policies, Programs, Actions:

- Prohibit land use activities that are not compatible within agriculturally designated areas. (Yolo County)
- Establish a coherent and logical pattern of urban uses that protect and enhance open space and agricultural uses by providing a clear and permanent boundary for urban uses with the [city, county]'s planning area. (City of Livermore)
- Preserve agricultural lands using a variety of programs, including the Williamson Act, Farmland Preservation Zones (implemented through the Williamson Act), conservation easements, greenbelts, Agricultural Lands Conversion Ordinances and Right-to-Farm Ordinances. (Yolo County, San Diego County)
- Prohibit redesignation of Agricultural or Open Space lands to other land use designation unless all of the following findings can be made:

  (A) There is a public need or net community benefit derived from the conversion of the land that outweighs the need to protect the land for long-term agricultural use.

  (B) There are no feasible alternative locations for the proposed project that are either designated for non-agricultural land uses or are less productive agricultural lands.

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(C) The use would not have a significant adverse effect on existing or potential agricultural activities on surrounding lands designated Agriculture. (Yolo County)

- Develop agricultural mitigation policy which, among other things, sets a ratio of no less than 1:1 for the conversion of agricultural lands, requires funds be set aside for ongoing administration and management of mitigation lands, and identifies agricultural lands appropriate for mitigation purposes. (Santa Clara County)
- Maintain large parcel sizes within agricultural zones and strict requirements regarding division of farmland (Yolo County, Napa County)
- Require the development of vacant lands within city boundaries prior to conversion of agricultural lands. (Santa Clara County)

Objective 2: Mitigate the impacts of urban areas on agricultural lands. (General)

Policies, Programs, Actions:

- Requiring development to minimize potential conflicts with adjacent agricultural operations through the incorporation of adequate buffers, setbacks, and project design measures to protect surrounding agriculture and minimize conflicts. (San Diego County, Riverside, Woodland)
- Discourage leapfrog development and development in peninsulas extending into agricultural lands to avoid adverse effects on agricultural operations. (Woodland)
- Encourage the coordinated placement of agricultural conservation easements on land most threatened by development, particularly those lands located close to cities and unincorporated communities. (Yolo County)
- Implement an urban growth boundary to prescribe growth limits in an attempt to control urban sprawl. (Gilroy)

Objective 3: Promote the economic feasibility of agriculture and preserve traditional farmland while encouraging the development of urban agriculture. (General)

Policies, Programs, Actions:

- Establish an Agricultural District overlay designation to enhance and aggressively promote the distinctive agricultural and recreational character of unique regions within the County. Agricultural Districts shall be established in areas where agricultural business development and expansion (including industrial processing, commercial sales and agricultural tourism) will be encouraged through the use of targeted regulatory streamlining, financial incentives, specialized marketing efforts, and other programs as may be determined to be appropriate. (Yolo County)
- Support the economic competitiveness of agriculture and encourage the diversification of potential sources of farm income, including value added products, agricultural tourism, roadside stands, organic farming, and farmers' markets. (San Diego County)
- Provide venues for farmer's markets, particularly in areas that lack access to fresh and healthy foods, and encourage serving locally grown and organic foods at City public facilities. (City of Sacramento)
- Promote urban agriculture by supporting community and rooftop gardens and recognize their value in providing fresh food in urban areas in addition to their recreational, community building, landscaping, and educational value. (City of Sacramento)

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Open Space

Open Space for Habitat and Conservation

Open Space for Recreational Uses

Visual Resources

Open Space for Habitat and Conservation

Goal: Expand and enhance an integrated network of open space to support recreation, natural resources, historic and tribal resources, habitat, water management, aesthetics, and other beneficial uses. (Yolo County)

Objective: Create a network of regional parks and open space corridors that highlight unique resources and recreational opportunities for a variety of users. (Yolo County)

Policies, Programs, Actions:

- Support the preservation of open space consistent with this General Plan, via acquisition of fee title or easement interest by land trusts, government agencies, and conservancies from willing landowners. (Yolo County)
- Maintain habitat corridors to connect conservation areas such as parks, [marine protected areas], and open space, protect biodiversity, accommodate wildlife movement and sustain ecosystems. (City of Citrus Heights)
- Establish an open space acquisition program that identifies acquisition area priorities based on capital costs, operation and maintenance costs, accessibility, needs, resource preservation, ability to complete or enhance the existing open space linkage system and unique environmental features. (City of Riverside)
- Maximize public benefits in the reclamation of mineral extraction and sanitary landfill areas. (City of Rialto)
- Develop an integrated creekside trail system including low impact development strategies. (City of Citrus Heights)
- Promote acquisition and improvement of both developed and undeveloped park sites and provide recreation facilities necessary to meet or exceed the level of 3.55 parkland acres per 1,000 residents. (City of Citrus Heights)
- work with the Park District to seek locations for and the development of neighborhood parks in those neighborhoods which lack park acreage. (City of Citrus Heights)

Open Space for Recreational Uses

Objective: Develop a high-quality network of parks and recreational facilities that meet the needs of families, young adults, seniors, children, and disabled individuals. (City of Brea)

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Policies, Programs, Actions:

- Work with the School District to provide joint-use facilities in areas where park and recreation facility deficits exist. Mitigate issues associated with school open space, such as vandalism, wear and tear, maintenance, and school expansion. (City of Rialto)
- Provide for recreational trail rights-of-way along creek channels through development easements and agreements. (City of Citrus Heights)
- Work with the Park District to seek locations for and the development of neighborhood parks in those neighborhoods which lack park acreage. (City of Citrus Heights)
- Develop, wherever possible, recreation facilities that have multi-use capabilities and high degree of adaptability to more intensive use or uses as recreation demand changes and/or population density increases. (City of Brea)
- Ensure that sports facilities for organized sports do not displace existing casual use facilities and parks. (City of Brea)
- Locate new local parks and recreation facilities near other community-oriented public facilities such as schools, libraries, and recreation centers where feasible, so that they may function as the "heart" of a community. (City of San Diego)
- Design parks that reflect community character and identity, incorporate local natural and cultural landscapes and features, and consider the surrounding land uses and urban form and cultural and historic resources. (City of San Diego)
- Connect public parks to trails and pathways and other pedestrian or bicycle networks where feasible to provide linkages and connectivity between recreational uses. (City of San Diego)

Visual Resources

Objective: Preserve visual resources located in the community. (General)

Policies, Programs, Actions:

- Require the protection of scenic highways, corridors, regionally significant scenic vistas, and natural features, including prominent ridgelines, dominant landforms, reservoirs, and scenic landscapes. (San Diego County)
- Require development within visually sensitive areas to minimize visual impacts and to preserve unique or special visual features, particularly in rural areas, through the following:
  - Creative site planning
  - Integration of natural features into the project
  - Appropriate scale, materials, and design to complement the surrounding natural landscape
  - Minimal disturbance of topography

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- Clustering of development so as to preserve a balance of open space vistas, natural features, and community character
- Creation of contiguous open space networks (San Diego County)

- Protect undeveloped ridgelines and steep hillsides by maintaining semi-rural or rural designations on these areas. Recognize the value of ridgelines, hillsides and arroyos as significant natural and visual resource sand strengthen their role as features which define the character of the City and its individual neighborhoods. (San Diego County, City of Riverside)
- Restrict outdoor light and glare from development projects in Semi-Rural and Rural Lands and designated rural communities to retain the quality of night skies by minimizing light pollution. (San Diego County)
- Minimize obtrusive light by limiting outdoor lighting that is misdirected, excessive, or unnecessary. The City shall require that new development avoid the creation of incompatible glare through development design features. (City of Sacramento)
- Manage stands of mature trees, particularly native species, as unique and visual resources. (City of Brea)
- Require new development to place utilities underground and encourage "undergrounding" in existing development to maintain viewsheds, reduce hazards associated with hanging lines and utility poles, and to keep pace with current and future technologies. (Yolo County)

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A

Safety

Avoiding and Mitigating Natural Disasters

Emergency Preparedness and Prevention

Avoiding and Mitigating Natural Disasters

Objective: Protect communities from natural disasters and hazards. (General)

Policies, Programs, Actions:

- Require geotechnical investigations by certified engineering geologist or other qualified professionals for all grading and construction projects subject to geologic hazards, including fault rupture, severe ground shaking, liquefaction, landslides, and collapsible or expansive soils. (Rialto)
- Promote the strengthening of planned utilities, the retrofit and rehabilitation of existing weak structures and lifeline utilities, and the relocation or strengthening of certain critical facilities to increase public safety and minimize potential damage from seismic and geologic hazards. (Rancho Cucamonga)
- Continue enforcement of the Development Guidelines to allow for prudent development and redevelopment of all properties located on slopes greater than 10 percent, and continue to preserve as open space properties located on slopes greater than 30 percent. (Rancho Cucamonga)
- For properties located within designated 100-year flood zones, require the submittal of information prepared by qualified specialists which certifies compliance with development standards established for 100-year flood zones. (Rialto)
- Maintain structural and operational integrity of essential public facilities in the event of a flooding hazard, and locate new essential public facilities outside of flood hazard zones. (Rancho Cucamonga)
- For new development in the tsunami evacuation zone, require use of low-impact engineering techniques, such as elevating structures above projected water levels, to mitigate impacts to people and structures. (Pacifica)
- Site critical public facilities—including hospital and healthcare facilities, emergency shelters, police and fire stations, and emergency communications facilities—outside of the tsunami evacuation zone and 100-year flood plains. (Pacifica)
- Ensure that a defensible perimeter is maintained around residential located in high or very high wildfire hazards zones, as per Fire Department guidelines. (Rialto)
- Locate new buildings associated with new discretionary development outside of avalanche hazard areas. (Truckee)
- Continue to identify avalanche hazard areas, and to enforce special standards for construction in avalanche hazard areas. (Truckee)

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- Use technology to improve safety at grade crossings while causing the least environmental harm, including Quiet Zone improvements such as upgraded and updated warning devices additional gate arms, extended and raised medians, improved signage, and coordinated traffic signals. (City of Riverside)

Emergency Preparedness and Prevention

Objective: Develop plans for dealing with emergencies, both community-wide and individual. (General)

Policies, Programs, Actions:

- Reduce the loss of life, property, and injuries incurred as a result of fires by offering and supporting comprehensive fire prevention, public education, and emergency response programs. (Rancho Cucamonga)
- Require adequate water supply and fire flow throughout the City to meet fire demand during times of peak domestic water demand through a cooperative relationship with the Water District. (Rancho Cucamonga)
- Minimize the risk of potential hazards associated with aircraft operations through the adoption and implementation of the Airport Protection Overlay Zone and the County Airport Land Use Compatibility Plan. (City of Riverside)
- Ensure that new roadways are developed in accordance with standards the Municipal Code. In all new development, require adequate access to be provided for emergency vehicles, including adequate widths, turning radii, hard standing areas, and vertical clearance. (Pacifica)
- Develop a plan to widen critical rights-of way that do not provide adequate clearance for emergency vehicles. For areas that are not feasibly accessible to emergency vehicles, develop a contingency plan for reaching and evacuating people in need of treatment. (Pacifica)
- Identify and establish specific travel routes for the transport of hazardous materials and wastes, with key considerations being capacity to safely accommodate additional truck traffic, avoidance of residential areas, and use of interstate or State divided highways as preferred routes. (Rialto)
- Encourage and promote practices that will reduce the use of hazardous materials and the generation of hazardous waste at their source, recycle the remaining hazardous wastes for reuse, and treat those wastes which cannot be reduced at the source or recycled. (Rialto, Rancho Cucamonga)
- Continue to provide community programs that develop positive relationships between the Police Department and community members, such as the Area Commander Program and Crime Free Multi-Housing Program, which provide a safe and secure environment for the community to discuss gang-related issues and effective solutions to help reduce crime and provide a safer living environment. (Rialto)
- Continue to promote neighborhood watch programs for residential areas aimed at empowering neighborhoods to watch for and report any suspicious activity. (Rancho Cucamonga)

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- Continue to provide high-quality patient care with cross-trained firefighter/paramedics and emergency medical technicians. Improve the level of patient care in the community through the development and implementation of innovative emergency medical service delivery strategies. (Rancho Cucamonga)
- Notify all developers, particularly those of multi-story or critical structures, of potential impacts resulting from winds, and require appropriate structural and design treatment. (Rancho Cucamonga, Santa Ana Winds)
- Create policies or procedures that provide flexibility regarding how prospective buyers and tenants of properties within the Airport Influence Area are informed of potential aircraft overflight impacts. (Rancho Cucamonga)
- Work to achieve consistency between General Plan land use and related policies and the Airport Comprehensive Land Use Plan, as is appropriate for the community. Measures may include restrictions on permitted land uses and development criteria, including height restrictions. (Redwood City)
- When an adequate model with sufficient local detail is available to project the impacts of sea level rise, take into account potential erosion caused by sea level rise by the year 2050 in the determination of developable area and the assessment of whether coastline-altering structures would be needed in the future to protect new development. (Pacifica)

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A

Environmental Justice

Pollution Exposure

Food Access

Safe and Sanitary Homes

Physical Activity

Access to Public Amenities

Pollution Exposure

Goal: Integrate air quality, land use and transportation planning and policy to reduce the emission of criteria pollutants and greenhouse gases from mobile sources. (City of Arvin)

Objective: Improve or maintain air quality for the promotion of population and environmental health. (General)

Policies, Programs, Actions:

- Ensure that new development with sensitive uses located adjacent TAC sources minimizes potential health risks. The City shall require new development with sensitive uses located adjacent to TAC sources be designed with consideration of site and building orientation, location of trees, and incorporation of ventilation and filtration to lessen any potential health risks. In addition, the City shall require preparation of a health risk assessment. (Sacramento)
- Require that development be located and designed to reduce vehicular trips (and associated air pollution) by utilizing compact regional and community-level development patterns while maintaining community character.(San Diego County)
- Require projects that generate potentially significant levels of air pollutants and/or GHGs such as quarries, landfill operations, or large land development projects to incorporate renewable energy, and the best available control technologies and practices into the project design. (San Diego County)
- Ensure that affected residents have the opportunity to participate in decisions that impact their health. (Jurupa Valley)

Goal: Improve the quality of the built and natural environment in the city to support a thriving community and to reduce disparate health and environmental impacts, especially on low-income and disadvantaged communities. (City of Richmond)

Policies and Programs:

- Protect the population from impacts of stationary and non-stationary sources of pollution. Monitor and assess the impact of air pollution on health. Avoid locating new sensitive uses such as schools, childcare centers, and housing in proximity to polluting

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mobile and stationary sources of pollution. Design buildings to mitigate poor air quality. Sources of pollution include heavy industry, port, truck routes, and busy roadways. (City of Richmond)

- Consider environmental justice issues as they are related to potential health impacts associated with land use decisions, including enforcement actions to reduce the adverse health effects of hazardous materials, industrial activity and other undesirable land uses, on residents regardless of age, culture, ethnicity, gender, race, socioeconomic status, or geographic location. (National City)
- Require industry to reduce emissions that negatively impact public health and the natural environment. Revise and strengthen the existing ordinance that defines penalties and mitigation measures for toxic releases and accidents. Encourage County, State, Federal environmental regulators to increase penalties for toxic releases and accidents to prevent lax adherence to regulations. (City of Richmond)
- Concentrate commercial, mixed-use, and medium to high density residential development along transit corridors, at major intersections, and near activity centers that can be served efficiently by public transit and alternative transportation modes. (National City)
- Consider environmental justice issues as they are related to the equitable provision of desirable public amenities such as parks, recreational facilities, community gardens, and other beneficial uses that improve the quality of life. (National City)
- Ensure that contaminated sites in the city are adequately remediated before allowing new development. Engage the community in overseeing remediation of toxic sites and the permitting and monitoring of potentially hazardous industrial uses. Develop a response plan to address existing contaminated sites in the city. Coordinate with regional, state, and federal agencies. Include guidelines for convening an oversight committee with community representation to advise and oversee toxic site cleanup and remediation on specific sites in the city. Address uses such as residential units, urban agriculture, and other sensitive uses. (City of Richmond)
- Ensure adequate buffers or noise mitigation measures between sensitive uses. Sensitive uses include residential units and major noise polluters such as roadways, railroads, port, and heavy industry. (City of Richmond)

Goal: Minimize exposure of the public to hazardous air pollutant emissions, particulates and noxious odors from highways, major arterial roadways, industrial, manufacturing, and processing facilities. (City of Arvin)

Policies and Programs:

- Coordinate with the SJVAPCD to ensure that construction, grading, excavation and demolition activities within the County's jurisdiction are regulated and controlled to reduce particulate emissions to the maximum extent feasible. (City of Arvin)
- Require that all access roads, driveways, and parking areas serving new commercial and industrial development be constructed with materials that minimize particulate emissions and are appropriate to the scale and intensity of use. (City of Arvin)

Goal: Proactively coordinate City air quality improvement activities with County and regional programs and those of neighboring communities. (City of Arvin)

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Policies and Programs:

- Designate an Air Quality and Climate Change Coordinator to coordinate City efforts and work with neighboring jurisdictions and affected agencies to minimize cross-jurisdictional and regional transportation and air quality issues. (City of Arvin)
- Consult with the SJVAPCD and KernCOG during CEQA review of discretionary projects having the potential for causing adverse air quality, transportation, and climate change impacts. Participate in the SJVAPCD Climate Change Action Plan implementation. (City of Arvin)
- Actively work with and support agricultural activities to develop, implement and find funding sources for programs and initiatives that improve air quality, reduce greenhouse gases and particulate matter. (City of Arvin)

Goal: Clean, breathable indoor and outdoor air. (City of Murrieta)

Policies and Programs:

- Update and enforce tobacco control laws that pertain to location and retailing practices, smoking restrictions, and smoking-free home and workplace laws. (City of Murrieta)
- Disseminate information to tenants and property owners about indoor mold growth hazards, reduction, and prevention methods. (City of Murrieta)
- Encourage smoke free workplaces, multifamily housing, parks, and other outdoor gathering places to reduce exposure to second-hand smoke. (National City)

Food Access

Goal: Reduced Rates of Obesity, Eating Disorders, and Chronic Disease Such as Heart Disease and Breast Cancer. Improve individual and community health through prevention, screening, education, and treatment strategies regarding nutrition and physical activity related health issues. (County of Marin)

Objective 1: Ensure that sources of healthy foods are available in all neighborhoods. (City of Chino)

Policies, Programs, Actions:

- Promote nutrition education and access to healthy foods. Provide affordable healthy foods, and fresh, locally grown fruits and vegetables in schools and other public places. (County of Marin)
- Increase access to healthy foods/beverages. Support neighborhood-oriented, specific sources of healthful foods, such as farmers' markets and local outlets. Support food banks, pantries, and other sources that help provide federal food assistance to low-income residents so that all families, seniors, schools, and community-based organizations are able to access, purchase, and increase intake of fresh fruits, vegetables, and other nutritious foods. (County of Marin)

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- Ensure that all residences are within walking distance of sources of fresh food, including grocery stores, farmers' markets, and community gardens, and shall prioritize underserved areas for new sources of healthy food. (City of Chino)
- Support the development of new retail venues that sell local, fresh produce, including farmers' markets, community-supported agriculture programs, and grocery stores. (City of Chino)
- Identify and utilize the provision of programs, incentives, and/or grants to encourage small grocery or convenience stores to sell fresh foods in underserved areas. These programs could include grants or loans to purchase updated equipment (refrigeration), publicity or directories of healthy food outlets, or connecting stores to wholesale sources of healthy, local, or organic food. (City of Chino, City of Murrieta)
- Allow the development of community gardens in residential and other land use designations. (City of Chino)
- The City shall encourage farmers' markets to accept food stamps and other public food benefits. (City of Chino)
- Take steps toward meeting the City's own food needs (e.g. cafeterias, public functions) and those of the schools through the purchase of local and organic food. (City of Chino)
- Work with the School District to establish strong nutritional standards for school lunches and to phase out vending machines and sugar sweetened beverages, particularly at elementary schools. (City of Chino)
- Identify and inventory potential community garden and urban farm sites on existing parks, public easements, right-of-ways, and schoolyards, and develop a program to establish community gardens in appropriate locations. (City of Chino)
- Identify and prioritize neighborhoods underserved by healthy food sources for development of healthy food sources. (City of Chino)
- Establish a process through which a neighborhood can propose and adopt a site as a community garden. (City of Chino)
- Identify appropriate locations for farmers markets and community- supported agriculture drop-off sites and prioritize such uses in these areas. (City of Chino)
- Develop a program to provide fast-track permitting for grocery stores in underserved areas. (City of Chino)

Objective 2: Avoid disproportionate concentrations of unhealthy food sources within neighborhoods. (City of Chino)

Policies and Programs:

- Restrict approvals of new liquor and convenience stores in areas with an existing high concentration of such stores. (City of Chino)
- Identify and inventory areas with a high ratio of convenience, liquor, and fast food stores, and develop a program to prioritize the development of new sources of healthy foods in these areas. (City of Chino)

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Safe and Sanitary Homes

Goal: Encourage a range of housing opportunities for all segments of the community. (City of Sacramento)

Objective: Promote an equitable distribution of housing types for all income groups throughout the city and promote mixed income neighborhoods rather than creating concentrations of below-market-rate housing in certain areas. Encourage new projects to include a range of housing types including single-family residences, townhomes, condominiums and rental units. (City of Sacramento, Richmond.)

Policies, Programs, Actions:

- Facilitate the development of housing to meet the community's fair share of the County's and region's housing needs. (San Jose)
- Increase, preserve and improve the affordable housing stock. (San Jose)
- Incentivize affordable housing through permit streamlining and financial incentives. (Jurupa Valley)
- Update the City's dispersion policy: 1) to align the location of future affordable housing developments with planned future Growth Areas identified in the Envision General Plan; 2) to be consistent with the City's inclusionary housing ordinance; 3) to maximize the access of transit, retail, services, and amenities to affordable housing developments; and 4) to reemphasize the support for integration and complete communities. (San Jose)
- Consider the economic integration of neighborhoods when financing new multifamily affordable housing projects. (City of Sacramento)
- Promote the siting, production, rehabilitation, and preservation of housing for ELI (Extremely Low-Income) households, including nontraditional housing types. (City of Sacramento)
- Remove regulatory constraints to equal housing opportunity. (Chico)
- Enhance low income independent housing for seniors, continue to develop and expand senior housing services (Marin County)
- Strongly enforce fair housing laws to protect residents from housing discrimination. Provide education, outreach, and referral services for residents regarding their rights as tenants and buyers. Provide education and outreach to landlords, property managers, real estate agents, and others on their obligations when housing is made available the City shall support fair housing education programs offered by local organizations such as the Apartment Owner's Association and the Board of Realtors. (Chico, and City of Sacramento)
- Pursue and maximize the use of all appropriate state, federal, local and private funding for the development, preservation, and rehabilitation of housing affordable for extremely low-, very low-, low-, and moderate income households, while maintaining economic competitiveness in the region. (City of Sacramento)
- Work with social service agencies and all federal, state, and local jurisdictions to provide an integrated system of care for people experiencing homelessness. (Richmond)

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Goal: Improve and maintain the quality of housing and residential neighborhoods. (Kings County)

Policies and Programs:

- Promote and improve the quality of residential properties by ensuring compliance with housing and property maintenance standards. (Kings County)
- Assist in the repair, rehabilitation, and improvement of residential structures; demolish and replace structures which are dilapidated and beyond repair. (Kings County)
- Preserve assisted rental housing for long-term occupancy by low- and moderate-income households. (Kings County)

Goal: Facilitate and encourage the provision of a range of housing types and prices to meet the diverse needs of residents. (Kings County)

Policies and Programs:

- Provide adequate sites for housing through appropriate land use, zoning and development standards to accommodate the regional housing needs for the 2009–2014 planning period. (Kings County)
- Work collaboratively with nonprofit and for-profit developers to seek state and federal grants to support the production of affordable housing. (Kings County)
- Support the construction of high quality single- and multi-family housing which is well designed and energy efficient. (Kings County)

Objective: Provide a variety of housing types that meet the housing needs of residents of all income levels in Chino. (City of Chino)

Policies and Programs:

- Residential neighborhoods should contain a mix of housing types including single-family homes on a range of lot sizes; townhomes; duplexes, triplexes and four-plexes; and apartments. (City of Chino)
- Wherever feasible, affordable housing shall be integrated into both new and established neighborhoods. (City of Chino)
- Allow and encourage non-traditional housing types that can provide affordable housing, such as accessory dwelling units. (City of Chino)
- Encourage the development of senior housing and assisted living facilities, especially near transit, recreational facilities, medical centers and hospitals, neighborhoods well served by pedestrian facilities, and access to healthy food. (City of Chino)
- Develop a program to work with large employers developing new projects in Chino to ensure local housing opportunities for their employees. (City of Chino)

EEC ORIGINAL PKG

Physical Activity

Goal: City resources for parks and recreation facilities are leveraged through partnerships, joint use agreements, private facilities, outside funding, and community volunteers. (City of Murrieta)

Policies and Programs:

- Maintain the joint use agreement with Murrieta Valley Unified School District and look for additional opportunities to partner in expanding resident access to shared facilities. (City of Murrieta)
- Continue to cooperate with school districts in locating schools to allow for park development adjacent to campuses. (City of Murrieta)
- Cooperate with federal, state, and county agencies to provide regional open space and recreation facilities for local residents. (City of Murrieta)
- Encourage the development of private and commercial recreation facilities. (City of Murrieta)
- Seek agreements and joint ventures with private entities to provide recreation facilities and activities. (City of Murrieta)
- Pursue support from federal, state, and private sources to assist with acquisition, design, and construction of parks and recreation facilities. (City of Murrieta)
- Promote a sense of community responsibility for maintaining and improving the parks and recreation system, and offer ways for individuals, groups, and businesses to invest time and resources in that effort. (City of Murrieta)

Goal: Recreation programs enrich the lives of residents across a broad spectrum of ages, interests, and abilities. (City of Murrieta)

- Seek resident involvement and feedback to create recreation programming that is relevant to a broad spectrum of community members. (City of Murrieta)
- Offer and encourage cultural arts programs and events that provide entertainment, such as concerts, as well as those that develop skills in dancing, drama, music, and the arts. (City of Murrieta)
- Use recreation programming to promote physical activity, healthy eating, and other healthy lifestyle habits. (City of Murrieta)
- Collaborate with other providers to expand therapeutic recreation programs for residents with special needs. (City of Murrieta)

Goal: Youth are a special focus of recreation facilities and programs. (City of Murrieta)

Policy and Programs:

- Expand recreation programs for youth and teens, including before- and afterschool care, sports and fitness, outdoor activity and excursions, and arts education. (City of Murrieta)
- Use recreation programming to promote success in school. (City of Murrieta)

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- Provide safe places for teens to socialize and participate in recreation activities. (City of Murrieta)
- Expand opportunities for youth to be involved in planning recreation programs, services, and events for youth. (City of Murrieta)
- Continue providing the Youth Advisory Committee for middle school and high school students. (City of Murrieta)

Policy and Programs:

- Create a Safe Routes to School plan in all schools. Prioritize improvements with the highest safety concerns. Actively seek State and Federal funding to support the Safe Routes to School plan. (City of El Monte)
- Pedestrian Safety. Enhance pedestrian safety by completing sidewalks, identifying areas for crosswalks and signaling, and prioritizing the funding, construction, and maintenance of safe routes to schools, parks, and public facilities. (City of El Monte)
- Bicyclist Safety. Improve bicycle safety by creating well-defined bicycle lanes, working with the school districts to educate children about safe cycling practices, and providing information about safe routes to school. (City of El Monte)
- Streetscape Design. Develop detailed standards and guidelines for the treatment of public streetscapes to improve safety and walkability. Recommendations should address street trees, street lighting, street furniture, traffic calming, and related items. (City of El Monte)
- Promote increased physical activity, reduced driving, and increased walking, cycling, and transit use. Such policies include those which:
  - Support the development of compact, transit-adaptive, and pedestrian- and bicycle-friendly development patterns.
  - Reduce driving and increase opportunities for active transportation (walking and biking) and transit use.
  - Require the incorporation of pedestrian and bicycle facilities in new development and on all new and renovated transportation facilities built and/or managed by the County.
  - Evaluate development based on its impacts to the environment, economy, infrastructure, and services. (Riverside County)

Goal: Excellent pedestrian and bicycle networks throughout the City. (City of South Gate)

Objective 1: Create a high quality pedestrian network in all areas of the City so that residents can safely walk to their destinations. (City of South Gate)

Policies and Programs:

- Creating a continuous, safe, and attractive pedestrian environment should be a key strategy for improving community health. (City of South Gate)
- Walking will be considered an integral mode of transportation for the City's circulation network. (City of South Gate)
- Balance the needs of pedestrians and cyclists with the needs of motor vehicles in decisions made about the transportation network. (City of South Gate)

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- To the extent that funding is available, the City will maintain sidewalks to protect public safety and create a visually attractive environment. (City of South Gate)
- Improve unsafe and unattractive pedestrian areas, as resources become available. The City will promote streets as public, pedestrian oriented places through the appropriate placement of new buildings, parked cars and garages. (City of South Gate)
- New development projects and public infrastructure projects will be required to provide safe and direct pedestrian connections to transit stops. (City of South Gate)
- Private development on street frontages that do not currently include sidewalks will be required to install sidewalks in front of the property when new development occurs. (City of South Gate)
- Allow sufficient pedestrian cross times, particularly for the elderly and strollers, when setting traffic light timing. (City of South Gate)

Objective 2: Create a citywide bicycle network that enables cycling to be used for both recreation and transportation. (City of South Gate)

Policies and Programs:

- Creating a continuous, safe, and attractive cycling network that connects all the City's neighborhoods and districts will be an important strategy for improving community health. (City of South Gate)
- Implement the policies and programs in the Mobility Element that provide for an extensive, safe and complete bicycle network that connects all the City's neighborhoods and districts. (City of South Gate)
- Balance the needs of bicycles with the needs of motor vehicles in all transportation and public works decisions. (City of South Gate)
- The City's bicycle network should be safely and directly connected to the regional bicycle network and the bicycle networks of adjacent jurisdictions. (City of South Gate)
- Where feasible, bicycle lanes and other bicycle facilities will be included as part of street improvement projects. (City of South Gate)
- Support regional efforts to increase cycling as a transportation alternative. (City of South Gate)
- Encourage or require a sufficient quantity of well-placed bike parking in all new development. (City of South Gate)

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Access to Public Amenities

Policies, Programs, Actions:

- Maintain and improve access to transit stops and stations for mobility-challenged population groups such as youth, the disabled, and seniors. (San Jose)
- Create a balanced park system that provides all residents access to parks, trails, open space, community centers, dog parks, skate parks, aquatics facilities, sports fields, community gardens, and other amenities. (San Jose)
- Apply resources to meet parks, recreation, and open space needs in underserved areas of the city, prioritizing lower income and higher density areas, which may have a demonstrably greater need for these amenities. (San Jose)

EEC ORIGINAL PKG

Noise

Goal: Ensure that existing and planned land uses are compatible with the current and projected noise environment (Yolo County)

Objective: Minimize the impact of noise from transportation sources including roads, rail lines, and airports on nearby sensitive land uses. (Yolo County, County of San Diego)

Policies, Programs, Actions:

- Increase setbacks between noise generators and noise sensitive areas (County of San Diego)
- Employ technologies when appropriate that reduce noise generation (i.e. alternative pavement materials on roadways). (County of San Diego)
- Protect schools, hospitals, libraries, churches, convalescent homes, and other noise sensitive uses from excessive noise levels by incorporating site planning and project design techniques to minimize noise impacts. The use of noise barriers shall be considered after all practical design-related noise measures have been integrated into the project. In cases where sound walls are necessary, they should help create an attractive setting with features such as setbacks, changes in alignment, detail and texture, murals, pedestrian access (if appropriate), and landscaping. (City of Murrieta)
- For County road improvement projects, evaluate the proposed project against ambient noise levels to determine whether the project would increase ambient noise levels by more than three decibels. If so, apply the limits in the noise standards listed in Table xx for noise sensitive land uses that may be affected by the increased noise levels. For federally-funded roadway construction projects, use the limits in the applicable FHWA standards (San Diego County)
- Integrate noise considerations into land use planning decisions to prevent new noise/land use conflicts. (City of Murrietta)
- Avoid placing noise-sensitive land uses (e.g., residential uses, hospitals, assisted living facilities, group homes, schools, day care centers, etc.) within the high noise impact areas (over 65 dB CNEL) for (designated airports) in accordance with the County Airport Land Use Compatibility Plan (City of Riverside)
- Evaluate noise impacts on any sensitive receptors from frequent, high-noise events when considering whether to approve the development proposal, taking into account potential for sleep disturbance, undue annoyance, and interruption in conversation, to ensure that the proposed development is compatible within the context of its surroundings. (City of Sacramento)
- If the noise source is BART, then the outdoor noise exposure criterion should be 70 Ldn for future development, recognizing that BART noise is characterized by relatively few loud events. (City of El Centro)
- Orient buildings such that the noise sensitive portions of a project are shielded from noise sources. (County of San Diego)
- Incorporate noise considerations into the site plan review process, particularly with regard to parking and loading areas, ingress/egress points and refuse collection areas. (City of Riverside)
- Use sound–attenuating architectural design and building features. (County of San Diego)

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- Require construction projects anticipated to generate a significant amount of vibration to ensure acceptable interior vibration levels at nearby residential and commercial uses based on the current City or Federal Transit Administration (FTA) criteria. (RDR) The City shall require new residential and commercial projects located adjacent to major freeways, hard rail lines, or light rail lines to follow the FTA screening distance criteria (City of Sacramento)
- Use the Noise Compatibility Guidelines and the Noise Standards as a guide in determining the acceptability of exterior and interior noise for proposed land uses. (County of San Diego)
- Discourage the use of noise walls. In areas where the use of noise walls cannot be avoided, evaluate and require where feasible, a combination of walls and earthen berms and require the use of vegetation or other visual screening methods to soften the visual appearance of the wall. (County of San Diego)
- Require an acoustical study to identify inappropriate noise level where development may directly result in any existing or future noise sensitive land uses being subject to noise levels equal to or greater than 60 CNEL and require mitigation for sensitive uses in compliance with the noise standards listed. (County of San Diego)
- Require new development to include noise mitigation to assure acceptable interior noise levels appropriate to the land use type: 45 dBA Ldn for residential, transient lodgings, hospitals, nursing homes and other uses where people normally sleep; and 45 dBA L eq (peak hour) for office buildings and similar uses. (City of Sacramento)

EEC ORIGINAL PKG

A

Healthy Communities

Economics and Health

A Changing Climate and Resiliency

Social Connection and Safety

Health and Human Services

Economics and Health

Goal: Encourage economic and racial integration, fair housing opportunity, and the elimination of discrimination. (City of Sacramento)

Policies, Programs, Actions:

- Provide widespread access to diverse employment and training opportunities and strive to increase job growth, particularly jobs that provide self-sufficient wages and health care benefits, to allow the community to broadly share in the region's prosperity. (San Jose)
- Attract and retain a diverse mix of businesses and industries that can provide jobs for residents of all skill and education levels to support a thriving community. (San Jose, Washington D.C.)
- Attract job opportunities accessible to all residents, particularly residents in low-income neighborhoods. (San Jose)
- Partner with educational, civic, labor, and business institutions to provide job training programs that enable the unemployed, under-employed, or economically or socially disadvantaged to enter or move up in the labor force. Support and enhance education, training and recruitment programs and services for local residents to increase job and employment opportunities and compete in the regional economy. Connect local businesses with such programs, organizations, or educational institutions. (Richmond and San Jose, modified)
- Encourage businesses and industries to hire locally and to demonstrate reasons for not hiring local employees. (Richmond)

Objective: Develop policies to benefit residents economically (General)

Policies, Programs, Actions:

- Continue to encourage new businesses to give local residents preference in hiring decisions, and develop incentives to support this effort. (San Pablo)
- Enhance aesthetics and quality of the housing stock and remove blight by implementing policies and programs identified in the Housing Element. (San Pablo)

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- Develop programs to attract and retain industries that can provide a living wage, provide health insurance benefits, and meet existing levels of workforce education. (Murrieta)
- Promote uses that address daily needs within the City and close to neighborhoods, reducing the need for residents to travel long distances to access jobs, goods and services. (City of Arvin)
- Encourage development that reduces VMT, decreases distances between jobs and housing, reduces traffic impacts, and improves housing affordability (Sonoma County).
- The attraction and retention of high quality grocery stores and other healthy food purveyors should be pursued as an economic development strategy for the City. Healthy food outlets include full-service grocery stores, regularly-held farmer's markets, fruit and vegetable markets, and convenience stores or corner stores that sell a significant proportion of healthy food. (City of South Gate)

Goal: Health and well-being for those who live, work, and play in the city. (City of Murrieta)

Policies and Programs:

- Develop programs to attract and retain industries that can provide a living wage, provide health insurance benefits, and meet existing levels of workforce education. (City of Murrieta)
- Encourage local employers to adopt healthy living/healthy employee programs and practice such as health challenges (e.g., weight loss contests, stop smoking, lunchtime/worktime sponsored events, bike to work days), healthy food choices, and healthy work environments. (City of Murrieta)
- The City can lead by example by expanding the Healthy Murrieta program and by developing City-sponsored programs to address employee health for city employees. Suggested programs could include weight loss challenges, exercise challenges, lunchtime exercise programs, sponsoring bike and walk to work days, and providing transit passes for employees. (City of Murrieta)

A Changing Climate and Resiliency

Policies, Programs, Actions:

- Plan for Climate Change. Plan for the public health implications of climate change, including disease and temperature effects. (County of Marin)
- Identify Potential Responses to Climate Change. Work with the Intergovernmental Panel on Climate Change (IPCC) and other leading health organizations to identify critical public health issues and identify potential responses necessary related to climate change.(County of Marin)

Goal: Recognize the multiple functions of the natural environment for safety, recreation, protection from climate changes, and economic uses. (County of Solano)

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Goal: Increase awareness of the effect humans have on the environment and encourage individuals and organizations to modify habits and operations that cause degradation to the environment and contribute to climate change. (County of Solano)

Goal: Prepare for and adapt to the effects of climate change. (County of Solano)

Goal: Promote a sustainable future where residents can enjoy a high quality of life for the long term, including a clean and beautiful environment and a balance of employment, housing, infrastructure, and services. (County of Sonoma)

Policies and Programs:

- Encourage reduction in greenhouse gas emissions, including alternatives to use of gas-powered vehicles. Such alternatives include public transit, alternatively fueled vehicles, bicycle and pedestrian routes, and bicycle- and pedestrian-friendly development design. (County of Sonoma)

Goal: Mitigate against climate change. (City of Rancho Cucamonga)

Policies and Programs:

- Consult with State agencies, SCAG, and the San Bernardino Associated Governments (SANBAG) to implement AB32 and SB375 by utilizing incentives to facilitate infill and transit oriented development. (City of Rancho Cucamonga)
- Encourage renewable energy installation, and facilitate green technology and business and a reduction in community-wide energy consumption. (City of Rancho Cucamonga)
- Encourage development of transit-oriented and infill development, and encourage a mix of uses that foster walking and alternative transportation. (City of Rancho Cucamonga)
- Provide enhanced bicycling and walking infrastructure, and support public transit, including public bus service, the Metrolink, and the potential for Bus Rapid Transit (BRT). (City of Rancho Cucamonga)
- Provide green building incentives, assess green building techniques as a formal stage of project review, and develop a green building ordinance or program that addresses both new and existing buildings. Adaptation strategies will also include increased water efficiency in buildings. (City of Rancho Cucamonga)
- Support tree planting, planting more vegetation (including native and drought-resistant planting), and preservation of open space. (City of Rancho Cucamonga)
- Develop green procurement plans and ensure energy savings in City operations and maintenance. (City of Rancho Cucamonga)
- Develop energy- or climate change-themed publications and workshops, facilitating energy audits for residents, and establishing partnerships to reduce greenhouse gas emissions. Increase public awareness about climate change, and encourage residents and businesses to become involved in activities and lifestyle changes that help reduce greenhouse gas emissions. (City of Rancho Cucamonga)

EEC ORIGINAL PKG

Social Connection and Safety

Goal: Improve public safety for all residents. (General)

Objective: Use the built environment and city planning tools to deter crime, increase respect for neighbors and property, and improve the public perception of safety throughout the community. (San Pablo)

Policies, Programs, Actions:

- Orient building and windows to provide maximum surveillance of exterior areas, and locate entryways such that they are visible to adjacent neighbors or passersby. (San Pablo)
- Encourage the development of complete neighborhoods that provide for the basic needs of daily life and for the health, safety, and mental well-being of residents (Riverside County)
- Use landscaping such as low hedges and flowerbeds to identify points of entry and movement on property, and use signage and symbolic barriers to direct vehicular and pedestrian traffic. (San Pablo)
- Make it easier to maintain property by recommending graffiti-resistant surface materials, vandal-proof lighting, and landscaping selected for durability and easy maintenance. (San Pablo)
- Promote activity in public areas throughout the day by coordinating shared uses of facilities (parking lots, parks, sports fields). (San Pablo)
- Ensure that minimum illumination standards for streetlights are met and, if necessary, update the standards to reflect best practices for safety lighting. (San Pablo)

Goal: Create and foster a sense of community among residents (General)

Objective 1: Promote social activities for community residents and foster a sense of community (General)

Policies, Programs, Actions:

- Coordinate with local businesses, organizations, colleges, and the school district to support a year-round calendar of community events in Davis Park and other City parks. Events should be geared toward families and youth, and contain components of physical activity, healthy food, arts, and music. (San Pablo)
- Encourage a sense of ownership, community pride and civic respect as a means of improving the safety and image of the City. (San Pablo)
- Continue community policing and relationship- building programs, including educational and mentoring initiatives with schools. (San Pablo)
- Continue to involve residents in neighborhood improvement efforts, including issues concerning safety, neighborhood character, planning, and revitalization. (San Pablo)
- Create public plazas with seating, art, and play features near shopping and business districts. (Murrieta)

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- Work with restaurants and cafes to create sidewalk outdoor seating areas to activate the sidewalk. (Murrieta)
- Allow and encourage residents to apply for street closure permits for neighborhood block parties and community wide social events, that strengthen neighborhood cohesion. (Murrieta, City of El Monte)
- Build an affordable, accessible, and flexible central gathering/meeting space that individuals and community groups can rent for a variety of social, cultural, educational, and civic purposes. (Murrieta)
- Encourage the development and display of public art to promote the history, heritage, and culture of the community. (Murrieta)
- Consider adopting a public art ordinance that 1) provides incentives for businesses to provide public art and 2) establishes a fee for commercial and industrial projects that do not wish to install public art. (Murrieta)

Objective 2: Help members on the margins of society integrate and become productive community members. (General)

Policies, Programs, Actions:

- Support organizations that provide substance abuse treatment services (San Pablo, Murrieta)
- Connect formerly-incarcerated persons to educational and job-training opportunities available at community college and elsewhere in the community. (San Pablo)

Objective 3: Enhance overall community safety by placing more emphasis on preventative measures to reduce crime, including the incorporation of crime prevention features in the built environment of each community to increase overall safety of residents and visitors within these communities. (Kings County)

Policies and Programs:

- Encourage new development to integrate Crime Prevention Through Environmental Design (CPTED) strategies and applications to enhance crime prevention in the County's Community Districts and serve as deterrents to crime. (Kings County)
- Coordinate community planning efforts with the County Sheriff's Department to build a sustainable positive law enforcement presence that results in safer living environments within community districts. (Kings County)
- Support community policing, neighborhood watch, and other law enforcement efforts that engage community residents. (Kings County)
- Support programs aimed at intervention with at risk youth as a preventative measure to reduce future crime potential. (Kings County)
- Invest in community planning efforts that aim to reverse trends of community deterioration and blight which lead toward the decline of personal and property safety within the County's community districts. (Kings County)

EEC ORIGINAL PKG

Health and Human Services

Objective: Ensure residents have access to basic health services

Policies, Programs, Actions:

- Establish relationships and collaborate with local health officials, planners, non- profit organizations, hospitals, local health clinics, and community groups to improve community health. (Murrieta)
- Work with local and regional health care agencies to promote preventive treatment and broad access to health care. (Murrieta)
- Work with existing organizations and agencies to support high-quality affordable and convenient access to a full range of traditional and alternative primary, preventive, emergency, and specialty health care options. (Murrieta)
- Partner with community groups encourage school-based health centers. (Murrieta)

Goal: Improve public health through implementation of programs and community design. (General)

Objective: Apply innovative and model best practices in the community health field. (Murrieta)

Policies, Programs, Actions:

- Collaborate with the County Department of Public Health's efforts to systematically collect, track, and analyze community health and social, economic, and physical environmental data. (Murrieta)
- Implement policies and programs that encourage bicycling and walking as alternatives to driving and as a means of increasing levels of physical activity. Encourage bicycle and pedestrian safety through education and incentive programs. (City of El Monte)
- Seek opportunities to promote healthy lifestyles, activities, and food choices at City offices and City-organized events. (Murrieta)
- Incentivize health promotion groups to participate at City-sponsored events (i.e., waive booth fees at fairs, etc.). (Murrieta)
- Promote the health and well-being of City employees through health challenges (e.g., weight loss contests, stop smoking, lunchtime/worktime sponsored events, bike to work days), healthy food choices, and healthy work environments, when feasible. (Murrieta)

Goal: Seek input from the County Department of Public Health and others on proposed development projects or other land use and transportation decisions to encourage that the decisions promote health. (Murrieta)

Objective 1: Minimize commutes and promote neighborhood cohesion. (General)

Policies, Programs, Actions

- Evaluate and make changes to the project review and permitting process to encourage and facilitate incorporation of universal, lifecycle design principles in new residential development, allowing community members to stay in their homes, and neighborhoods, longer and increasing community cohesion. (San Pablo)

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- Establish travel demand management programs to reduce peak-hour traffic congestion and help reduce regional vehicle miles traveled. (San Pablo)

Objective 2: Improve indoor air quality, both indoor and outdoor, as a public health measure. (General)

Policies, Programs, Actions

- Update and enforce tobacco control laws that pertain to location and retailing practices, smoking restrictions, and smoking-free home and workplace laws. (Murrieta)
- Disseminate information to tenants and property owners about indoor mold growth hazards, reduction, and prevention methods. (Murrieta)
- Encourage that the municipal vehicle fleet achieve the highest possible number of fuel-efficient and low emissions vehicles commercially available. (Murrieta)

Objective 3: Ensure that residents have a range of choices for accessible, affordable, and nutritious foods (Murrieta)

Policies, Programs, Actions

- Encourage equitable distribution of healthy food retail and dining options in all commercial and employment areas of the City. (Murrieta)
- Research and consider land use regulations to limit fast food outlet density. (Murrieta)
- Encourage restaurants to voluntarily eliminate transfats from their menus. (Murrieta)
- Identify and utilize available incentives, grants, and/or programs to encourage restaurants to create a healthier dining experience for customers by highlighting healthy dishes, offering smaller portion sizes, and disclosing nutrition facts. (Murrieta)
- Support community education programs on healthy eating habits and lifestyles, including topics such as nutrition, physical activity, and vegetable gardening. (Murrieta)
- Encourage larger food retailers to carry specialty ethnic food items and support the opening of smaller ethnic food stores. (Murrieta)

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Air Quality

Objective 1: Reduce exposure to localized air pollution and improve overall air quality (General)

Objective 2: Minimize and mitigate air quality concerns through design, incentives, and coordination. (General)

Policies, Programs, Actions:

- Require that new multi-family residential buildings and other sensitive land uses in areas with high levels of localized air pollution be designed to achieve good indoor air quality through landscaping, ventilation systems, or other measures. (City of Murrieta)
- Provide incentives to promote air pollution reductions, including incentives for developers who go above and beyond applicable requirements and mitigate pollution for facilities and operations that are not otherwise regulated. (City of Chula Vista)
- Require uses such as smog check stations, automotive painting and repair facilities conduct such activities in enclosed and filtered spaces to prevent odors and emissions from affecting passers-by, nearby residents, and building occupants. (National City)
- Adopt land use policies and decisions that improve environmental quality and reduce resident and worker exposure to toxins and pollution. (Salinas)
- Encourage non-polluting industry and clean green technology companies to locate to the City. (City of Murrieta)

Objective: Require design of residential subdivisions and nonresidential development through "green" and sustainable land development practices to conserve energy, water, open space, and natural resources. (San Diego County)

Policies, Programs, Actions:

- Reduce greenhouse gas emissions from new development by discouraging auto-dependent sprawl and dependence on the private automobile; promoting water conservation and recycling; promoting development that is compact, mixed use, pedestrian friendly, and transit-oriented; promoting energy-efficient building design and site planning; improving the jobs/housing ratio in each community; and other methods of reducing emissions. (Sacramento)
- Retrofit existing buildings using low maintenance, durable building materials and high-efficiency energy systems and appliances. (Citrus Heights)
- Incorporate solar considerations into development regulations that allow existing and proposed buildings to use solar facilities. Encourage construction and subdivision design that allows the use of solar energy systems (City of Riverside)
- Require that property setbacks and building massing of new construction located within existing developed areas maintain an envelope that maximizes solar access to the extent feasible. (San Diego County)

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- Employ strategies that reduce driving rates and improve air quality through land use and urban design will be implemented by the City and other responsible parties. These strategies include transit-oriented development, compact development, an appropriate mix of land uses, a jobs/housing balance, transit oriented development, and walkable streets. (Southgate)

Objective: Require all new building projects to incorporate energy-conserving design, construction, and operation techniques and features into all aspects of the project including buildings, roofs, pavement, and landscaping. (Yolo County)

Policies, Programs, Actions:

- Require that new buildings be designed and constructed in accordance with "green building" programs that incorporate techniques and materials that maximize energy efficiency, incorporate the use of sustainable resources and recycled materials, and reduce emissions of GHGs and toxic air contaminants (San Diego County)
- Encourage the use of building materials and methods that increase energy efficiency a minimum of 15 percent beyond State Title 24 standards for residential buildings and 20 percent beyond State Title 24 standards for commercial buildings (Yolo County)
- Strongly encourage LEED certification or equivalent for all public, private and existing buildings and strongly encourage LEED Neighborhood Design (ND) certification or equivalent for other applicable projects, particularly within the Specific Plan areas. (Yolo County)

Objective: Consider GHG reduction in aspects of city planning and work on lowering emissions (General)

Policies, Programs, Actions:

- Provide incentives such as expedited project review and entitlement processing for developers that maximize use of sustainable and low GHG land development practices in exceedance of State and local standards. (San Diego County)
- Prepare, maintain, and implement a climate change action plan with a baseline inventory of GHG emissions from all sources; GHG emissions reduction targets and deadlines, and enforceable GHG emissions reduction measures. (San Diego County)
- Promote and, as appropriate, develop standards for the retrofit of existing buildings to incorporate design elements, heating and cooling, water, energy, and other elements that improve their environmental sustainability and reduce GHG (San Diego County)
- Require County operations and encourage private development to provide incentives (such as priority parking) for the use of low- and zero-emission vehicles and equipment to improve air quality and reduce GHG emissions. (San Diego County)
- Analyze and research the feasibility of using small scale energy-producing technologies in public buildings, where feasible, including solar or wind energy and other green technologies. (Redwood City)

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Equitable and resilient communities

Community Engagement

Community Engagement

Objective: Increase participation in community events. (City of South Gate)

Policies and Programs:

- The City will strive to preserve and strengthen social capital by supporting formal and informal social networks in the community. (City of South Gate)
- Increase rates of participation in community events such as voting, youth activities, adult education, senior activities and family-oriented programs. (City of South Gate)
- Prioritize projects that significantly address social and economic needs of the economically vulnerable populations. Address and reverse the underlying socioeconomic factors and residential social segregation in the community that contributes to crime and violence in the city. (City of Richmond)
- Information about community events should continue to be distributed to a wide range of community organizations including churches, senior facilities, schools, etc. using existing city-sponsored platforms such as the City website. (City of South Gate)
- Pursue the following cross-cutting strategies to support social capital: (City of South Gate)
  - Implement land use policies that reduce commute times.
  - Support policies and programs to beautify neighborhoods.
  - Create public gathering places, such as parks and plazas.
  - Take actions to reduce crime and violence across the City.
  - Support neighborhood watch or policing programs.
  - Support neighborhood associations throughout the City.
  - Actively enforce code violations.
  - Reduce conditions of blight and poverty across the City.
- Actively develop community awareness, understanding, and interest in land use issues and public policy issues, including land use, and empower the community to engage in the shaping of those policies. (San Jose)

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- Strengthen ethnic, cultural, and socioeconomic diversity by supporting programs that celebrate cultural differences and similarities and promote tolerance. (Chico)
- Provide a transparent process for public engagement of diverse stakeholders. (San Jose)
- Provide support for increased community participation, particularly in areas, such as those with language barriers or a concentration of low income households that historically have had less familiarity or experience with participation in the development and implementation of City policies and particularly those communities that historically have been impacted by power plants, trash transfer stations, and other municipal or industrial uses, in the planning and development processes. (San Jose, City of Sacramento)
- Facilitate the involvement of community residents, businesses, and organizations in the development, adoption, and implementation of community health initiatives and consider their input throughout the decision-making process. (National City)

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Economic Development

Goal: – Promote economic development through focused land use planning, targeted circulation and infrastructure improvements, and expanded resource availability. (Salinas)

Objective: Create land use and infrastructure conditions to attract economic development. (General)

- Increase the flexibility of Zoning Code standards and regulations to accommodate the types of economic development activity desired by the City and making the locations identified in the Economic Opportunity Areas more attractive for development. Allow more approvals to be issued at the administrative level. (Salinas)
- Encourage a balance between job type, the workforce, and housing development to reduce the negative impacts of long commutes and provide a range of employment opportunities for all residents. (Sacramento)
- Require the provision of bicycle parking and related facilities in new employment-generating development to facilitate multi-modal commute choices. (San Pablo)
- establish a list of "ready-to-go" or "shovel-ready" sites in consultation with property owners, and provide the list to interested developers and businesses seeking sites in the city (Fresno)
- Redesign existing wastewater and storm drainage infrastructure systems, including broad municipal level wastewater and storm water solutions for water reuse, and ensure that outdated infrastructure is upgraded to accommodate existing and future businesses. (Salinas)
- Ensure an adequate supply of appropriately zoned land that is readily served by infrastructure to support local economic development for base level job growth. (Chico)
- Promote quality in-fill housing along corridors and on infill sites in adjacent neighborhoods to support retail development. (City of Highland)

Goal: Maintain and implement an Economic Development Strategy to enhance long-term prosperity. (Chico)

Objective: Foster collaborative relationships between public sector, private businesses, and community. (General)

- Invest in a coordinated program that attracts investment capital and research activity in agricultural technology to Salinas and the Salinas Valley. (Salinas)
- Develop an infrastructure funding toolkit which describes infrastructure funding options/mechanisms available to the City and for partnerships with the private sector. (Salinas)

Goal: Enhance retail, entertainment, and tourism opportunities throughout the City. (Salinas)

Objective: Attract new businesses and consumers while protecting existing residents and employers. (General)

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- Develop and maintain a business retention and expansion program.(Salinas)
- Provide an appropriate mix of retail development in focused commercial centers along commercial corridors. (City of Highland)
- Encourage projects and programs that help increase the quality of life for local businesses and their employees. Support the development and enhancement of "Third Places" (places people go after work or when not at home), including open space, recreation, art, and entertainment venues. (Chico)

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Climate Change

Code Changes, Zoning Changes, and/or Policy

- Energy
- Transportation and Land Use
- Natural and Working Lands (NWL)
- Agriculture
- Water
- Waste Management
- Short-Lived Climate Pollutants
- Green Buildings

Mitigation

- Construction
- Operation

This appendix is a general reference document. It is not official guidance that dictates requirements for a city or county in addressing GHGs in its general plan or for local project CEQA mitigation.

This is not an exhaustive list, nor does it represent the complete list of actions identified by the State to help meet the 2030 or 2050 target. Local governments are encouraged to examine additional policies and refine existing policies and measures to address GHG emissions to meet their specific needs. There is no "one size fits all" solution and different policies will be more suitable in urban and suburban areas versus rural areas, among other considerations.

Climate change planning documents from the California Air Pollution Control Officers Association (CAPCOA) provided the basis for much of the content for these recommendations. Refer to the climate change chapter and resource referenced in the introduction for addition guidance on policies, emissions targets and other aspects of developing a GHG emissions reduction program.

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Due to the nature of climate change policies and programs, this section is organized differently than preceding sections.

PART 1

Generalized examples of local municipal code changes, zoning changes, or policy directions that could apply broadly to the community within the general plan or climate action plan area:

Energy

- Adopt and implement a zero net energy goal for the community.
- Building and energy efficiency actions present a general plan opportunity for local GHG emission reduction action. Nearly 70 percent of all single family homes in California were built before the adoption of California's Building Energy Efficiency Standards. Many local governments have already adopted energy efficiency standards for existing buildings that exceed Title 24. In addition, some local governments have adopted time-of-sale ordinances requiring energy efficiency upgrades exceeding Title 24 upon a change of title.
- Adopt a Community Choice Aggregation Ordinance, or work with the local utility to offer renewable energy purchasing to customers.
- Streamline permitting and environmental review and reduce fees for small-scale renewable energy systems.
- Create property-assessed clean energy financing districts or other financing mechanisms to fund permanent energy efficiency, water-efficiency, and renewable energy improvements in the residential and commercial sectors.
- Adopt local ordinance to require energy efficiency upgrades at time of a major remodel.
- Reduce permit fees and streamline permitting requirements for energy-efficiency- and renewable energy-related building renovations.
- Amend the building code to improve energy efficiency in new construction and in repairs and alternations to existing buildings.
- Implement building energy audit and retrofit programs and residential solar programs.
- Adopt residential and commercial energy conservation, renewable energy, and/or zero net energy ordinances (consider requirements for audits or updates at major renovation or time of sale).
- Incorporate renewable energy and energy efficiency into public facilities capital improvements.
- Replace public lighting with energy-efficient lighting.
- Permit renewable energy generation facilities as of right in zones with compatible uses.
- Create incentive program to promote building energy efficiency projects

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- Create incentive programs to promote the use of biomass wastes, including agricultural, forest, and urban woody waste materials, and livestock manure and sewage sludge, for the generation of biofuels and electricity.
- Implement large scale energy storage in commercial and industrial buildings to control peak loads.

Transportation and Land Use

- Local and regional actions have a significant influence on vehicle miles traveled (VMT). ARB regulates vehicle fuel efficiency and the carbon intensity of fuel, but VMT is impacted by land use decisions and continues to increase in California. Regional and local governments and agencies influence VMT-related GHG emissions both on a project-level basis and in integrated, long-term blueprints such as the sustainable community strategy and regional transportation plan. In addition, local land use decisions can promote climate-friendly policies such as transit-oriented and mixed-use development that can also create consistency with the region's SCS, if applicable.
- Update Lead Agency's transportation impact analysis guidelines and congestion management plans to comply with SB 743.
- Adopt general plan policies and diagram designations and zone map and standards that are consistent with the Sustainable Communities Strategy.
- In appropriate locations, adopt as-of-right zoning to enable mixed use, walkable compact development.
- Streamline permitting and environmental review and reduce fees for construction of secondary units to promote infill in targeted areas.
- Streamline local permitting and siting for hydrogen fueling and electric vehicle (EV) charging infrastructure.
- Adopt a jurisdiction-wide transportation demand management plan.
- Require employer-based trip reduction programs and provide funding to support them if feasible.
- Update code of ordinances to reduce parking requirements and eliminate parking minimums.
- Adopt an electric vehicle (EV) readiness plan.
- Adopt green building standards that exceed minimum State building standards for EV-capable parking spaces (e.g., by requiring installation of EV chargers and/or a larger number of EV-capable parking spaces).
- Replace public fleet vehicles and trips with electric or alternative fueled vehicles as much as feasible and provide EV chargers in public spaces.
- Adopt and implement a bicycle and pedestrian master plan.
- Develop a transportation impact fee program.
- Develop environmental credit program.
- Support biogas use in the transportation sector.

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- Adopt community design and neighborhood development standards that encourage. mixed use, walkable, infill development that includes a range of housing types and affordability levels.
- Provide incentives for certifying development plans and projects using LEED for Neighborhood Development or similar third-party certification system.
- Partner with local/regional transit agencies to enhance transit ridership.
- Adopt a Transportation Management Ordinance to require carpool and/or vanpool preferential parking spaces close to the major employment areas.
- Promote a Safe Routes to School Program that encourages youth to walk or ride bicycles to schools.
- Promote intelligent traffic management systems to improve traffic flow.
- Promote use of alternative fuel or high-fuel efficient vehicles by public agencies and private businesses.
- Require local specific plans for rideshare-designated parking spaces, new bus stops, employment centers, and commercial areas.
- Expand transit and rail services and clean fueled transit vehicles.
- Promote ridesharing and last-mile connections.

Natural and Working Lands (NWL)

- Policy in this sector should balance carbon sequestration with other co-benefits. The overall objective is to maintain NWL as a carbon sink and minimize the net GHG and black carbon emissions associated with management, biomass disposal, and wildfire events. Examples that could be considered include:
- Incorporate NWL conservation into local land use plans including adoption of a natural and working lands climate plan.
- Adopt policies that encourage management practices known to enhance carbon sequestration on NWL.
- Adopt policies to expand urban forests for net long-term carbon storage.
- Adopt urban forestry and green infrastructure programs.
- Adopt ordinance preserving and enhancing carbon sequestration of wetlands, forests, croplands, and grasslands.
- Adopt plans to conserve lands, water, and other natural features and resources for habitat and natural community.
- Adopt ordinance preserving trees through the review of proposed land use developments where trees are presented on either public or private property.
- Adopt plans and support projects for forest management activities to restore California forest lands that have high tree mortality and unnaturally dense fuel loads to a fire resilient condition that will mitigate wildfire size and severity.

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- Promote and encourage the development of value-added alternatives, such as compost, energy, biochar, and wood products to avoid open burning of forest biomass wastes.
- Develop strategies to value the benefits of forest fuels reductions on upper-watershed water quality, quantity, and timing.

Agriculture

- Incorporate farmland conservation in local land use plans.
- Provide incentives for carbon sequestration and carbon-based conservation farming techniques - including the use of biochar and compost from biomass wastes that would have otherwise been landfilled or open pile burned.
- Promote value-added alternatives, such as compost, energy, biochar, and wood products to avoid open burning of agricultural biomass wastes.
- Develop incentives to reduce application of pesticides and fertilizers.

Water

- Adopt water-efficient landscaping ordinance, including use of compost/mulch, to reduce water use.
- Develop a plan requiring water recycling, and greywater and rain water reuse and provide funding for incentives and other program delivery mechanisms if feasible
- Develop a residential water efficiency auditing program.
- Create an incentive program to promote efficient water use projects.

Waste Management

- Prohibit disposal of organic materials at landfills and/or prohibit jurisdiction's hauler(s) and self-haulers from taking organic material to landfills.
- Require that collected organics materials be used in edible food recovery programs or as feedstock for composting and anaerobic digestion; include assessment of 15 years organics recycling capacity needs in General Plan; and provide appropriate zoning in compatible areas for large and community-scale compost and digestion operations.
- Require implementation of residential and commercial recycling, organics collection, and edible food recovery programs.
- Require generators of edible food to have contracts/agreements with food rescue organizations and prohibit edible food from being disposed or destroyed.
- Require procurement of locally produced biogas, compost, and mulch.
- Adopt ordinance for zero waste goals.
- Adopt ordinance requiring hauling routes that minimize vehicle emissions compared to current practice (e.g., through use of renewable fuels, route optimization plan, etc.).

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- Adopt a construction & demolition waste recycling ordinance.
- Adopt green building standards that include targets to exceed minimum State building standards for new construction, including requiring new construction to include bin space for organics recycling.
- Require that landfills incorporate the financial impact of organics disposal reductions pursuant to SB 1383 into their Financial Assurance plans.
- Create an effective solid waste management plan to reduce source generation and to divert waste from landfills to achieve emission reductions.
- Ensure compost materials meets standards to be used in rural lands application for carbon sequestration.

Short-Lived Climate Pollutants

- Require biogas generation at wastewater treatment plants and methane capture at landfill facilities.
- Require that air conditioning and refrigeration units in new construction (and at major renovation) rely on refrigerants with low global warming potential (e.g., they use CO2 or ammonia instead of hydro fluorocarbons).
- Promote alternative disposal options for woody biomass wastes to avoid open pile burning.
- Support hazardous fuel reduction, defensible space clearing and forest fuel reduction in rural forested areas with high tree mortality and unnaturally high fuel loads to reduce the size and severity of catastrophic wildfires which reduces the release non-anthropogenic black carbon and methane.
- Adopt use of low global warming potential (GWP) alternative refrigerants.
- Adopt programs, ordinances, or regulations to reduce wood smoke from residents, commercial, and recreational activities.
- Require alternatives to wood heating in new developments, where natural gas infrastructure is available.
- Provide incentives to reduce wood smoke by changing out uncertified wood heating devices to either certified devices, or to gas, electric, or pellet devices.

Green Buildings

- Require energy efficiency upgrades to existing buildings, where appropriate, upon issuing a permit for substantial modification.
- Require new construction to achieve third-party green building certification, such as the GreenPoint Rated program and the LEED rating system.
- Certify to LEED for Existing Buildings: Operations and Maintenance green building rating system.
- Establish target dates and pathways toward transitioning to zero net carbon buildings.
- Require electrification of residential heating.

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- Incentivize development of "living buildings" and support off-grid allowances for proposals that meet the requirements of the "Living Buildings Challenge" or equivalent certification program.
- Require local ordinance to provide for adequate space for recycling/organics collection in all new residential and commercial construction.
- Require implementation of CALGreen building code requirements to divert and recycle construction and demolition waste, and use locally-sourced building materials and recycled content building materials, including mulch/compost, to the extent possible.
- Adopt Community Design Guideline for new buildings to maximize energy conservation designs to promote passive solar energy generation, natural ventilation, effective use of daylight, or other on-site electricity generation.
- Encourage the use of renewable energy and storage.
- Link green building with transportation planning to encourage lowest possible transportation impacts.
- Develop strategies to reduce urban heat islands through cool roofs or parking lot PV systems.

PART 2

Examples of mitigation measures that could be required of individual projects

Construction

- Enforce idling time restrictions for construction vehicles.
- Require construction vehicles to meet latest engine standards.
- Divert and recycle demolition waste, and use locally-sourced building and recycled content materials to the extent possible.
- Minimize tree removal, and mitigate indirect GHG emissions from vegetation removal.
- Utilize existing on-site power poles rather than temporary gasoline/diesel power generators.
- Increase use of electric and renewable fuel construction equipment.
- Require diesel equipment fleets to exceed any current emission standard.
- Require best available emissions control technology for all construction equipment.

Operation

- Achieve a zero net emissions goals for all new development.
- Develop an offsite retrofit program to support the conversation of existing housing stock to be more efficient at resource consumption.

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- Comply with lead agency's standards for mitigating transportation impacts under SB 743.
- Require on-site EV charging capabilities for parking spaces serving the project.
- Provide fewer on-site parking spaces than required by code if appropriate
- Dedicate on-site parking for shared vehicles.
- Provide adequate, safe, convenient, and secure on-site bicycle parking and storage in multi-family residential projects and in non-residential projects.
- Provide on- and off-site safety improvements for bike/ped/transit connections and/or implement relevant improvements identified in an applicable bicycle and/or pedestrian master plan.
- Require on-site renewable energy generation.
- Prohibit wood-burning fireplaces in new development.
- Require cool roofs.
- Require net energy metering (NEM) ready roofs.
- Require organic collection in new development.
- Require low-water landscaping in new development. Require water efficient landscape maintenance to conserve water and reduce landscape waste.
- Achieve Zero Net Energy performance.
- Require new construction to achieve third-party green building certification, such as the GreenPoint Rated program and the LEED rating system.
- Require the design of bike lanes to connect the regional bicycle network.
- Expand urban forestry and green infrastructure in new land development.
- Require preferential parking spaces for park and ride to incentivize carpooling, vanpooling, commuter bus, and rail service.
- Require a transportation management plan for specific plans.
- Develop a rideshare program to facilitate participation of commuters to the major employment centers.
- Require design of bus stops/shelter/express lane in new development to promote the usage of mass-transit.
- Require that gas outlets be provided in residential backyards for use with outdoor cooking appliances such as gas barbeques if natural gas service is available.

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- Require that electrical outlets be installed on the exterior walls of both the front and back of residences to promote the use of electric landscape maintenance equipment.
- Require the design of an electric box in residential unit garage to promote electric vehicle usage.
- Require electric vehicle charging station (conductive/inductive) and signage for non-residential developments.
- Provide electric outlets to promote electric landscape maintenance equipment be utilized to the extent feasible on parks and public/quasi-public lands.
- Require each residential unit to be pre-plumber and structurally engineered for the future installation of a solar energy system.
- Require the installation of energy conservation appliances such as tankless water heaters and whole house fans.
- Require each residential and commercial building be equipped with energy efficient AC units and heating system with programmable thermostat timers.
- Require each residential and commercial building utilize low flow water fixtures such as low flow toilets and faucets.
- Require the use of energy efficient lighting for all street, parking, and area lighting.
- Require the landscaping design for parking lots with shade trees to reduce urban heat island.
- Incorporate water retention in design of parking lots and landscape.

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Appendix B

Transportation Safety

Addressing Transportation Safety

Transportation by its nature involves some degree of collision risk. Every addition or change to land use or the transportation system will affect transportation patterns, and as a result may involve some redistribution of that risk. This section is not intended to provide a comprehensive list of potential transportation safety risks, but rather guidance on how to approach safety analysis given numerous potential risks.

In the past, transportation safety has focused on streamlining automobile flow and accommodating driver error. An updated and more holistic approach has developed over the past decade, however. This updated approach focuses on three overlapping strategies:

- Reduce speed and increase driver attention
- Protect vulnerable road users
- Reduce overall VMT and sprawl (see Ewing et al. (2003) below for definition of "sprawl")

Designing streets with pedestrians in mind can decrease crashes and injuries



Image source https://*usa.streetsblog.org*

Newer design guidance builds on more recent research on transportation safety and articulates this updated approach. For example, the NACTO guidelines (which have been endorsed by Caltrans, as well as the cities of Davis, Oakland, San Francisco, San Diego, and San Mateo) state:

> "Conventional street design is founded in highway design principles that favor wide, straight, flat and open roads with clear zones that forgive and account for inevitable driver error. This is defined as "passive" design. In recent years a new paradigm has emerged for urban streets called proactive design. A proactive approach uses design elements to affect behavior and to lower speeds. Embracing proactive design may be the single most consequential intervention in reducing pedestrian injury and fatality. Since human error is inevitable, reducing the consequences of any given error or lapse of attention is critical. Cities around the country that have implemented measures to reduce and stabilize speed have shown a reduction in serious injuries and deaths for everyone on the road, from drivers to passengers to pedestrians."

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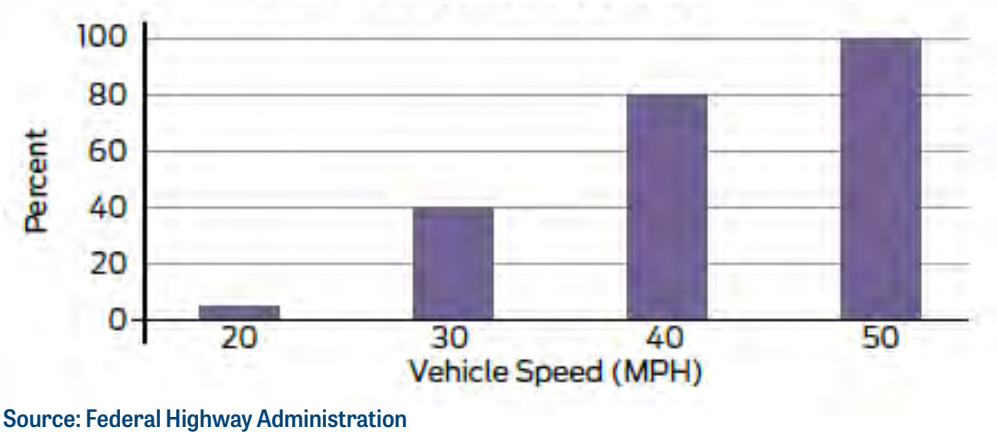
Reducing Speed and Increasing Driver Attention

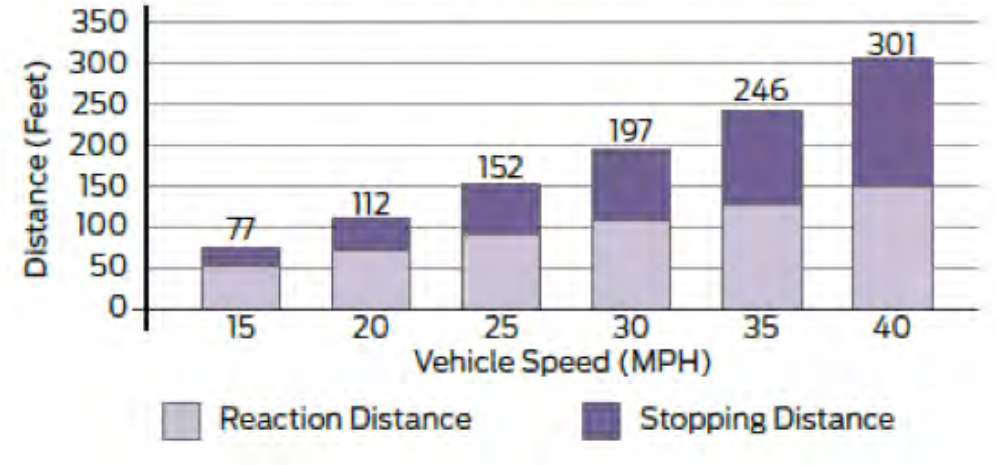
Vehicle speed plays a fundamental role in transportation safety. The NACTO Urban Street Design Guide, reports: "Vehicle speed plays a critical role in the cause and severity of crashes." The chart below shows increased pedestrian fatality risk associated with higher motor vehicle speeds.

Risk of Pedestrian Fatality by Auto Speed



Source: Federal Highway Administration

Reaction & Stopping Distance vs. Speed



Source: Federal Highway Administration

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Higher speeds increase both the likelihood and severity of collisions (Elvik (2005)). According to Elvik:

- "Speed is likely to be the single most important determinant of the number of traffic fatalities."
- "...[S] peed has a major impact on the number of accidents and the severity of injuries and that the relationship between speed and road safety is causal, not just statistical."
- "Changes in speed are found to have a strong relationship to changes in the number of accidents or the severity of injuries."
- "The relationship between speed and road safety is robust and satisfies all criteria of causality commonly applied in evaluation research."

Regardless of posted speed limits, designing roads to accommodate higher speeds safely actually leads to higher speeds. Except on limited access highways (i.e. freeways), widening and straightening roads does not increase safety. "Wider and straighter roadways lead motorists to travel at higher speeds, thus offsetting any safety benefits associated with increased sight distances" (Dumbaugh et al., 2009, citing Aschenbrenner & Biehl, 1994; Wilde, 1994).

Dumbaugh et al. (2009) breaks the problem down into its constituent parts, (1) crash incidence and (2) crash severity:

> "The safety problem with urban arterials can best be understood as a product of systematic design error. Widening and straightening these roadways to increase sight distances also has the effect of enabling higher operating speeds, which in turn increase stopping sight distance, or the distance a vehicle travels from the time when a driver initially observes a hazard, to the time when he or she can bring the vehicle to a complete stop. Higher stopping sight distances pose little problem when vehicles are traveling at relatively uniform speeds and have few reasons for braking. When these operating conditions can be met, as they are on grade-separated freeways, higher operating speeds have little or no effect on crash incidence.

Speed reduction and improved multi-modal infrastructure can improve safety



Image by Urban Advantage, Moule & Polyziodes

> "But these operating conditions typically cannot be met on urban surface streets, where pedestrians, bicyclists, and crossing vehicles are all embedded in the traffic mix. Avoiding crashes under these conditions often requires motorists to bring their vehicles to a quick stop, which higher operating speeds and stopping sight distances make more difficult (Dumbaugh, 2005b; 2006). The result is a systematic pattern of error in which drivers are unable to adequately respond to others entering the roadway, leading to increased crash incidence."

Dumbaugh et al. also points out that speed reduction requires design features and/or commercial vibrancy and activity that provide cues to motorists to slow their vehicle's speed, rather than simply a slower posted speed limit:

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"...Placing commercial uses on arterial thoroughfares created a pedestrian safety problem... In practice, the solution to this problem in the United States has been to continue to locate such uses on arterial thoroughfares, but to reduce posted speed limits. In the absence of aggressive police enforcement, however, such practices have been uniformly unsuccessful at reducing vehicle operating speeds (Armour, 1986; Beenstock, Gafni, & Goldin, 2001; Zaal, 1994). The principal alternative, adopted by European designers, is to design urban surface streets to reduce vehicle speeds to safe levels.

"We found pedestrian-scaled retail (the type of retail that was abandoned during the postwar period) to be associated with reductions in all types of crashes, and at significant levels for both total and injurious crashes. This is consistent with recent research on the subject, which finds that the pedestrian-scaled nature of these environments communicate to motorists that greater caution is warranted, leading to increased driver vigilance, lower operating speeds, and thus a better preparedness to respond to potential crash hazards that may emerge. The effective result is a reduction in crash incidence (Dumbaugh, 2005a; 2005b; 2006b; Garder, 2004; Naderi, 2003; Ossenbruggen, Pendharkar & Ivan, 2001)" (Dumbaugh et al. 2009, p. 323).

Dumbaugh et al. concludes that, except for limited-access freeways, reducing speeds is essential for safety, and also helps create livability:

"In areas where pedestrian activity is present or expected, or where eliminating a roadway's access function [to businesses, residences, jobs, etc.] is either undesirable or inappropriate, the primary alternative to access management is to reduce operating speeds to levels that are compatible with the street's access-related functions (see Figure 8). This approach, sometimes referred to as the livable street approach, incorporates design features that encourage lower operating speeds, such as making buildings front on the street, incorporating aesthetic street lighting or landscaping along the roadside, enhancing the visual quality of pavement and signage, and adopting traffic calming or intersection control measures. In short, livable streets emphasize access over mobility. When compared to conventional arterial treatments, livable streets report roughly 35–40% fewer crashes per mile traveled, and completely eliminate traffic-related fatalities (Dumbaugh, 2005a; Naderi, 2003)" (Dumbaugh, 2009, p. 325).

Providing greater clear space around a roadway, e.g. wider shoulders or clearing trees, can lead to degraded driver attention, in addition to higher speeds. "In dense urban areas, less-"forgiving" design treatments—such as narrow lanes, traffic-calming measures, and street trees close to the roadway—appear to enhance a roadway's safety performance when compared to more conventional roadway designs. The reason for this apparent anomaly may be that less-forgiving designs provide drivers with clear information on safe and appropriate operating speeds" (Ewing and Dumbaugh, 2009). Greater accommodation of driver error especially increases risk to vulnerable road users such as pedestrians and cyclists.

Lane width has a particularly discernable impact on safety. The traditional approach to sizing lanes opts for wider lanes to accommodate driver error and to attempt to increase throughput. However, research reveals that wider lanes hinder both of these objectives. Karim (2015) examined the relationship between lane width and crash rates. A number of findings were corroborated across cities:

- Wider lanes (over 10.8 to 11.2 feet) are associated with 33% higher impact speeds and higher crash rates.
- Both narrow (less than 9.2 feet) and wide (over 10.2 to 10.5 feet) lanes have proven to increase crash risks, with equal magnitude. Wider lanes (wider than 10.8 feet) adversely affect overall side-impact collisions.

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- The overall capacity of narrower lanes is higher.
- For large vehicles, no difference on safety and carrying capacity is observed between narrower and wider lanes.
- Pedestrian volumes decline as lanes widen.
- Intersections with narrower lanes provide the highest capacity for bicycles.

The study finds that the street environment impacts driver behavior, and narrower lanes in urban areas result in less aggressive driving and more ability to slow or stop a vehicle over a short distance to avoid collision. It also points out that co-benefits of narrower lanes include utilization of space to provide an enhanced public realm, including cycling facilities and wider sidewalks, or to save money on the asphalt not used by motorists (Karim, 2015).

Yeo et al (2014) summarizes past studies that show both reducing intersection density and widening traffic lanes to worsen safety:

> "Wider traffic lanes turn out to be the reason for a higher risk of fatal crashes (Noland and Oh 2004), whereas a street with a narrower curb-to-curb distance is relatively safe (Gattis and Watts 1999). Areas with a high level of intersection density also tend to have fewer fatal crashes (Ladron de Guevara et al. 2004). According to Ewing and Dumbaugh (2009), the aforementioned road designs and street patterns create a less forgiving environment for drivers and thus help decrease traffic speed" (Yeo et al., 2014, p. 402).

Numerous studies found that narrowing lanes from today's standard practice would improve safety. However, one multi-state study found three specific circumstances where narrower lanes did not increase safety in all states studied, but only some of them. The following is provided as a caveat:

> "The research found three situations in which the observed lane width effect was inconsistent—increasing crash frequency with decreasing lane width in one state and the opposite effect in another state. These three situations are:
>
> - Lane widths of 10 feet or less on four-lane undivided arterials.

Street design greatly impacts safety for all users of the transportation system





Image by Urban Advantage, Raimi & Associates

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- Lane widths of 9 feet or less on four-lane divided arterials.
- Lane width of 10 feet or less on approaches to four-leg STOP-controlled arterial intersections.

"Because of the inconsistent findings mentioned above, it should not be inferred that the use of narrower lane must be avoided in these situations. Rather, it is recommended that narrower lane widths be used cautiously in these situations unless local experience indicates otherwise" (Potts, et al. 2007).

Protecting Vulnerable Road Users

Safety measures should focus first on protecting people. Thus, for example, lead agencies might analyze how a land use project or transportation infrastructure project that increases traffic speeds may burden its travel-shed with additional, undue risk. These risks might be mitigated by, for example, (1) reducing motor vehicle travel speeds, (2) increasing driver attention, (3) protecting vulnerable road users (e.g. providing a protected, Class IV bicycle path and/or shortening pedestrian crossing distances and providing pedestrian refuges and bulb-outs), or (4) reducing VMT by providing VMT mitigation. Mitigation should avoid creating additional risk to vulnerable road users and it should not reduce active transportation mode accessibility or connectivity.

Generally speaking, the safety of vulnerable road users (e.g. pedestrians and bicyclists) should be given relatively more attention, due to their vastly increased risk of serious injury and fatality. Also, policy and planning priorities to encourage multimodal and low-carbon travel, and improving safety is a key step in increasing use of those modes. Where there are safety tradeoffs, therefore, it is important to prioritize protection of vulnerable road users. Impacts to potential vulnerable road users should be considered whether or not specific facilities for those users are present.

Active transportation has substantial health benefits, so restricting pedestrian or bicycle access and connectivity in order to reduce collision risk may worsen overall health outcomes. And, any decision about whether to apply a safety measure that restricts access by pedestrians and cyclists should consider (1) the reduction in walking and biking that will result, and the resulting reduction in "safety in numbers" as well as overall health, and (2) the risk created by pedestrians or cyclists subverting the design purpose for convenience (e.g. crossing a street where prohibited) that might lead to additional safety risk.

Reducing overall VMT and Sprawl

Higher total amounts of motor vehicle travel create higher crash exposure. Reducing vehicle miles traveled reduces collision exposure and improves safety (Dumbaugh and Rae, 2009, p. 325; Ewing, Scheiber, and Zegeer, 2003). As a result, infill development, which exhibits low VMT, itself provides safety benefits by reducing motor vehicle collision exposure, lowering speeds, and increasing pedestrian and cyclist volumes leading to "safety in numbers" (in addition to improving overall health broadly and substantially).

The fundamental relationship between VMT and safety is summarized by Yeo et al. (2014):

"Multiple traffic safety studies showed that higher VMT was positively associated with the occurrence of traffic crashes or fatalities (e.g., Ewing et al. 2002, 2003; NHTSA 2011). The causal relationship between the mileage of total vehicle trips and crash occurrences can be explained by probability. With higher VMT, it is more likely that more crashes will occur (Jang et al. 2012)."

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Sprawl-style development has also been shown to lead to elevated crash risk. The cause lies both in higher VMT levels and in design variables which influence speed and driver behavior (Yeo 2014). Ewing et al. (2003) points out that "[s]uburban and outlying intersections have been significantly overrepresented in pedestrian crashes compared with more urban areas, after control for exposure and other location factors."

More generally, Ewing et al. (2003) reveals that sprawl development (measured by (1) lowness of density, (2) lack of mixing of uses, (3) absence of thriving activity centers such as strong downtowns or suburban town centers, and (4) largeness of block sizes and poorness of street connectivity) leads to elevated transportation risk levels:

> "Our study indicates that sprawl is a significant risk factor for traffic fatalities, especially for pedestrians. The recognition of this relationship is key; traffic safety can be added to the other health risks associated with urban sprawl—namely, physical inactivity and air and water pollution.
>
> "...Sprawling areas tend to have wide, long streets that encourage excessive speed. A pedestrian struck by a motor vehicle traveling at 40 mph has an 85% chance of being killed, compared with a 45% chance of death at 30 mph and a 5% chance at 20 mph. Thus, developing land in a more compact manner may reduce pedestrian deaths, provided that the street network is designed for lower-speed travel."

Ewing et al. (2003) further demonstrates that, on the whole, counties characterized by the most sprawling land use patterns exhibit substantially higher crash risk (between four and five times the all-mode fatality rate) compared to the most compact counties:

TABLE 2: US COUNTIES WITH HIGHEST AND LOWEST SPRAWL INDEX VOLUMES

County	Sprawl Index*	All-mode traffic fatality rate (per 100,000)
Counties with more compact urban form		
New York, NY (New York)	352	4.42
Kings County, NY (New York)	264	4.46
Bronx County, NY (New York)	250	4.20
Queens County, NY (New York)	219	4.58
San Francisco County, CA (San Francisco)	209	6.31
Hudson County, NJ (Jersey City)	190	5.91
Philadelphia County, PA (Philadelphia)	188	8.04
Suffolk County, MA (Boston)	179	4.49
Richmond County, NY (New York)	163	5.63
Baltimore City, MD (Baltimore)	163	7.68

*Lower sprawl index values indicate more sprawling urban form.

Source: Ewing et al., 2003.

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County	Sprawl Index*	All-mode traffic fatality rate (per 100,000)
Counties with more sprawling urban form		
Stokes County, NC (Winston Salem)	71	15.66
Miami County, KS (Kansas City)	71	38.80
Davie County, NC (Winston Salem)	71	25.84
Isanti County, MN (Minneapolis St. Paul)	70	12.78
Walton County, GA (Atlanta)	70	19.77
Yadkin County, NC (Winston Salem)	69	38.52
Goochland County, VA (Richmond)	68	35.58
Fulton County, OH (Toledo)	67	38.02
Clinton County, MI (Lansing)	67	16.99
Geauga County, OH (Cleveland)	63	20.90

*Lower sprawl index values indicate more sprawling urban form.
Source: Ewing et al., 2003.

Beyond crash incidence rates and severity, delay in receiving medical care after a crash contributes to worse health outcomes from transportation safety in sprawling neighborhoods. Traditional impact analysis focuses on congestion as an inhibitor to emergency responses times. However, research shows that emergency response suffers more from greater distances to destinations found in sprawling areas than from congestion in compact and congested areas:

> "Emergency medical service (EMS) delay is another possible mediator that could help explain the direct non-VMT-involved sprawl effect on traffic fatalities. Urban sprawl increases EMS waiting time, and delay in ambulance arrival can increase the severity of traffic-related injuries (Trowbridge et al. 2009). 'For every 10% increase in population density'...the models estimated by Lambert and Meyer (2006, 2008) predict 'a 10.4% decrease in EMS run time' in the Southeastern United States and nationwide 'an average 0.61 percent decrease in average EMS run time'" (Yeo et. al, 2014).

Collectively, research points to an approach on safety that aligns well with other state priorities and laws (e.g. infill priority, greenhouse gas reduction), as well as with the visions of many local jurisdictions for their own growth. Compact infill development, in addition to providing livable and vibrant neighborhoods, walkable communities, environmental benefits, land conservation, fiscal benefit and cost reduction for citizens, also improves traffic safety:

> "Our study, which addresses the built environment in a more comprehensive manner [than past studies], found population density to be associated with significantly fewer total and injurious crashes. ...Individuals living in higher density environments drive less (Ewing & Cervero, 2001), thus reducing their overall exposure to crashes. When these reductions in VMT are aggregated across a larger population, they can potentially add up to notable reductions in population-level crash incidence" (Dumbaugh and Rae, 2009).

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"[Our] research findings suggest that enhancing traffic safety by reducing fatalities can be achieved by fighting against urban sprawl and promoting smart growth countermeasures. It will be important to revive city centers, to increase density, and to provide for mixed land uses. Urban design solutions that can enhance walkability at the meso- and microlevels may help reduce traffic fatalities" (Yeo et. al, 2014).

Addressing Tradeoffs and Finding Win-Win Safety Improvements

When addressing safety impacts, a jurisdiction should frame and address those risks in a manner that helps forward the community's overall goals, while improving safety. Some modern approaches to reducing safety risk, developed over the past decade or two based on research, allow all safety to be improved while meeting these other goals. Here are three examples:

(1) Adding additional lanes to a roadway leads to additional risk for pedestrian crossing. Addressing that risk by adding extra green time in the traffic signal timing will lead to shorter pedestrian crossing times and/or additional pedestrian wait time. Addressing these secondary risks by prohibiting pedestrian crossing will reduce connectivity of the pedestrian network, leading to reduced pedestrian mode share, which will increase risk by decreasing "safety in numbers" benefits and impact the health benefits associated with active mode travel. Meanwhile, improving safety with street design features that lower travel speeds to reduce crash incidence and severity can increase use of active modes.

(2) Surface roadway lanes can be redesigned from traditional 12.0 foot widths to with 9.2 to 10.8 foot widths with little or no down-side. Such a narrowing of lanes maintains motor vehicle capacity, increases bicycle capacity, maintains large vehicle capacity and safety, improves pedestrian crossings safety and comfort, increases pedestrian volumes, improves driver attention, decreases crash rates, decreases crash severity, reduces construction costs, reduces maintenance costs, reduces impermeable surface area, reduces construction and maintenance air quality and GHG emissions, and reduces space consumption (Karim, 2015).

(3) Improving safety by adding signage and pavement markings that help reduce speeds and increase pedestrian visibility can have an array of benefits, including:

- Decrease in crash incidence for all users, including vulnerable road users
- Decrease in crash severity for all users, including vulnerable road users
- Increase safety and comfort for pedestrians and cyclists, resulting in increased walking and biking mode share, in turn increasing safety in numbers effects for vulnerable road users and improving public health both via improved safety and increased physical activity.

While reductions in automobile speed may initially increase auto mode travel times, improving conditions for pedestrians and cyclists can lead to finer grain land use development over time, and ultimately improve destination proximity and overall access to destinations (Mondschein et al., 2015, Osman, et al., 2016).

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Examples of Detriments to Safety

The following are examples of possible detriments to overall safety if not mitigated:

- An increase in VMT. More vehicle travel exposes motorists and other road users to more crash risk
- An increase in pedestrian wait times. Many studies have found that pedestrian wait times play a role in crashes. Long wait times increase the risk some pedestrians will cross against a signal, creating a vulnerable road user collision risk (FHWA-RD-03-042, 2004)
- Design elements that would create hazardous conditions for vulnerable road users
- Substantially increasing motor vehicle speeds, or increasing them to greater than 25 miles per hour where vulnerable road users are present without providing proper infrastructure for vulnerable road users (e.g. Class IV bikeways for cyclists)
- Substantially increasing intersection pedestrian crossing distances, e.g. for addition of a through or turn lane
- Signal lengths of greater than 90 seconds, which may lead to people crossing on a red signal
- Installation of large curb radii, promoting higher speed motor vehicle turning movements, particularly endangering pedestrians and cyclists
- Addition or widening of on- and off-ramps where they meet surface roadways that increases pedestrian crossing distances or times, increase pedestrian wait times, or lead to a prohibition of pedestrian crossing
- Addition or widening of off-ramps in a manner that leads to higher speeds on surface streets
- Excessively large clearance zones along shoulders
- Wider than needed travel lanes (e.g. wider than 10.8 feet on surface streets)
- Multiple turn lanes at an intersection (e.g. a double left or double right turn lane)
- Placement of driveways in locations which will lead to highly elevated collision risk
- Excessively large driveways across sidewalks
- Substantially increased distances between pedestrian and bicycle crossings
- Roadway design speed (regardless of posted speed limit) that leads to actual speeds that are unsafe for cyclists and pedestrians

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Examples of Problematic Approaches to Safety

Safety issues can be mischaracterized with overly narrow perspective or traditional design guidance that has not been updated to reflect research. The following are examples of mischaracterizations of safety issues:

- Avoidance of installation of corner or mid-block crossings to avoid additional pedestrian traffic and conflict with vehicles (reduces pedestrian mode share, undoing safety in numbers)
- Providing wide (e.g. 12 foot) travel lanes on surface roadways (see discussion above)
- Avoidance of implementing sidewalk bulbs, widened sidewalks, parklets, or other curb extensions or removal of on-street parking for fear of exposing vulnerable users to vehicular traffic (these features slow traffic and improve walkability as discussed above)
- Addressing off-ramp queuing by limiting stop control on an exit ramp (this can lead to vehicles flowing unimpeded and at high speeds onto a local street, increasing risk for all road users)
- Avoidance of protected bicycle facilities adjacent to transit boarding islands to avoid conflicts between transit users and cyclists (this is safe with good design)
- Maintaining or providing parking spaces to avoid circling or other problematic traffic maneuvers. Adding parking increases VMT, which adds overall crash exposure; instead implement parking pricing

Providing infrastructure for bicyclists, pedestrians, and vulnerable road users can reduce fatality and injury rates





Image by Urban Advantage, SANDAG

Examples of Potential Transportation Safety Mitigation Measures

- Intersection improvements
  - » Visibility improvement
  - » Shortening corner radii
  - » Pedestrian safety islands
  - » Accounting for pedestrian desire lines

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- Signal changes
  - » Reducing signal cycle lengths to less than 90 seconds to avoid pedestrian crossings against the signal
  - » Providing a leading pedestrian interval
  - » Provide a “scramble” signal phase where appropriate
- Roadway improvements
  - » Add curb extensions or bulb-outs
  - » Add bicycle facilities (On higher speed roads, add protected bicycle facilities)
  - » Reduce travel lane width below 10.8 feet (but not below 9.2 feet)
  - » Add traffic calming measures
  - » Add landscaping features
- Network improvements
  - » Provide shorter blocks
  - » Provide mid-block crossings
- Reduce VMT
  - » Increase density and/or diversity of land uses
  - » Provide travel demand management measures
  - » Provide transit
  - » Provide pedestrian facilities
  - » Provide bicycle facilities

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B

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Appendix C

New state legislation related to General Plans

AB 52 (Gatto, 2014)

Specifies that a project with an effect that may cause a substantial adverse change in the significance of a tribal cultural resource, as defined, is a project that may have a significant effect on the environment. Requires a lead agency to begin consultation with a California Native American tribe that is traditionally and culturally affiliated with the geographic area of the proposed project, if the tribe requested consultation to the lead agency in writing

AB 1505 (Ducheny, 1999) | Farmworker housing

Requires the housing element to identify adequate sites for farmworker housing.
Amends Sections 51238, 51238.5, 65580, 65583, and 65950 of, and adds Section 51230.2 to, the Government Code.

AB 2838 (Hertzberg, 2000) | Local agency formation commissions

Provides that a LAFCO require as a condition to annexation that a city prezone the territory to be annexed, and requires that approval of the annexation be consistent with planned and probable use based upon review of the general plan and prezoning designations. Also authorizes the LAFCO to review the consistency of a proposal within a city's general plan when a proposed action would require the extension of critical services.
Amends and adds several sections of multiple state codes.

AB 2292 (Dutra, 2002) | General plans: residential density

Prohibits a city or county from reducing the residential density for any parcel to a density that is below the density that was utilized by the Department of Housing and Community Development in determining compliance with housing element law.
Adds Section 65863 to the Government Code.

SB 1468 (Knight, 2002) | General plans: military facilities

Requires specified elements (land use, open space, and circulation) to incorporate consideration of military facilities and readiness activities. Also requires that, in counties with a military airport, the county's general plan and any applicable specific plans be consistent with safety and noise standards in the Air Installation Compatible Use Zone prepared for that military airport.
Amends Sections 65040.2, 65302, 65302.3, 65560, and 65583 of, and adds Section 65040.9 to, the Government Code, amends Section 21675 of the Public Utilities Code.

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AB 1108 (Pavley, 2002) | Environmental quality: scoping meetings: military areas.

Requires a CEQA lead agency to submit notices to the military service if a project includes a general plan amendment and is within specific boundaries of a low-level flight path, military impact zone, or special use airport.

Amends Section 21083.9 of, and adds Sections 21098 and 21098.1 to, the Public Resources Code.

SB 18 (Burton, 2004) | Traditional tribal cultural places

Requires agencies to consult with California Native American tribes, and provide opportunities for involvement to tribes, during the preparation or amendment of the general plan.

Amends Section 815.3 of the Civil Code, amends Sections 65040.2, 65092, 65351, 65352, and 65560 of, adds Sections 65352.3, 65352.4, and 65562.5 to the Government Code.

AB 3065 (Kehoe, 2004) | General plan: safety element
See also SB 1241 (Kehoe, 2012)

Revises safety element requirements for state responsibility areas and very high fire hazard severity zones. Also requires that the safety element be submitted to the State Board of Forestry and Fire Protection and to local agencies that provide fire protection to territory in the city or county.

Amends Section 65302 of, and repeals and adds Section 65302.5 of, the Government Code, and repeals Section 4128.5 of the Public Resources Code.

SB 926 (Knight, 2004) | Economic development

Makes several changes to planning and general plan law, including changes to procedure for military consultation, and requires consultation with DOC and OES prior to preparation of safety element.

Amends and adds several sections of multiple state codes.

SB 1462 (Kuehl, 2004) | Military readiness activities: special use airspace

Requires the planning agency, during preparations to adopt or substantially amend a general plan, to refer the proposed action to branches of the US Armed Forces when the proposed action lies within 1,000 feet of a military installation, within special use airspace, or beneath a low-level flight path.

Amends Sections 65352, 65404, 65940, and 65944 of the Government Code.

AB 1268 (Wiggins, 2004) | Land use

Authorizes the text and diagrams in the land use element that address the location and extent of land uses and the zoning ordinances that implement these provisions to express community intentions regarding urban form and design.

Adds Section 65302.4 to the Government Code.

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AB 2140 (Hancock, 2006) | General plans: safety element

Authorizes a city or county to adopt with its safety element a federally specified local hazard mitigation plan, and limits the state share for projects eligible under the CA Disaster Assistance Act unless a local jurisdiction has adopted a local hazard mitigation plan in accordance with the federal Disaster Mitigation Act as part of its safety element.

Adds Sections 8685.9 and 65302.6 to the Government Code.

AB 1019 (Blakeslee, 2007) | Land use: annexation: housing

Authorizes an agreement on a revised determination of regional housing needs if an annexation of unincorporated land to a city occurs after the council of governments, or the department for areas with no council of governments, has made its final allocation.

Amends Section 65584.07 of the Government Code.

AB 162 (Wolk, 2007) | Land use: water supply

Requires specified elements to address flood hazards and identify areas that may accommodate floodwater for purposes of groundwater recharge and stormwater management. Requires safety element to address flood hazards as specified.

Amends Sections 65302, 65303.4, 65352, 65584.04, and 65584.06 of, and adds Sections 65300.2 and 65302.7 to, the Government Code.

AB 1358 (Leno, 2008) | Planning: circulation element: transportation

Requires a city or county, upon any substantive revision of the circulation element, to modify the circulation element to plan for a balanced, multimodal transportation network that meets the needs of all users of streets, roads, and highways, in a manner that is suitable to the rural, suburban, or urban context of the general plan.

Amends Sections 65040.2 and 65302 of the Government Code.

SB 375 (Steinberg, 2008) | Transportation planning: travel demand models: sustainable communities strategy: environmental review

Requires regional transportation plans to include a sustainable communities strategy. Also makes various changes to timing for review and revision of housing elements.

Amends and adds several sections of multiple state codes.

AB 45 (Blakeslee, 2009) | Distributed generation: small wind energy systems

Authorizes a county to adopt an ordinance that provides for the installation of small wind energy systems outside an urbanized area, and to establish a process for the issuance of conditional use permits for these systems.

Adds and repeals Article 2.11 (commencing with Section 65893) of, and repeals the heading of Article 2.11 (commencing with Section 65892.13) of, Chapter 4 of Division 1 of Title 7 of the Government Code.

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SB 575 (Steinberg, 2009) | Local planning: housing element

Requires a local government to review its housing element as frequently as appropriate, but no less often than required by a specified schedule.

Amends Sections 65080, 65583, and 65588 of the Government Code, and amends Section 75123 of the Public Resources Code.

SB 812 (Ashburn, 2010) | Developmental services: housing

Requires a local government to include needs of individuals with a developmental disability in the housing element's analysis of special housing needs.

Amends Section 65583 of the Government Code.

SB 226 (Simitian, 2011) | Environmental quality

Limits the application of CEQA in the case of the approval of an infill project that satisfies specified standards if an EIR was certified for a planning level decision, including the enactment or amendment of a general plan, community plan, specific plan, or zoning code. Also authorizes the referral of a proposed action to adopt or substantially amend a general plan to a city or county bordering the city or county within which the project is located to be conducted concurrently with the CEQA scoping meeting.

Amends Section 65919.10 of the Government Code, and amends Sections 21083.9 and 21084 of, and adds Sections 21080.35, 21094.5, 21094.5.5, and 25500.1 to, the Public Resources Code.

SB 244 (Wolk, 2011) | Local government: land use: general plan: disadvantaged unincorporated communities.

Requires the land use element to include analysis of the presence of island, fringe, or legacy unincorporated communities. Subsequently amended by SB 1090 (2012).

Amends Sections 56375, 56425, and 56430 of, and adds Sections 53082.5, 56033.5, and 65302.10 to, the Government Code, and adds Section 13481.7 to the Water Code.

SB 1090 (Comm. On Governance and Finance, 2012) | Local government: omnibus bill

Amends statutory language added by SB 244 (2011). Requires the update of the land use element to be based on specified available data and to include identification of each island or fringe community that is a disadvantaged unincorporated community.

Amends and adds several sections of multiple state codes.

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SB 1241 (Kehoe, 2012) | Land use: general plan: safety element: fire hazard impacts
See also AB 3065 (Kehoe, 2004)

Revises safety element requirements for state responsibility areas and very high fire hazard severity zones and requires the safety element to take into account specified considerations, including the most recent version of the Office of Planning and Research's "Fire Hazard Planning" document.
Amends Sections 65302 and 65302.5 of, and adds Sections 65040.20 and 66474.02 to, the Government Code, and adds Section 21083.01 to the Public Resources Code.

SB 743 (Steinberg, 2013) | Environmental Quality

Addresses several topics, including aesthetics and parking for certain infill projects. Also requires the Office of Planning and Research to update the Guidelines Implementing the California Environmental Quality Act to replace exisiting requirements for studying transportation impacts under CEQA.

SB 1462 (Comm. On Governance and Finance, 2014) | Local government: omnibus bill

Eliminates the requirement that the noise element recognize the guidelines established by the Office of Noise Control.
Amends and adds several sections of multiple state codes.

AB 1690 **(Gordon, 2014) | Local planning: housing elements**

Authorizes a city or county to accommodate the very low and low-income housing need on sites designated for mixed uses if those sites allow 100% residential use and require that residential use occupy 50% of the total floor area of a mixed-use project.

AB 1739 (Dickinson, 2014) | Groundwater management

Requires, prior to the adoption or any substantial amendment of a general plan, the planning agency to review and consider certain specified groundwater plans and refer a proposed action to certain specified groundwater management agencies.
Amends and adds several sections of multiple state codes.

AB 52 (Gatto, 2014) | Native Americans: California Environmental Quality Act

Specifies that a project with an effect that may cause a substantial adverse change in the significance of a tribal cultural resource, as defined, is a project that may have a significant effect on the environment. Requires a lead agency to begin consultation with a California Native American tribe that is traditionally and culturally affiliated with the geographic area of the proposed project, if the tribe requested consultation to the lead agency in writing.

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AB 2501 (Bloom, 2016) | Housing: density bonuses

Requires the local government to adopt procedures and timelines for processing a density bonus application, provide a list of documents and information required to be submitted with the application in order for it to be deemed complete, and notify the applicant whether it is complete. Specifies the definition for the term "density bonus." Requires the local government to provide the requested concessions or incentives unless it finds that the concession or incentive does not result in cost reductions, to provide for affordable housing costs or rents for the targeted units, as specified. Expands the definition of housing development definition to include mixed-use housing.

Together, the following bills make several changes to housing element law:

SB 575 (Torlakson, 2005)

AB 1390 (Jones, 2005)

SB 1087 (Florez, 2005)

AB 1233 (Jones, 2005)

AB 2634 (Lieber, 2006)

SB 253 (Torlakson, 2005)

AB 2572 (Emmerson, 2006)

AB 382 (Committee on Housing and Community Development, 2007)

AB 2135 (Ting, 2014)

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Appendix D

Noise Element Guidelines

Guidelines for the Preparation and Content of the Noise Element of the General Plan

The noise element of the general plan provides a basis for comprehensive local programs to control and abate environmental noise and to protect residents from excessive exposure. The fundamental goals of the noise element are:

- To provide sufficient information concerning the community noise environment so that noise may be effectively considered in the land use planning process. In so doing, the necessary groundwork will have been developed so that a community noise ordinance may be utilized to resolve noise complaints.
- To develop strategies for abating excessive noise exposure through cost-effective mitigating measures in combination with zoning, as appropriate, to avoid incompatible land uses.
- To protect those existing regions of the planning area whose noise environments are deemed acceptable and also those locations throughout the community deemed "noise sensitive."
- To utilize the definition of the community noise environment in the form of CNEL or Ldn noise contours as provided in the noise element for local compliance with the State Noise Insulation Standards. These standards require specified levels of outdoor to indoor noise reduction for new multifamily residential constructions in areas where the outdoor noise exposure exceeds CNEL (or Ldn) 60 dB.

The 1976 edition of the Noise Element Guidelines, prepared by the California Department of Health Services (DHS), was a result of SB 860 (Beilenson, 1975), which became effective January 1, 1976. SB 860, among other things, revised and clarified the requirements for the noise element of each city and county general plan and gave DHS the authority to issue guidelines for compliance thereto. Compliance with the 1976 version of these guidelines was mandated only for those noise elements that were not submitted to the Office of Planning and Research by the effective date of SB 860 and to subsequent revisions of previously submitted noise elements.

A comparison between the 1976 Noise Element Guidelines and this revised edition will not reveal substantial changes. The basic methodology advanced by that previous edition remains topical. Where necessary, code references have been updated and the text revised to reflect statutory changes.

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Definitions

Decibel, dB: A unit of measurement describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micropascals (20 micronewtons per square meter).

A-Weighted Level: The sound level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the response of the human ear and gives good correlation with subjective reactions to noise.

L10: The A-weighted sound level that is exceeded ten percent of the sample time. Similarly, L50, L90, etc.

Leq: Equivalent energy level. The sound level corresponding to a steady-state sound level containing the same total energy as a time-varying signal over a given sample period. Leq is typically computed over 1-, 8-, and 24-hour sample periods.

CNEL: Community Noise Equivalent Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of five decibels to sound levels in the evening from 7 p.m. to 10 p.m. and after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

Ldn: Day-Night Average Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after the addition of 10 decibels to sound levels in the night after 10 p.m. and before 7 a.m. (Note: CNEL and Ldn represent daily levels of noise exposure averaged on an annual or daily basis, while Leq represents the equivalent energy noise exposure for a shorter time period, typically one hour.)

Noise Contours: Lines drawn about a noise source indicating equal levels of noise exposure. CNEL and Ldn are the metrics utilized herein to describe annoyance due to noise and to establish land use planning criteria for noise.

Ambient Noise: The composite of noise from all sources near and far. In this context, the ambient noise level constitutes the normal or existing level of environmental noise at a given location.

Intrusive Noise: That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence, and tonal or informational content as well as the prevailing noise level.

Noisiness Zones: Defined areas within a community wherein the ambient noise levels are generally similar (within a range of 5 dB, for example). Typically, all other things being equal, sites within any given noise zone will be of comparable proximity to major noise sources. Noise contours define different noisiness zones.

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Noise Element Requirements

Government Code Section 65302(f): A noise element shall identify and appraise noise problems in the community. The noise element shall recognize the guidelines established by the Office of Noise Control in the State Department of Health Services and shall analyze and quantify, to the extent practicable, as determined by the legislative body, current and projected noise levels for all of the following sources:

1. Highways and freeways.
2. Primary arterials and major local streets.
3. Passenger and freight online railroad operations and ground rapid transit systems.
4. Commercial, general aviation, heliport, helistop, and military airport operations, aircraft overflights, jet engine test stands, and all other ground facilities and maintenance functions related to airport operation.
5. Local industrial plants, including, but not limited to, railroad classification yards.
6. Other ground stationary sources identified by local agencies as contributing to the community noise environment.

Noise contours shall be shown for all of these sources and stated in terms of community noise equivalent level (CNEL) or day-night average level (Ldn). The noise contours shall be prepared on the basis of noise monitoring or following generally accepted noise modeling techniques for the various sources identified in paragraphs (1) to (6), inclusive.

The noise contours shall be used as a guide for establishing a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise.

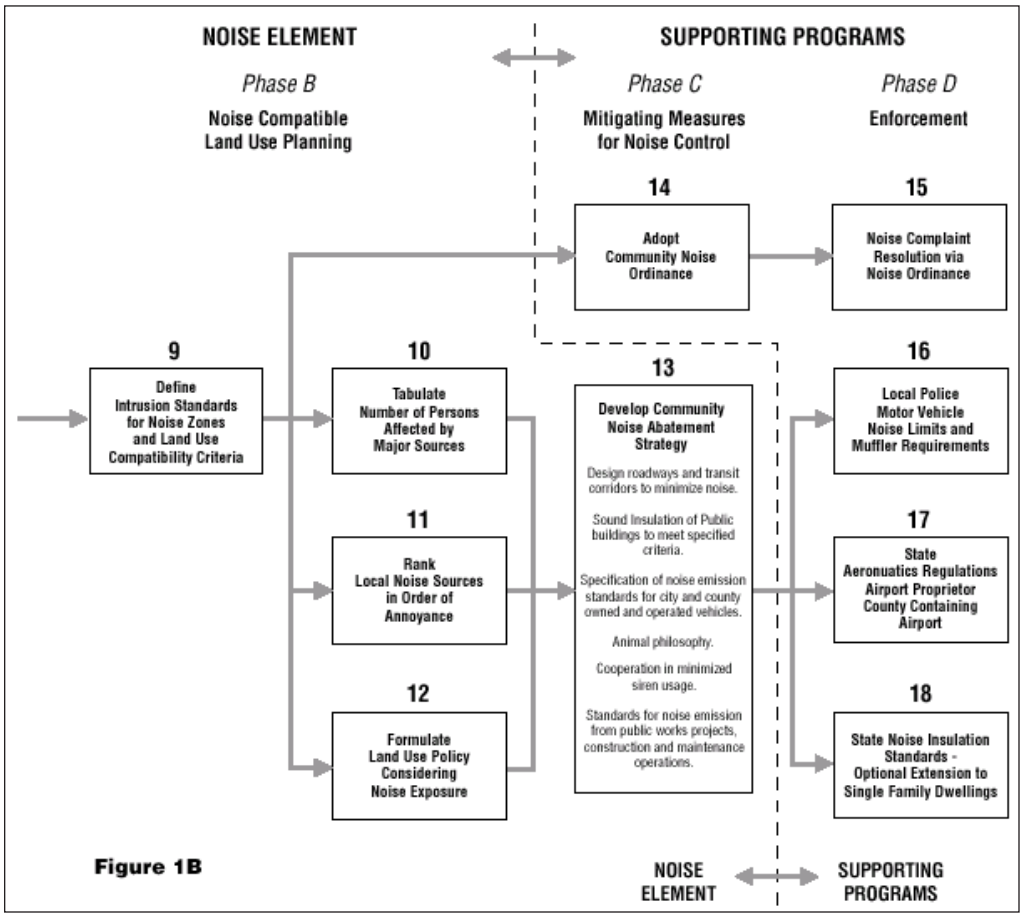

Figure 1B

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The noise element shall include implementation measures and possible solutions that address existing and foreseeable noise problems, if any. The adopted noise element shall serve as a guideline for compliance with the state's noise insulation standards.

Noise Element Development Process

The sequential steps for development of a noise element as an integral part of a community's total noise control program are illustrated in the flow diagrams of figures 1A and 1B. The concept presented herein utilizes the noise element as the central focus of the community's program and provides the groundwork for all subsequent enforcement efforts. The process may be described in terms of four phases:

Phase A: Noise Environment Definition

Phase B: Noise-Compatible Land Use Planning

Phase C: Noise Mitigation Measures

Phase D: Enforcement

These phases encompass a total of eighteen defined tasks, the first thirteen of which relate directly to the statutory requirements contained in Government Code §65302(f). The remainder relate to critical supportive programs (noise ordinances, etc.). Citations from §65302(f) are contained within quotation marks.

Phase A: Noise Environment Definition

The purpose of this phase is to adequately identify and appraise the existing and future noise environment of the community in terms of Community Noise Equivalent Level (CNEL) or Day-Night Average Level (Ldn) noise contours for each major noise source and to divide the city or county into noise zones for subsequent noise ordinance application.

Step 1:

Identify a specific individual or lead agency within the local government to be responsible for coordination of local noise control activities. This individual or agency should be responsible for coordinating all intergovernmental activities and subsequent enforcement efforts.

Step 2:

Review noise complaint files as compiled by all local agencies (police, animal control, health, airport, traffic department, etc.) in order to assess the following:

1. Location and types of major offending noise sources.
2. Noise-sensitive areas and land uses.
3. Community attitudes towards specific sources of noise pollution.
4. Degree of severity of noise problems in the community.
5. Relative significance of noise as a pollutant.

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Step 3:

Specifically identify major sources of community noise based upon the review of complaint files and interagency discussion and the following statutory subjects:

1. Highways and freeways.
2. Primary arterials and major local streets.
3. Passenger and freight online railroad operations and ground rapid transit systems.
4. Commercial, general aviation, heliport, helistop, and military airport operations, aircraft overflights, jet engine test stands, and all other ground facilities and maintenance functions related to airport operation.
5. Local industrial plants, including, but not limited to, railroad classification yards.
6. Other ground stationary noise sources identified by local agencies as contributing to the community noise environment. (§65302(f))

In addition, the land uses and areas within the community that are noise sensitive should be identified at the same time.

Step 4:

Given the identification of major noise sources and an indication of the community's attitude toward noise pollution (when available), it is advisable to conduct a community noise survey. The purposes of the survey are threefold:

First and foremost, to define by measurement the current noise levels at those sites deemed noise sources and to establish noise level contours around them. The noise contours must be expressed in terms of CNEL or Ldn.

Second, the collected data will form the basis for an analysis of noise exposure from major sources.

Finally, the survey should define the existing ambient noise level throughout the community. Intrusive noises over and above this general predetermined ambient level may then be controlled through implementation of a noise ordinance.

Step 5:

Given the definition of existing ambient noise levels throughout the community, one may proceed with a classification of the community into broad regions of generally consistent land uses and similar noise environments. Because these regions will be varying distances from identified major noise sources, the relative levels of environmental noise will be different from one another. Therefore, subsequent enforcement efforts and mitigating measures may be oriented towards maintaining quiet areas and improving noisy ones.

Step 6:

Directing attention once again to the major noise sources previously identified, it is essential to gather operations and activity data in order to proceed with the analytical noise exposure prediction. This data is somewhat source-specific but generally should consist of the following information and be supplied by the owner/operator of the source:

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1. Average daily level of activity (traffic volume, flights per day, hours of operation, etc.).
2. Distribution of activity over day and night time periods, days of the week, and seasonal variations.
3. Average noise level emitted by the source at various levels of activity.
4. 4. Precise source location and proximity to noise-impacted land uses.
5. 5. Composition of noise sources (percentage of trucks on highway, aircraft fleet mix, industrial machinery type, etc.).

Step 7:

In addition to collecting data on the variables affecting noise-source emission for the existing case, future values for these parameters need to be assessed. This is best accomplished by correlating the noise element with other general plan elements (i.e. land use, circulation, housing, etc.) and regional transportation plans and by coordination with other responsible agencies (Airport Land Use Commission, Caltrans, etc.).

Step 8:

Analytical noise exposure modeling techniques may be utilized to develop source-specific noise contours around major noise sources in the community.

> "The noise contours shall be prepared on the basis of noise monitoring or following generally accepted noise modeling techniques..." (§65302(f))

Simplified noise prediction methodologies are available through the Department of Health Services for highway and freeway noise, railroad noise, simple fixed stationary and industrial sites, and general aviation aircraft (with less than twenty percent commercial jet aircraft activity—two engine jet only). Noise contours for larger airport facilities and major industrial sites are sufficiently complex that they must be developed via sophisticated computer techniques available through recognized acoustical consulting firms. (Airport contours generally have already been developed in accordance with requirements promulgated by Caltrans' Division of Aeronautics: Noise Standards, Title 21, Section 5000, et seq., California Code of Regulations.)

Although considerable effort may go into developing noise contours that, in some instances, utilize rather sophisticated digital programming techniques, the present state of the art is such that their accuracy is usually no better than +/- 3 dB. In fact, the accuracy of the noise exposure prediction decreases with increasing distance from the noise source. In the near vicinity of the source, prediction accuracy may be within the range of +/- 1 dB, while at greater distances this may deteriorate to +/- 5 dB or more. At greater distances, meteorological and topographic effects, typically not totally accounted for in most models, may have significant influence. Thus, while dealing with the concept of noise contours, it is best not to think of them as absolute lines of demarcation on a map (such as topographical contours), but rather as bands of similar noise exposure.

In addition to assessment of the present-day noise environment, it is recommended that the noise exposure data be projected through the time horizon of the general plan. The noise element should be updated and corrected every five years, or sooner as is necessary, and, at that time, the forecasted noise exposure should be projected an additional five years.

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Phase B: Noise-Compatible Land Use Planning

A noise planning policy needs to be rather flexible and dynamic to reflect not only technological advances in noise control, but also economic constraints governing application of noise-control technology and anticipated regional growth and demands of the community. In the final analysis, each community must decide the level of noise exposure its residents are willing to tolerate within a limited range of values below the known levels of health impairment.

Step 9:

Given the definition of the existing and forecasted noise environment provided by the Phase A efforts, the locality preparing the noise element must now approach the problem of defining how much noise is too much. Guidelines for noise-compatible land use are presented in Figure 2. The adjustment factors given in Table 1 may be used in order to arrive at noise-acceptability standards that reflect the noise-control goals of the community, the particular community's sensitivity to noise (as determined in Step 2), and the community's assessment of the relative importance of noise pollution.

Step 10:

As a prerequisite to establishing an effective noise-control program, it is essential to know, in quantitative terms, the extent of noise problems in the community. This is best accomplished by determining, for each major noise source around which noise contours have been developed, the number of community residents exposed and to what extent. It is also useful to identify those noise-sensitive land uses whose noise exposure exceeds the recommended standards given in Figure 2. The exposure inventory can be accomplished by using recent census data, adjusted for regional growth, and tabulating the population census blocks within given noise contours.

Step 11:

Once the noise exposure inventory is completed, the relative significance of specific noise sources in the community (in terms of population affected) will become apparent. The local agencies involved may wish to use this information to orient their noise-control and abatement efforts to achieve the most good. Clearly, control of certain major offending sources will be beyond the jurisdiction of local agencies; however, recognition of these limitations should prompt more effective land use planning strategies.

Step 12:

A major objective of the noise element is to utilize this information to ensure noise-compatible land use planning:

> "The noise contours shall be used as a guide for establishing a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise." (§65302(f))

The intent of such planning is to:

1. Maintain those areas deemed acceptable in terms of noise exposure.
2. Use zoning or other land use controls in areas with excessive noise exposure to limit uses to those which are noise compatible and to restrict other, less compatible uses.

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Phase C: Noise Mitigation Measures

Step 13:

Based upon the relative importance of noise sources in order of community impact and local attitudes towards these sources, "[t]he noise element shall include implementation measures and possible solutions that address existing and foreseeable noise problems, if any" (§65302(f)).

Selection of these noise-mitigating measures should be coordinated through all local agencies in order to be most effective. Minimization of noise emissions from all local government-controlled or sanctioned activities should be a priority item. This includes low noise specifications for new city or county owned and operated vehicles (and noise reduction retrofitting where economically possible) and noise emission limits on public works projects. Local governments should insure that public buildings (especially schools) are sufficiently insulated to allow their intended function to be uninterrupted by exterior noise. Local agencies can work with state and federal bodies to minimize transportation noise, primarily through transitway design, location, or configuration modifications.

Additional measures might include such policies as limitation of siren usage by police, fire, and ambulance units within populated areas. Animal control units may be encouraged to minimize barking dog complaints through use of an improved public relations campaign termed "Animal Philosophy." This involves working with pet owners to determine why the dog barks and attempting solutions rather than just issuing citations. Local zoning and subdivision ordinances may require the use of noise-reducing building materials or the installation of sound-insulating walls along major roads in new construction and subdivisions.

In general, local noise reduction programs need to address the problems specific to each community, with the ultimate goals being the reduction of complaint frequency and the provision of a healthful noise environment for all residents of the community.

The remaining steps are beyond the scope of the noise element requirements, but pertain to coordination with other state noise-control programs and achievement of the goals set forth in the noise element through development of an active local noise-control effort.

Step 14:

While the noise element identifies problem areas and seeks to develop medium- and long-range solutions to them, a community noise ordinance is the only viable instrument for short-term or immediate solutions to intrusive noise. A model noise ordinance that can be tailored to the specific needs of a given community by simply incorporating those sections deemed most applicable has been developed by the Department of Health Services. The model ordinance also suggests a cure for non-stationary or transient types of noise events, for which noise contours are generally meaningless.

Phase D: Enforcement

To adequately carry out the programs identified in the noise element and to comply with state requirements for certain other noise-control programs, specific enforcement programs are recommended at the local level.

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Step 15:

Adopt and apply a community noise ordinance for resolution of noise complaints.

FIGURE 2

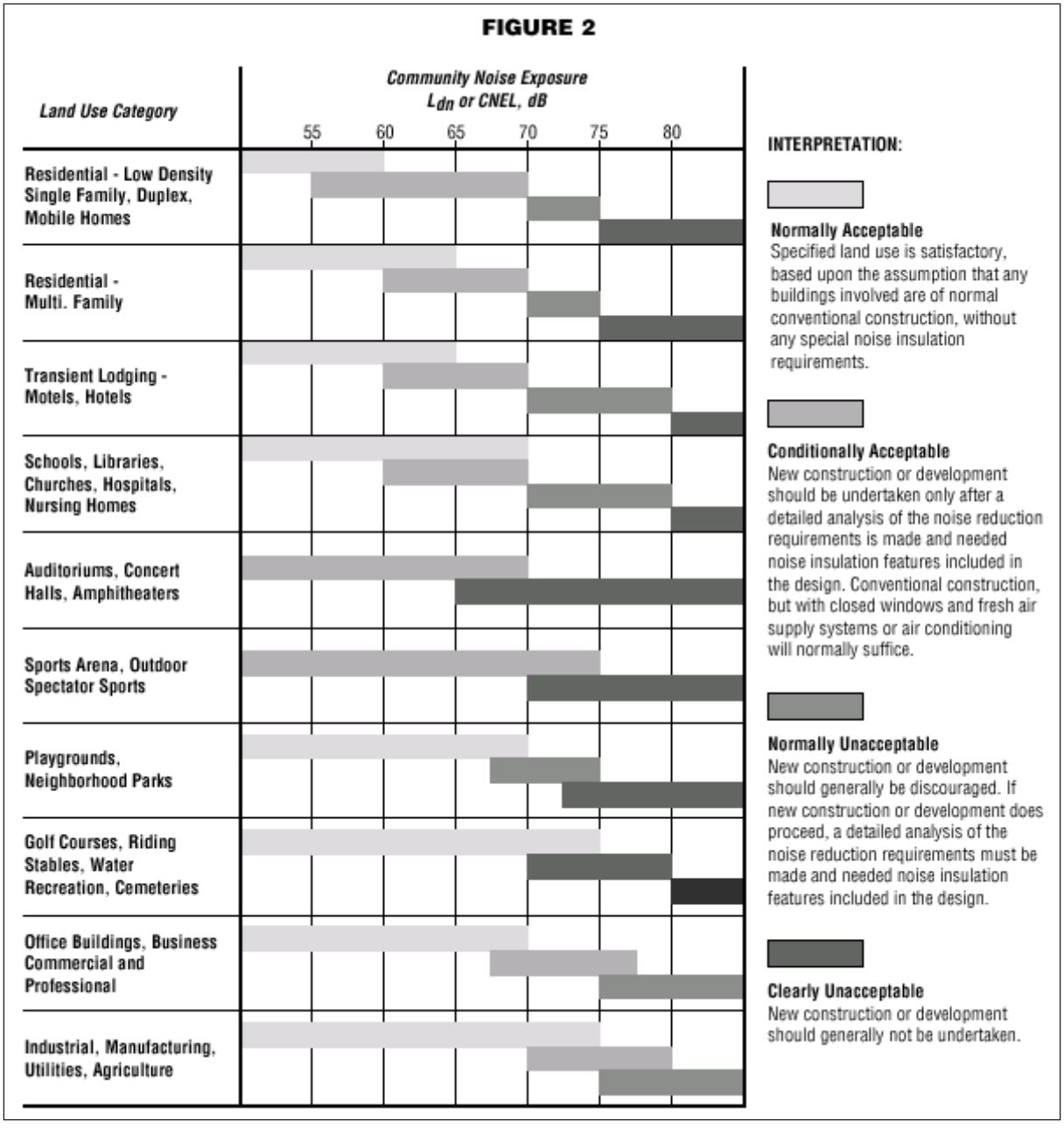

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Table 1

Type of Correction	*Description*	*Amount of Correction to be Added to Measured CNEL in dB*
Seasonal Correction	Summer (or year-round operation)	**0**
	Winter only (or windows always closed)	**- 5**
Correction for Outdoor Residual Noise Level	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking).	**+ 10**
	Quiet suburban or rural community (not located near industrial activity).	**+ 5**
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas).	**0**
	Noisy urban residential community (near relatively busy roads or industrial areas.	**- 5**
	Very noisy urban residential community.	**- 10**
Correction for Previous Exposure and Community Attitudes	No prior experience with the intruding noise.	**+ 5**
	Community has had some previous exposure to intruding but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	**0**
	Community has had considerable previous exposure to the intruding noise and the noise maker's relations with the community are good.	**- 5**
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	**- 10**
Pure Tone or Impulse	No pure tone or impulsive character.	**0**
	Pure Tone or impulsive character present.	**+ 5**

Step 16:

Recent studies have shown that the most objectionable feature of traffic noise is the sound produced by vehicles equipped with illegal or faulty exhaust systems. In addition, such hot rod vehicles are often operated in a manner that causes tire squeal and excessively loud exhaust noise. There are a number of statewide vehicle noise regulations that can be enforced by local authorities as well as the California Highway Patrol. Specifically, Sections 23130, 23130.5, 27150, 27151, and 38275 of the California Vehicle Code, as well

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as excessive speed laws, may be applied to curtail this problem. Both the Highway Patrol and the Department of Health Services (through local health departments) are available to aid local authorities in code enforcement and training pursuant to proper vehicle sound-level measurements.

Step 17:

Commercial and public airports operating under a permit from Caltrans' Aeronautics Program are required to comply with both state aeronautics standards governing aircraft noise and all applicable legislation governing the formation and activities of a local Airport Land Use Commission (ALUC). The function of the ALUC is, among other things, to develop a plan for noise-compatible land use in the immediate proximity of the airport. The local general plan must be reviewed for compatibility with this Airport Land Use Compatibility Plan and amended if necessary (Public Utilities Code §21676). Therefore, the developers of the noise element will need to coordinate their activities with the local ALUC to ensure that compatible standards are utilized throughout the community and that the noise element develops as part of a coherent master plan, of which the ALUP forms an integral component.

Step 18:

"The adopted noise element shall serve as a guideline for compliance with the State's noise insulation standards." (§65302(f))

Recognizing the need to provide acceptable habitation environments, state law requires noise insulation of new multifamily dwellings constructed within the 60 dB (CNEL or Ldn) noise exposure contours. It is a function of the noise element to provide noise contour information around all major sources in support of the sound transmission control standards (Appendix, Chapter 2-35, Part 2, Title 24, California Code of Regulations).

Relationship Of The Noise Element To Other General Plan Elements

The noise element is related to the land use, housing, circulation, and open-space elements. Recognition of the interrelationship of noise and these four other mandated elements is necessary in order to prepare an integrated general plan. The relationship between noise and these four elements is briefly discussed below.

- Land Use—A key objective of the noise element is to provide noise exposure information for use in the land use element. When integrated with the noise element, the land use element will show acceptable land uses in relation to existing and projected noise contours. Section 65302(f) states that: "The noise contours shall be used as a guide for establishing a pattern of land uses in the land use element that minimizes the exposure of community residents to excessive noise."
- Housing—The housing element considers the provision of adequate sites for new housing and standards for housing stock. Since residential land use is among the most noise sensitive, the noise exposure information provided in the noise element must be considered when planning the location of new housing. Also, state law requires special noise insulation of new multifamily dwellings constructed within the 60 dB (CNEL or Ldn) noise exposure contour. This requirement may influence the location and cost of this housing type. In some cases, the noise environment may be a constraint on housing opportunities.
- Circulation—The circulation system must be correlated with the land use element and is one of the major sources of noise. Noise exposure will thus be a decisive factor in the location and design of new transportation facilities and the possible mitigation of noise from existing facilities in relation to existing and planned land uses. The local planning agency may wish to review the circulation and land use elements simultaneously to assess their compatibility with the noise element.

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- Open Space—Excessive noise can adversely affect the enjoyment of recreational pursuits in designated open space. Thus, noise exposure levels should be considered when planning for this kind of open-space use. Conversely, open space can be used to buffer sensitive land uses from noise sources through the use of setbacks and landscaping. Open-space designation can also effectively exclude other land uses from excessively noisy areas.

Selection Of The Noise Metric

The community noise metrics to be used in noise elements are either CNEL or Ldn (as specified in §65302(f)). A significant factor in the selection of these scales was compatibility with existing quantifications of noise exposure currently in use in California. CNEL is the noise metric currently specified in the State Aeronautics Code for evaluation of noise impacts at specific airports that have been declared to have a noise problem. Local compliance with state airport noise standards necessitates that community noise be specified in CNEL. The Ldn represents a logical simplification of CNEL. It divides the day into two weighted time periods (Day—7 a.m. to 10 p.m. and Night—10 p.m. to 7 a.m.) rather than the three used in the CNEL measure (Day—7 a.m. to 7 p.m., Evening—7 p.m. to 10 p.m., and Night—10 p.m. to 7 a.m.) with no significant loss in accuracy.

Criteria For Noise-Compatible Land Use

Figure 2 summarizes the suggested use of the CNEL/Ldn metrics for evaluating land use noise compatibility. Such criteria require a rather broad interpretation, as illustrated by the ranges of acceptability for a given land use within a defined range of noise exposures.

Denotation of a land use as "normally acceptable" on Figure 2 implies that the highest noise level in that band is the maximum desirable for existing or conventional construction that does not incorporate any special acoustic treatment. In general, evaluation of land use that falls into the "normally acceptable" or "normally unacceptable" noise environments should include consideration of the type of noise source, the sensitivity of the noise receptor, the noise reduction likely to be provided by structures, and the degree to which the noise source may interfere with speech, sleep, or other activities characteristic of the land use.

Figure 2 also provides an interpretation as to the suitability of various types of construction with respect to the range of outdoor noise exposure.

The objective of the noise compatibility guidelines in Figure 2 is to provide the community with a means of judging the noise environment it deems to be generally acceptable. Many efforts have been made to account for the variability in perceptions of environmental noise that exist between communities and within a given community.

Beyond the basic CNEL or Ldn quantification of noise exposure, one can apply correction factors to the measured or calculated values of these metrics in order to account for some of the factors that may cause the noise to be more or less acceptable than the mean response. Significant among these factors are seasonal variations in noise source levels, existing outdoor ambient levels (i.e., relative intrusiveness of the source), general societal attitudes towards the noise source, prior history of the source, and tonal characteristics of the source. When it is possible to evaluate some or all of these factors, the measured or computed noise exposure values may be adjusted by means of the correction factors listed in Table 1 in order to more accurately assess local sentiments towards acceptable noise exposure.

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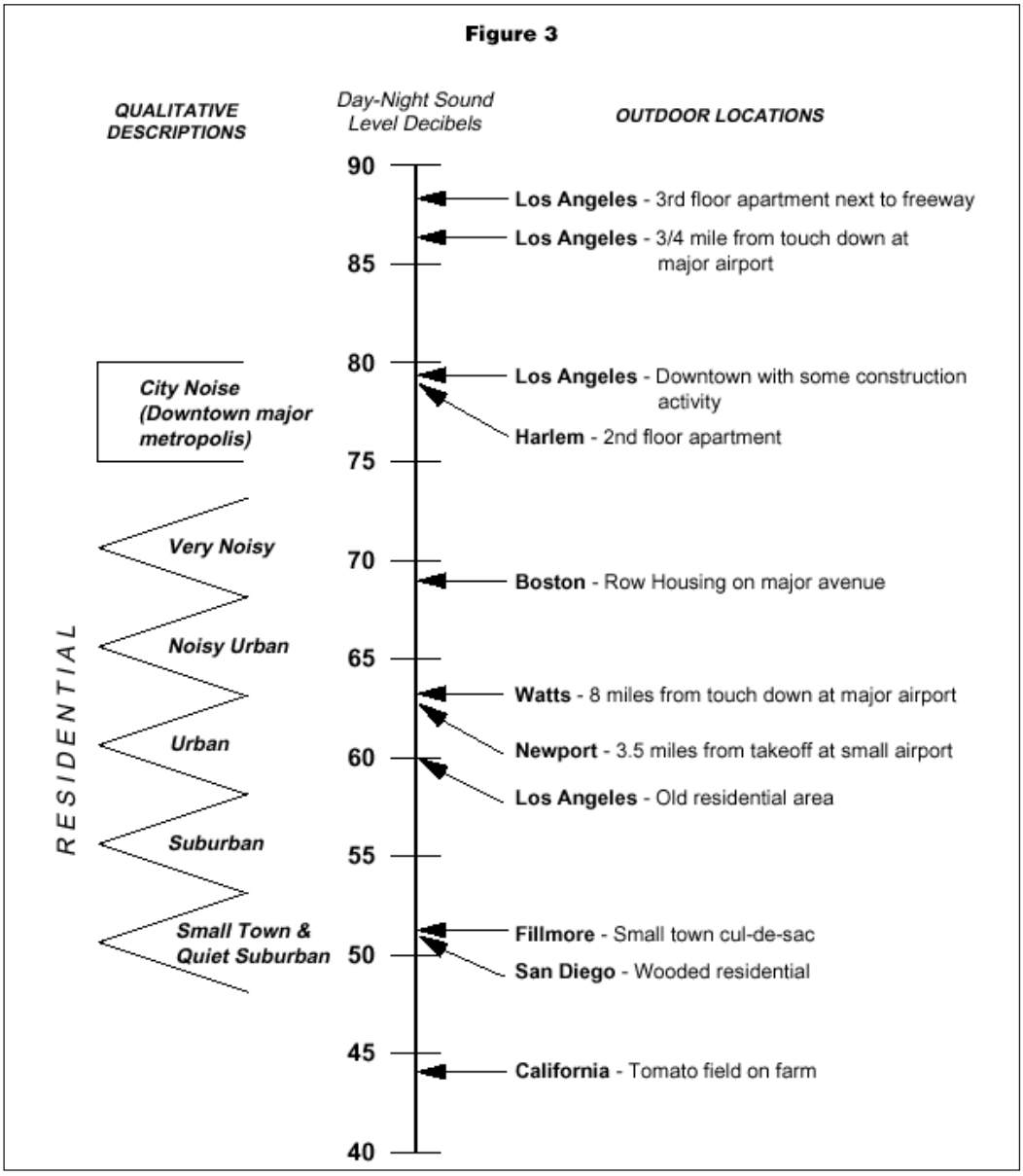
In developing these acceptability recommendations, efforts were made to maintain consistency with the goals defined in the federal EPA's "Levels Document" and the State Sound Transmission Control Standards for multifamily housing. In both of these documents, an interior noise exposure of 45 dB CNEL (or Ldn) is recommended to permit normal residential activity. If one considers the typical range of noise reduction provided by residential dwellings (12 to 18 dB with windows partially open), the 60 dB outdoor value identified as "clearly acceptable" for residential land use would provide the recommended interior environment.

Figure 3 has been included in order to better explain the qualitative nature of community noise environments expressed in terms of Ldn. It is apparent that noise environments cover a broad range and that, in general, it may be observed that the quality of the environment improves as one moves further away from major transportation noise sources.

Figure 3



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Appendix E

Glossary

Defining the Parts of a General Plan

A general plan is made up of text describing goals and objectives, principles, standards, and plan proposals, as well as a set of maps and diagrams. Together, these constituent parts paint a picture of the community's future development. The following discussions help to clarify the meanings of these and other important terms.

Development Policy

A development policy is a general plan statement that guides action. In a broad sense, development policies include goals and objectives, principles, policies, standards, and plan proposals.

Diagram

A diagram is a graphic expression of a general plan's development policies, particularly its plan proposals. Many types of development policies lend themselves well to graphic treatment, such as the distribution of land uses, urban design, infrastructure, and geologic and other natural hazards.

A diagram must be consistent with the general plan text (Gov. code §65300.5) and should have the same long-term planning perspective as the rest of the general plan. The Attorney General has observed that "...when the Legislature has used the term 'map,' it has required preciseness, exact location, and detailed boundaries...." as in the case of the Subdivision Map Act. No such precision is required of a general plan diagram (67 Cal.Ops.Atty.Gen. 75,77).

As a general rule, a diagram or diagrams, along with the general plan's text, should be detailed enough so that the users of the plan, whether staff, elected and appointed officials, or the public, can reach the same general conclusion on the appropriate use of any parcel of land at a particular phase of a city's or county's physical development. Decision-makers should also be able to use a general plan, including its diagram or diagrams, in coordinating day-to-day land use and infrastructure decisions with the city's or county's future physical development scheme.

At the same time, given the long-term nature of a general plan, its diagram or diagrams and text should be general enough to allow a degree of flexibility in decision-making as times change. For example, a general plan may recognize the need for and desirability of a community park in a proposed residential area, but the precise location of the park may not be known when the plan is adopted. The plan would not need to pinpoint the location, but it should have a generalized diagram along with policies saying that the park site will be selected and appropriate zoning applied at the time the area is subdivided. In this sense, while zoning must be consistent with the general plan, the plan's diagram or diagrams and the zoning map are not required to be identical.

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Goal

A goal is a general direction-setter. It is an ideal future end related to the public health, safety, or general welfare. A goal is a general expression of community values and, therefore, may be abstract in nature. Consequently, a goal is generally not quantifiable or time-dependent.

Although goals are not mentioned in the description of general plan contents in Government code section 65302, they are included here for several reasons. First, defining goals is often the initial step of a comprehensive planning process, with more specific objectives defined later, as discussed in Chapter 3. Second, goals are specifically mentioned in the statutes governing housing element contents (Gov. code §65583). Third, while the terms "goal" and "objective" are used interchangeably in some general plans, many plans differentiate between broad, unquantifiable goals and specific objectives. Either approach is allowable, as flexibility is a characteristic of the general plan.

Examples of goals:

- Quiet residential streets
- A diversified economic base for the city
- An aesthetically pleasing community
- A safe community

Goals should be expressed as ends, not actions. For instance, the first example above expresses an end, namely, "quiet residential streets." It does not say, "Establish quiet residential streets" or "To establish quiet residential streets."

Objective

An objective is a specified end, condition, or state that is an intermediate step toward attaining a goal. It should be achievable and, when possible, measurable and time-specific. An objective may pertain to one particular aspect of a goal or it may be one of several successive steps toward goal achievement. Consequently, there may be more than one objective for each goal.

Examples of objectives:

- The addition of 100 affordable housing units over the next five years
- A 25 percent increase in downtown office space by 2030
- A 50 percent reduction in the rate of farmland conversion over the next ten years
- A reduction in stormwater runoff from streets and parking lots

Principle

A principle is an assumption, fundamental rule, or doctrine guiding general plan policies, proposals, standards, and implementation measures. Principles are based on community values, generally accepted planning doctrine, current technology, and the general plan's objectives. In practice, principles underlie the process of developing the plan but seldom need to be explicitly stated in the plan itself.

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Examples of principles:

- Mixed use encourages urban vitality
- The residential neighborhoods within a city should be within a convenient and safe walking distance of an elementary school
- Parks provide recreational and aesthetic benefits
- Risks from natural hazards should be identified and avoided to the extent practicable

Policy

A policy is a specific statement that guides decision-making. It indicates a commitment of the local legislative body to a particular course of action. A policy is based on and helps implement a general plan's vision.

A policy is carried out by implementation measures. For a policy to be useful as a guide to action it must be clear and unambiguous. Adopting broadly drawn and vague policies is poor practice. Clear policies are particularly important when it comes to judging whether or not zoning decisions, subdivisions, public works projects, etc., are consistent with the general plan.

When writing policies, be aware of the difference between "shall" and "should." "Shall" indicates an unequivocal directive. "Should" signifies a less rigid directive, to be honored in the absence of compelling or contravening considerations. Use of the word "should" to give the impression of more commitment than actually intended is a common but unacceptable practice. It is better to adopt no policy than to adopt a policy with no backbone.

Solid policy is based on solid information. The analysis of data collected during the planning process provides local officials with the knowledge about trends, existing conditions, and projections that they need to formulate policy. If projected community conditions are not in line with a general plan's objectives, local legislative bodies may adopt policies that will help bring about a more desirable future.

Examples of policies:

- The city shall not approve a parking ordinance variance unless the variance pertains to the rebuilding of an unintentionally destroyed non-conforming use
- The city shall not approve plans for the downtown shopping center until an independently conducted market study indicates that the center would be economically feasible
- The city shall give favorable consideration to conditional use permit proposals involving adaptive reuse of buildings that are designated as "architecturally significant" by the cultural resources element

Standards

A standard is a rule or measure establishing a level of quality or quantity that must be complied with or satisfied. Standards define the abstract terms of objectives and policies with concrete specifications.

The Government Code makes various references to general plan standards. For example, §65302(a) states in part that the land use element must "...include a statement of the standards of population density and building intensity recommended for the various

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districts and other territory covered by the plan." Other examples of statutory references to general plan standards include those found in §66477 (the Quimby Act) and §66479 (reservations of land within subdivisions). Of course, a local legislature may adopt any other general plan standards it deems desirable.

Examples of standards:

- High-density residential means 20 to 30 dwelling units per acre and up to 41 dwelling units per acre with a density bonus
- The first floor of all new construction shall be at least two feet above the base flood elevation

Plan Proposal

A plan proposal describes the development intended to take place in an area. Plan proposals are often expressed on the general plan diagram.

Examples of plan proposals:

- First Street and Harbor Avenue are designated as arterials
- The proposed downtown shopping center will be located within the area bound by D and G Avenues and Third and Fourth Streets
- A new parking structure shall be located in the vicinities of each of the following downtown intersections: First Street and A Avenue, and Fifth Street and D Avenue

Implementation Measure

An implementation measure is an action, procedure, program, or technique that carries out general plan policy. Each policy must have at least one corresponding implementation measure.

Examples of implementation measures:

- The city shall adopt a specific plan for the industrial park
- Areas designated by the land use element for agriculture shall be placed in the agricultural zone

Linking Objectives to Implementation

The following examples show the relationships among objectives, policies, and implementation measures. The examples are arranged according to a hierarchy from the general to the specific—from goals to implementation measures. In an actual general plan, there might be more than one policy under each objective, more than one implementation measure under each policy, etc.

Goal:

- A thriving downtown that is the center of the city's retail and service commercial activities.

Objective:

- Development of a new regional shopping center in the downtown.

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Policy:

- The city shall not approve discretionary projects or building permits that could impede development of the downtown regional shopping center.

Implementation measures:

- The city shall adopt an interim zoning ordinance restricting further development in the general vicinity of the proposed downtown shopping center until a study has been completed determining its exact configuration.
- During the interim zoning period, the city shall adopt a special regional shopping center zoning classification that permits the development of the proposed downtown mall.
- Upon completion of the study, the city council shall select a site for the downtown mall and shall apply the shopping center zone to the property.

Goal:

- Affordable, decent, and sanitary housing for all members of the community.

Objective:

- 500 additional dwelling units for low-income households by 2010.

Policy:

- When a developer of housing within the high-density residential designation agrees to construct at least 30 percent of the total units of a housing development for low-income households, the city shall grant a 40 percent density bonus for the housing project.

Implementation measure:

- The city shall amend its zoning ordinance to allow for a 40 percent density bonus in the high-density residential zone.

Noise Related Definitions

Decibel, dB: A unit of measurement describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micropascals (20 micronewtons per square meter).

A-Weighted Level: The sound level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the response of the human ear and gives good correlation with subjective reactions to noise.

L10: The A-weighted sound level that is exceeded ten percent of the sample time. Similarly, L50, L90, etc.

Leq: Equivalent energy level. The sound level corresponding to a steady-state sound level containing the same total energy as a time-varying signal over a given sample period. Leq is typically computed over 1-, 8-, and 24-hour sample periods.

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CNEL: Community Noise Equivalent Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of five decibels to sound levels in the evening from 7 p.m. to 10 p.m. and after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m.

Ldn: Day-Night Average Level. The average equivalent A-weighted sound level during a 24-hour day, obtained after the addition of 10 decibels to sound levels in the night after 10 p.m. and before 7 a.m. (Note: CNEL and Ldn represent daily levels of noise exposure averaged on an annual or daily basis, while Leq represents the equivalent energy noise exposure for a shorter time period, typically one hour.)

Noise Contours: Lines drawn about a noise source indicating equal levels of noise exposure. CNEL and Ldn are the metrics utilized herein to describe annoyance due to noise and to establish land use planning criteria for noise.

Ambient Noise: The composite of noise from all sources near and far. In this context, the ambient noise level constitutes the normal or existing level of environmental noise at a given location.

Intrusive Noise: That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence, and tonal or informational content as well as the prevailing noise level.

Noisiness Zones: Defined areas within a community wherein the ambient noise levels are generally similar (within a range of 5 dB, for example). Typically, all other things being equal, sites within any given noise zone will be of comparable proximity to major noise sources. Noise contours define different noisiness zones.

Safety Related Definitions

Alquist-Priolo Earthquake Fault Zone: A regulatory zone, delineated by the State Geologist, within which site-specific geologic studies are required to identify and avoid fault rupture hazards prior to subdivision of land and/or construction of most structures for human occupancy.

Climate Adaptation: Adjustment or preparation of natural or human systems to a new or changing environment that moderates harm or exploits beneficial opportunities.

Climate Mitigation (Greenhouse Gas Emissions Reductions): A human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. Refer to Chapter 7, Climate Change, for more information.

Critical Facility: Facilities that either (1) provide emergency services or (2) house or serve many people who would be injured or killed in case of disaster damage to the facility. Examples include hospitals, fire stations, police and emergency services facilities, utility facilities, and communications facilities.

Extreme Weather Event: In most cases, extreme weather events are defined as lying in the outermost ("most unusual") ten percent of a place's history. Analyses are available at the national and regional levels.

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Fault: A fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. A fault zone is a zone of related faults which commonly are braided, but which may be branching. A fault trace is the line formed by the intersection of a fault and the earth's surface.

Active Fault: A fault that has exhibited surface displacement within Holocene time (approximately the past 11,000 years).

Potentially Active Fault: A fault that shows evidence of surface displacement during Quaternary time (the last 2 million years).

Flooding: A rise in the level of a water body or the rapid accumulation of runoff, including related mudslides and land subsidence, that results in the temporary inundation of land that is usually dry. Riverine flooding, coastal flooding, mud flows, lake flooding, alluvial fan flooding, flash flooding, levee failures, tsunamis, and fluvial stream flooding are among the many forms that flooding takes.

Ground Failure: Mudslide, landslide, liquefaction or soil compaction.

Hazardous Building: A building that may be hazardous to life in the event of an earthquake because of partial or complete collapse. Hazardous buildings may include:

1. Those constructed prior to the adoption and enforcement of local codes requiring earthquake resistant building design.
2. Those constructed of unreinforced masonry.
3. Those which exhibit any of the following characteristics:
    - exterior parapets or ornamentation which may fall on passersby
    - exterior walls that are not anchored to the floors, roof or foundation
    - sheeting on roofs or floors incapable of withstanding lateral loads
    - large openings in walls that may cause damage from torsional forces
    - lack of an effective system to resist lateral forces
    - non-ductile concrete frame construction

Hazardous Material: An injurious substance, including pesticides, herbicides, toxic metals and chemicals, liquefied natural gas, explosives, volatile chemicals, and nuclear fuels.

Hazard Mitigation: Sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects.

Landslide: A general term for a falling, sliding, or flowing mass of soil, rocks, water, and debris. Includes mudslides, debris flows, and debris torrents.

Liquefaction: A process by which water-saturated granular soils transform from a solid to a liquid state during strong ground shaking.

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Maladaptation: Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Natural Infrastructure: The preservation or restoration of ecological systems, or utilization of engineered systems that use ecological processes, to increase resiliency to climate change, manage other environmental hazards, or both. This may include, but is not limited to, floodplain and wetlands restoration or preservation, combining levees with restored natural systems to reduce flood risk, and urban tree planting to mitigate high heat days.

Peakload Water Supply: The supply of water available to meet both domestic water and fire fighting needs during the particular season and time of day when domestic water demand on a water system is at its peak.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Seiche: An earthquake-induced wave in a lake, reservoir, or harbor.

Seismic Hazard Zone: A regulatory zone, delineated by the State Geologist, within which site-specific geologic, soils, and foundation engineering studies are required to identify and avoid earthquake-caused ground-failure hazards, or selected other earthquake hazards, prior to subdivision of land and for construction of most structures for human occupancy.

Storm surge: An abnormal rise of water generated by a storm, over and above the predicted astronomical tides.

Subsidence: The gradual, local settling or sinking of the earth's surface with little or no horizontal motion (subsidence is usually the result of gas, oil, or water extraction, hydrocompaction, or peat oxidation, and not the result of a landslide or slope failure).

Seismically Induced Surface Rupture: A break in the ground's surface and associated deformation resulting from the movement of a fault.

Tsunami: A wave, commonly called a tidal wave, caused by an underwater seismic disturbance, such as sudden faulting, landslide, or volcanic activity.

Wildland Fire: A fire occurring in a suburban or rural area that contains uncultivated lands, timber, range, watershed, brush or grasslands. This includes areas where there is a mingling of developed and undeveloped lands.

Flood Management: The overarching term that encompasses both floodwater management and floodplain management.

Floodwater Management: Floodwater management includes actions to modify the natural flow of floodwaters to reduce losses to human resources and/or to protect benefits to natural resources associated with flooding. Examples of floodwater management actions include containing flows in reservoirs, dams, and natural basins; conveying flows via levees, channels, and natural corridors; managing flows through reservoir reoperation; and managing watersheds by decreasing rainfall runoff and providing headwater stream protection.

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Floodplain Management: Floodplain management includes actions to the floodplain to reduce losses to human resources within the floodplain and/or to protect benefits to natural resources associated with flooding. Examples of floodplain management actions include minimizing impacts of flows (e.g., flood-proofing, insurance); maintaining or restoring natural floodplain processes (e.g., riparian restoration, meander corridors, etc.); removing obstacles within the floodplain voluntarily or with just compensation (e.g., relocating at-risk structures); keeping obstacles out of the floodplain (through subdivision and zoning decisions); education and emergency preparedness planning (e.g., emergency response plans, data collection, outreach, insurance requirements, etc.); and ensuring that operations of floodwater management systems are not compromised by activities in the floodplain.

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NAAQS Table

The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards (40 CFR part 50) for pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. ***Primary standards*** provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. ***Secondary standards*** provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

The EPA has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" air pollutants. Periodically, the standards are reviewed and may be revised. The current standards are listed below. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air ($\mu g/m^3$).

Pollutant [links to historical tables of NAAQS reviews]	**Primary/ Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ (1)	Not to be exceeded
Nitrogen Dioxide (NO_2)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years

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Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
		primary and secondary	1 year	53 ppb (2)	Annual Mean
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 µg/m^3	annual mean, averaged over 3 years
		secondary	1 year	15.0 µg/m^3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 µg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years

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Pollutant [links to historical tables of NAAQS reviews]	Primary/ Secondary	Averaging Time	Level	Form
	secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

(1) In areas designated nonattainment for the Pb standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 µg/m3 as a calendar quarter average) also remain in effect.

(2) The level of the annual NO2 standard is 0.053 ppm. It is shown here in terms of ppb for the purposes of clearer comparison to the 1-hour standard level.

(3) Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) O3 standards additionally remain in effect in some areas. Revocation of the previous (2008) O3 standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.

(4) The previous SO2 standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2)any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous SO2 standards or is not meeting the requirements of a SIP call under the previous SO2 standards (40 CFR 50.4(3)). A SIP call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

Menu of Control Measures for NAAQS Implementation

The Menu of Control Measures (MCM) provides state, local and tribal air agencies with the existing emission reduction measures as well as relevant information concerning the efficiency and cost effectiveness of the measures. State, local and tribal agencies will be able to use this information in developing emission reduction strategies, plans and programs to assure they attain and maintain the National Ambient Air Quality Standards (NAAQS). The MCM is a living document that can be updated with newly available or more current data as it becomes available.

- Menu of Control Measures

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The San Andreas Fault System, California

U.S. GEOLOGICAL SURVEY
PROFESSIONAL PAPER 1515



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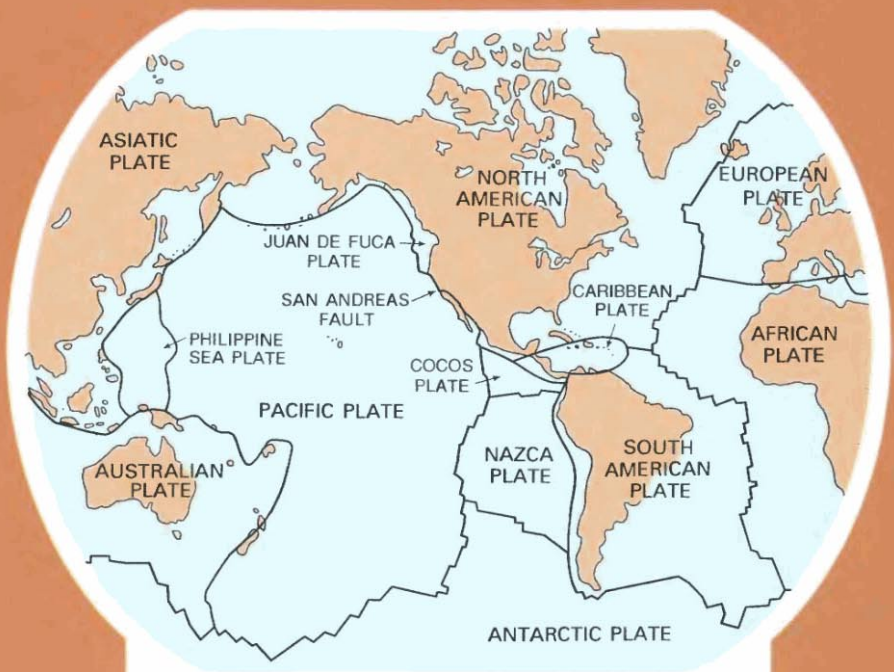

SIMPLIFIED MAP OF THE EARTH'S CRUSTAL PLATES

FRONT COVER: On the Carrizo Plain in central California, the San Andreas fault appears as a conspicuous gash across the terrain. Streams are offset and deflected at the fault. View northwestward.

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MAP OF THE SAN ANDREAS FAULT SYSTEM, CALIFORNIA

Maps of northern and southern California printed on flyleaf inside front cover and on adjacent pages show faults that have had displacement within the past 2 million years. Those that have had displacement within historical time are shown in red. Bands of red tint emphasize zones of historical displacement; bands of orange tint emphasize major faults that have had Quaternary displacement before historical time. Faults are dashed where uncertain, dotted where covered by sedimentary deposits, and queried where doubtful. Arrows indicate direction of relative movement; sawteeth on upper plate of thrust fault.

These maps are reproductions, in major part, of selected plates from the "Fault Map of California," published in 1975 by the California Division of Mines and Geology at a scale of 1:750,000; the State map was compiled and data interpreted by Charles W. Jennings. New data about faults, not shown on the 1975 edition, required modest revisions, primarily additions; however, most of the map was left unchanged because the California Division of Mines and Geology is currently engaged in a major revision and update of the 1975 edition. Because of the reduced scale here, names of faults and places were redrafted or omitted. Faults added to the reduced map are not as precise as on the original State map, and the editor of this volume selected certain faults and omitted others. Principal regions for which new information was added are the region north of the San Francisco Bay area and the offshore regions.

Many people have contributed to the present map, but the editor is solely responsible for any errors and omissions. Among those contributing informally, but extensively, and the regions to which each contributed were G.A. Carver, onland region north of lat 40° N.; S.H. Clarke, offshore region north of Cape Mendocino; R.J. McLaughlin, onland region between lat 40°00' and 40°30' N. and long 123°30' and 124°30' W.; D.S. McCulloch, offshore region between lat 35° and 40° N.; J.G. Vedder, offshore region south of lat 35° N.; and D.G. Herd, southern San Francisco Bay region. The Fault Evaluation Program of the California Division of Mines and Geology, under the direction of E.W. Hart, provided much data about many faults. Unpublished material about the Bartlett Springs fault zone that was gathered by Geomatrix Consultants for the Pacific Gas and Electric Co. was very useful. In addition, selected publications that provided invaluable data include Bortugno (1982), Herd (1977), Herd and Helley (1977), Pampeyan and others (1981), and Yerkes and others (1980). Full references for these publications are listed at the end of chapter 2.

To all of the above, and to numerous others, the editor expresses his great appreciation.

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THE SAN ANDREAS FAULT SYSTEM, CALIFORNIA

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The San Andreas fault in central California. Striking linearity of the trace of the fault is characteristic of strike-slip faults. Carrizo Plain to left; Temblor Range to right. View northwest.

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The San Andreas Fault System, California

ROBERT E. WALLACE, *Editor*

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1515

An overview of the history, geology, geomorphology, geophysics, and seismology of the most well known plate-tectonic boundary in the world



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U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., *Secretary*

U.S. GEOLOGICAL SURVEY

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in California since the great Alaska earthquake of 1964, and the general acceptance of the concept of plate tectonics and sea-floor spreading by earth scientists in the late 1960's, the San Andreas fault has gained wide attention. The fault has long been recognized as the source of the destructive San Francisco earthquake of 1906 and of the similarly large Fort Tejon earthquake of 1857, as well as the smaller (M=7.1), but also destructive, Loma Prieta earthquake of 1989. Many textbooks in recent decades have included photographs, maps, and descriptions of the San Andreas fault, and so among earth scientists around the world, few geologic features have greater identity than the San Andreas fault. The fault—better designated a "fault system" because of its complexities—represents an exceptional example of a plate margin that can be seen and studied on land; many other plate margins are covered by the oceans.

This volume is addressed to a varied audience, but especially to earth scientists who wish to gain a brief overview of the San Andreas fault system. We hope that the nontechnical reader also will find the volume interesting and useful. Each chapter has its own references that direct the investigator more to specific literature; suggestions for additional reading and sources of information are included at the end of the volume.

The public-safety issues of earthquake-hazard mitigation and earthquake prediction are not covered in this volume except by implication. Fundamental concepts and understanding of how the solid Earth works are essential to the development of realistic and effective procedures for hazard mitigation. Without such understanding, mitigation measures may be ineffective and wasteful of resources. Earthquake prediction requires geologic and geophysical models and data that constitute valid bases for extrapolation into the future. We believe that these concerns are well served by the reviews in this volume.

The 10 chapters that follow review geologic, geomorphic, geophysical, geodetic, and seismologic information about the San Andreas fault system. Although the material is intended to represent our current state of knowledge and understanding, many investigators will find their own specialities inadequately treated. A full discussion of the more rapidly changing and controversial ideas currently in play is impossible, given the constraints of this volume.

Manuscript approved for publication, May 4, 1990.

The need for such a volume has been recognized since the 1960's, but until recent years, data about the San Andreas fault system was so incomplete that a significant review seemed premature. Now, a general overview of many significant elements seems possible, but even so, the questions far outnumber the answers, and if history is any guide, many of the concepts put forth here will have changed markedly within the next few years. Indeed, one of the purposes of this volume is to assist and hasten the evolution of our understanding through the consolidation, under a single cover, of some of the current ideas and models.

Reference to a few of the more outstanding problems concerning the San Andreas fault system may serve to suggest how little is yet known about the fault system and how much remains to be learned. In studying the San Andreas fault system, opportunities abound for learning how the Earth works in a general sense.

A group of particularly significant problems can be collectively expressed under the question: "How does a fault system that has primarily strike slip terminate at its northwest and southeast ends, and how does it bottom out at depth?"

At the northwest end of the fault system, the Mendocino triple junction represents an intriguing structural knot where the North American, Pacific, and Gorda plates join. A fourth block at depth, made up of material below the North American plate but east of the San Andreas fault and south of the Gorda plate, also is juxtaposed with these three named plates. How are the diverse motions of these four plates or blocks accommodated where they join? Clearly, severe space problems must occur at detailed scales, even though the gross theoretical geometry of triple junctions has been fairly well described. How do these four structural blocks interact to influence the energetics of the fault system (see chap. 10)? How did the triple junction migrate over time, and how are the consequences of that migration recorded geologically?

Crustal convergence also strongly influences the fault system. Where major bends occur, as in the Transverse Ranges region, structural complexities arise. There, major left-lateral faults splay from the main San Andreas fault, and dense clusters of earthquakes extend to depths of 20 km. Elsewhere, as in the Santa Cruz Mountains, some segments of the fault dip at steep, but not vertical, angles.

Adjacent to the San Andreas fault on its east side lies the North American plate, at least in the upper few tens of kilometers; but below this plate, as indicated above, is

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a block of almost unknown characteristics left in the wake of the eastward-moving and subducting plate now represented by its remnants, the Gorda and Juan de Fuca plates. After pulling away from the Pacific plate in its eastward passage, did this plate leave remnants here and there under the North American plate? Did the spreading center spread continuously, or did it move eastward in one or more leaps? What sort of mantle material rose to fill in behind the stern of the eastward-moving plate? Was this newly emplaced material similar to that being generated at modern spreading centers, and to what extent did the overlying blanket of continental material alter both the geometry and thermal histories of the emplaced rocks?

Some of the models mentioned above imply decoupling between the subducting plate and the North American plate, as well as a rather significant discontinuity between the North American plate and the underlying backfill behind the stern of the eastward-moving plate. Some of the problems of this "window" behind the subducting plate are discussed in chapter 3. The San Andreas fault, indeed, may bottom in a zone of decoupling, either within the crust or below, possibly a low-angle thrust fault, as described in chapter 1, or perhaps involving gravitationally driven detachments. The characteristics of this decoupling are almost unknown. Much needs to be learned before the style of stress and strain propagation across such discontinuities can be addressed adequately.

Present-day strain is demonstrable by geodetic techniques (see chap. 7), and longer-term strain is represented geologically by the pattern of folds, faults, and magmatic intrusion into the upper crust (see chaps. 3, 4). Release of elastic strain, its timing and spatial distribution, is nicely displayed by seismicity, especially microseismicity (see chap. 5). Heat-flow measurements provide an important insight into the energetics of the San Andreas fault system (see chap. 10). Integration and comparison of these data sets, however, reveal numerous unresolved problems and apparent paradoxes. As reported in chapter 10, no sharp increase in heat flow is found directly over the San Andreas fault, even though heat would be expected to be generated in the narrow fault zone by the annual slip of several centimeters on the fault. Instead, the heat flow is distributed across a broad zone, further suggesting distributed slip on a subhorizontal plane that decouples the upper-crustal materials from those below.

The detailed characteristics of the fault zone itself are far from fully understood. Low values of stress drop that occur during seismic events have long been known (see chaps. 5, 10). The dominance of right-lateral slip along the fault, despite evidence for fault-normal compression, together with the absence of a pronounced heat-flow anomaly, attests to general weakness of the fault. How the fault zone has grown to its present 0.5- to 1-km width, given this weakness, is also a puzzle. Furthermore, at many places along the fault, as in central California, the width of the fault zone is appropriately considered to be 10 km or more wide; that is the width of highly sheared and deformed rocks which lie between relatively undeformed terrane to the northeast and southwest. What is the nature of asperities, or strong points, on the fault, and how do its stronger and weaker parts interact? To what extent does plastic-behaving fault gouge move within the fault zone to change the overall geometry?

The role of water in the kinematics and dynamics of the fault system can scarcely be overemphasized, and yet almost nothing is known about the actual hydrotectonic relations. To what extent does elevated or reduced pore pressure modify the properties of the lithologic packages of rocks at different places along and across the fault? What geochemical changes in the fault zone are enhanced by the movement of fluids along the fault and through rocks adjacent to the fault? What mineralogic changes take place as a result of thermal changes related to friction, possibly accompanied by exsolution of water from minerals? Can localized, tectonically elevated pore pressure initiate slip, and once slip acceleration occurs, what role does friction play in the dynamics of slip? Why are so few volcanic rocks associated with the fault except for those related to the passing triple junction?

What are the rates of fault slip, folding, and the overall budget of deformation among various forms of strain? How do erosional rates compare with tectonic rates in changing the landscape, and to what extent do these processes deviate from linearity? How do complex geomorphic processes interact among themselves, as well as with the tectonic processes? How can the ubiquitous landforms be interpreted to illuminate the younger history of the San Andreas fault?

Strands and branches of the San Andreas fault system bound numerous exotic terranes, those aggregates of rocks which are so dissimilar that they could not have been born in their present relation to one another. The patterns of movement and distances traveled by these terranes may constitute the most significant characteristic and role of the San Andreas fault in the overall scheme of global tectonics. By whatever mechanisms these exotic blocks or terranes were transported, the western part of North America has been enlarged by the accretion of these "strangers," while at the same time other pieces of older continental material have been plucked away, eventually to join land somewhere to the northwest.

This volume represents but a small punctuation mark in the early stage of our understanding of the San Andreas fault system and the tectonics that it highlights. Most of the story has yet to be learned.

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The San Andreas fault system, a complex of faults that display predominantly large-scale strike slip, is part of an even more complex system of faults, isolated segments of the East Pacific Rise, and scraps of plates lying east of the East Pacific Rise that collectively separate the North American plate from the Pacific plate.

1. GENERAL FEATURES

By ROBERT E. WALLACE

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INTRODUCTION

This chapter briefly describes the San Andreas fault system, its setting along the Pacific Ocean margin of North America, its extent, and the patterns of faulting. Only selected characteristics are described, and many features are left for depictions on maps and figures. The other chapters in this volume elaborate on the history and evolution of the fault system, and the behavior of the Earth's crust and upper mantle within the fault system.

Because of the extent and complexity of the San Andreas fault system, it is helpful to distinguish between the broad, complex feature as seen on a map of the Western United States and the individual faults on which displacements occur to produce single earthquakes. From larger to smaller features, the terms "fault system," "fault zone," "fault," and "fault branches, splays, strands, and segments" are useful.

The term "San Andreas fault system" refers to the network of faults with predominantly right-lateral strike slip that collectively accommodate most of the relative motion between the North American and Pacific plates. The boundaries of this fault system are poorly defined, but to separate the San Andreas fault system from other tectonic provinces and systems, it is useful to limit the term to the set of faults along the Pacific rim of North America, both on land and off shore. Accordingly, at the latitude of San Francisco, the system is approximately 80 km wide, and at the latitude of San Diego approximately 150 km wide (see fig. 1 and maps at front of book).

The term "fault zone" refers to the complex zone of sheared rock that may be from 0.5 to more than 1 km wide and hundreds of kilometers long. The fault zone has developed over a period of millions of years while growing in width and complexity. The terms "fault," "fault branches," and "fault strands" refer to smaller elements and can be applied as needed. For example, surface rupture accompanying an earthquake commonly produces a complex pattern of fractures, and detailed elements can be discussed more effectively by using such terms as "fault branch, splay, or strand." The term "fault segment" recognizes that the fault is not completely continuous but is in sections or parts with poorly defined boundaries, as discussed below in the subsection entitled "Segmentation."

◀ FIGURE 1.1.—The San Andreas fault zone appears as a gash across the terrain in the Carrizo Plain area of south-central California. Streams are deflected or offset, as in foreground. Note that strata of Pleistocene age are tilted to steep angles on right (west) side of fault. View southeastward.

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FIRST REFERENCES TO THE SAN ANDREAS FAULT

The San Andreas fault first came into prominence only after it was fully understood by geologists as the cause of the great San Francisco earthquake of 1906. The name had been first used only 9 years previously by A.C. Lawson (1895) for a small segment of the fault on the San Francisco peninsula, where he reported that "a remarkably straight fault * * * has conditioned the San Andreas and Crystal Springs Valley" (p. 439). Lawson applied the name "San Andreas fault" almost incidentally in a discussion of "subsequent streams that flowed in the valleys." He suggested vertical displacement on the fault but apparently was not convinced of that, inasmuch as he failed to show the fault or, with one exception, displaced strata on several cross sections in his report (for example, pl. 7). Clearly, neither the amount of displacement on the fault nor its great regional and tectonic significance was appreciated at the time of Lawson's work.

In one of the first reports about the 1906 earthquake, G.K. Gilbert (1907) accurately described the fault and its characteristic displacement, but he did not use the name "San Andreas fault." In his field notes for April 28, 1906, just 10 days after the great earthquake, Gilbert described 20 ft of right-lateral displacement of a road where it crosses the fault at the head of Tomales Bay. He had been following the surface rupture for several days, and on April 26 he recorded in his notes that along the west side of Bolinas Bay "some of the cracks were clearly secondary; others may have been primary." By the time the final report of the State Earthquake Investigation Commission was published (Lawson, 1908), the name "San Andreas" had been adopted, and its characteristics and role in causing the earthquake were clear. That report, which contains a remarkably extensive and accurate account, constitutes a major milestone in our understanding of the San Andreas fault and of strike-slip faults as a class.

EXTENT AND PATTERNS OF FAULTING

OVERVIEW OF THE PACIFIC MARGIN OF NORTH AMERICA

The San Andreas fault system is part of a complex system of faults, isolated segments of the East Pacific Rise, and scraps of plates lying east of the East Pacific Rise that collectively separate the North American plate from the Pacific plate (fig. 1.2). On a more generalized or global scale, the North American plate can be thought of as lying across and partly covering the northern part of the Pacific system of plates. In simplified terms, the Pacific system of plates includes three elements: a westward expanding plate (the Pacific plate), an eastward-expanding plate (the Juan de Fuca plate), and a spreading center (the East Pacific Rise) from which the plates expand as new material is added. To the north, the Pacific plate is underriding, or being subducted under, the North American plate along the Aleutian thrust.

Some investigators (Atwater, 1970; Atwater and Molnar, 1973) suggested that the North American plate has converged with and, indeed, slid over the Pacific system of plates, leaving only segments of the East Pacific Rise exposed, to which such names as "Juan de Fuca and Gorda Ridges" are applied. Similarly, related scraps of the eastward-expanding plate are the Juan de Fuca and Gorda plates (fig. 1.2). Absolute plate motions derived by Minster and Jordan (1980), and Jordan and Minster (1988) are shown in figure 1.2, along with the plate-motion vectors derived from the relative migration of mantle plumes or hotspots responsible for volcanic activity in Yellowstone National Park and the Hawaiian Islands.

At its north end, the San Andreas fault joins the Mendocino Fracture Zone at a high angle, and there three plates are juxtaposed: one moving relatively northwestward, the second southeastward, and the third eastward and northeastward, to form a triple junction. At its southeast end, the San Andreas fault system merges more gradually with the set of transform faults underlying the Gulf of California. Just northwest of the area of merging, however, the trend of the San Andreas fault system changes to much more westerly, whereas a set of echelon faults accompanied by volcanism less than a million years old form a north-south-trending zone that extends northward across the Mojave Desert into Owens Valley of eastern California (Hill and others, 1985). This zone may be considered the East Pacific Rise overridden, and thus modified in pattern, by the North American plate.

The San Andreas fault system may be viewed as forming the hypotenuse of a right triangle of which the northward extension of the East Pacific Rise and the eastward extension of the Mendocino Fracture Zone are the legs. The model of an overridden, subducted oceanic plate within this triangle and underlying the North American plate (Dickinson and Snyder, 1979) presents significant tectonic problems (see chap. 3).

The San Andreas fault system has rearranged an assemblage of microplates, or terranes, some of which originated tens of degrees of longitude apart. During the fault's approximately 29-m.y. existence, an extremely complex pattern of rock distribution, has thus has been created (see chap. 3).

MAJOR ELEMENTS OF THE SAN ANDREAS FAULT SYSTEM

The San Andreas fault system consists primarily of the San Andreas fault and several major branches, such as

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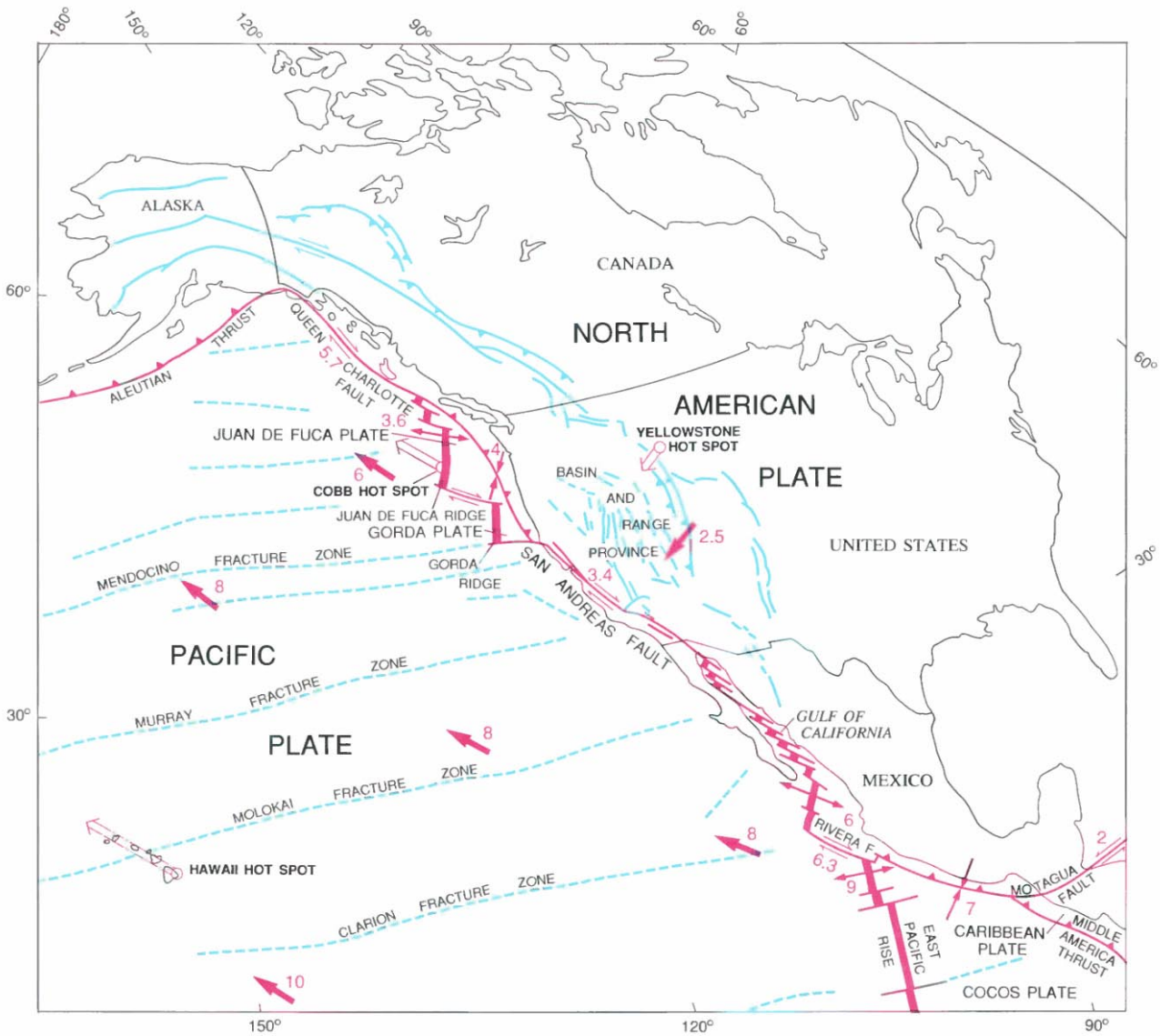

EXPLANATION

5.7 **Strike-slip fault**—Showing slip vectors and rate (cm/yr)

4 **Subduction zone**—Showing slip vectors and rate (cm/yr) of convergence; sawteeth on upper plate

6 **Spreading center**—Showing vectors and rate (cm/yr) of spreading

8 **Vector and rate (cm/yr) of absolute plate motion**

Hot spot and vector of plate motion relative to it

Fracture zone in Pacific plate

Fault in North American plate—Sawteeth on upper plate of thrust fault

FIGURE 1.2.—Northeastern Pacific Basin, showing relation of the San Andreas fault as one element in the complex boundary between the North American and Pacific plates. Modified from Drummond (1981).

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the Hayward and Calaveras faults in central California and the San Jacinto and Elsinore faults in southern California (fig. 1.3). In addition, in southern California the San Andreas fault splits into northern and southern branches in the eastern Transverse Ranges east of Los Angeles. These major faults accommodate about two-thirds of the right-slip motion between the North American and Pacific plates.

Numerous smaller branches, and extensions of segments of the fault, include in northern California such faults as the Rodgers Creek and Maacama faults, which may be considered northward extensions of the Hayward fault. The Green Valley and Bartlett Springs fault zones extend the Calaveras fault northward in a complex way (see maps at front of book). At the south end of the system, the Imperial fault represents a transition from the more continuous San Andreas fault to a more nearly echelon pattern characteristic of the faults under the Gulf of California. The Superstition Hills and Coyote Creek faults similarly represent a transition from the San Jacinto fault to a more segmented pattern to the south in Mexico.

In this volume, the San Andreas fault system is considered to lie principally within a belt about 100 km wide by 1,300 km long, but this boundary is arbitrary. Indeed, part of the relative strike-slip motion between the North American and Pacific plates seems to be taken up as far as 1,000 km east of the coastline throughout the Great Basin province (Jordan and Minster, 1988). The name "San Andreas fault system," however, should be confined to the more limited belt with the highest concentration of right-lateral strike slip.

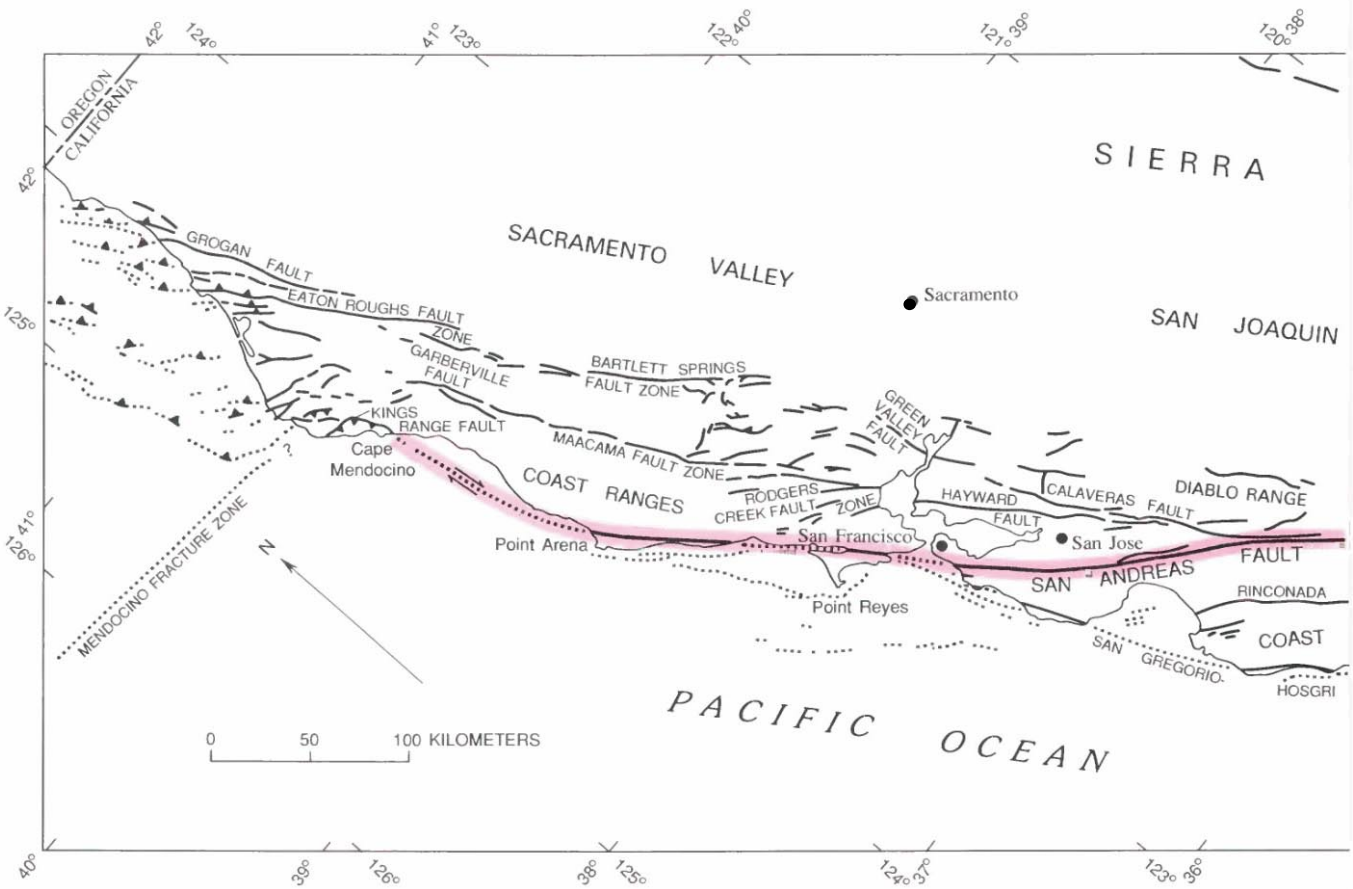

FIGURE 1.3.—The San Andreas fault system in California. Arrows on San Andreas fault (red) indicate direction of relative movement.

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PRINCIPAL TRENDS

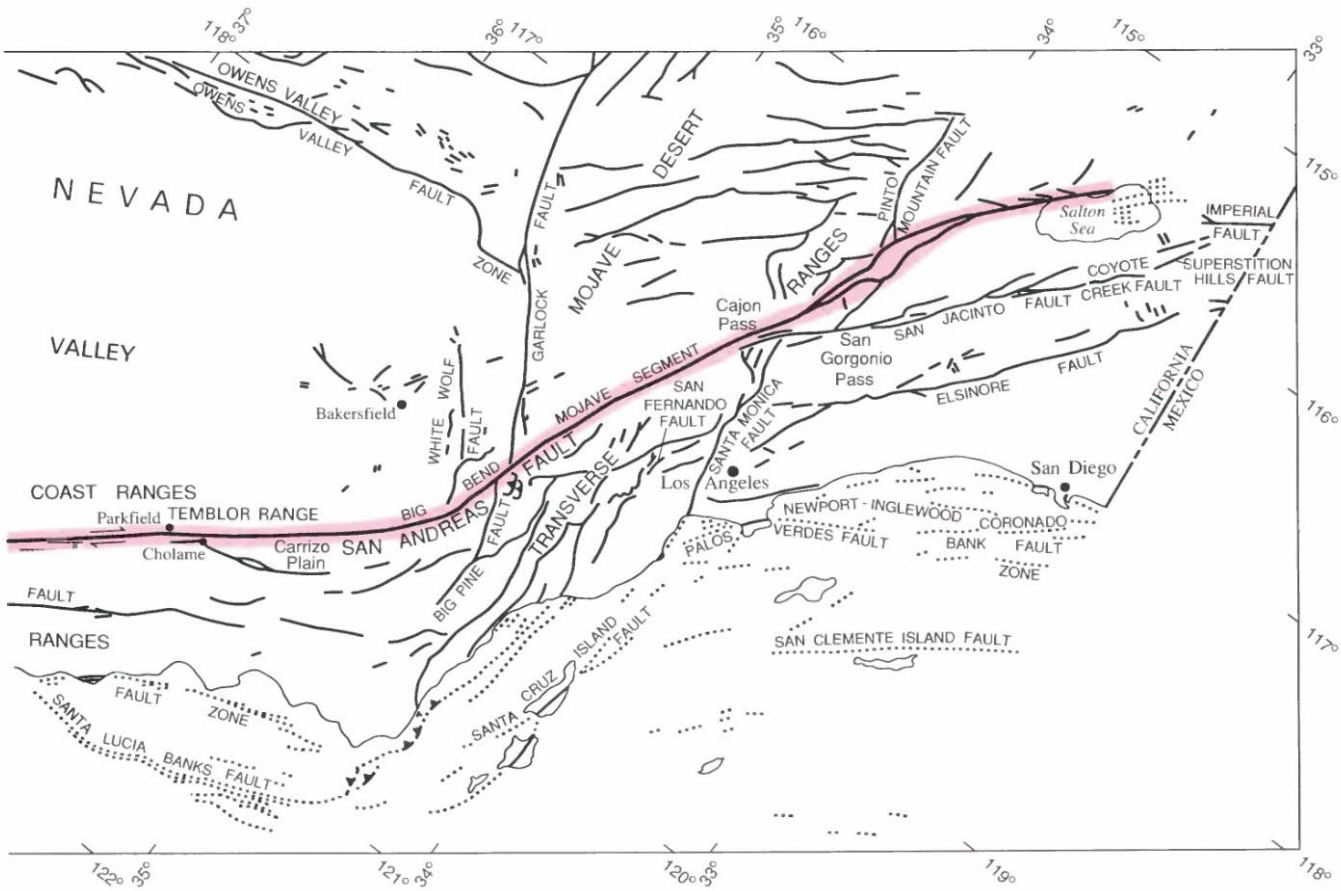
With some notable exceptions, the fault trends about N. 35°–40° W. (fig. 1.3). In its central section between the latitudes of San Jose and Bakersfield, the fault is relatively simple and straight, but farther to the south and north several branches splay from the main active trace. Near San Jose, where the fault bends about N. 50° W., the Calaveras and Hayward faults splay to the east and trend between N. 20° and 35° W. South of the latitude of Bakersfield, the main fault changes most sharply in strike, in what commonly is referred to as the Big Bend reach of the fault. For 120 km or more the fault strikes about N. 60° W., where it bounds the Mojave block on the south. This bend has significant tectonic implications (see chaps. 2 and 3, and maps at front of book).

South of the latitude of Los Angeles, the Elsinore and San Jacinto faults splay to the southeast, forming, in a general way, a reversed image of the splays in the San Francisco Bay region, although both faults trend about N. 50 W.

COMPLEXITIES OF THE FAULT SYSTEM

OTHER RELATED FAULTS

In addition to the right-lateral strike-slip faults that characterize the San Andreas fault system, faults displaying left-lateral strike slip, as well as thrust faults and reverse faults of many sizes, are present (see maps at front of book). Normal faults are less common but are present in some places, for example, in zones of extension



Faults dotted where concealed; sawteeth on upper plate of thrusts. Mendocino Fracture Zone queried where uncertain.

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at the crest of folds associated with the major faults, in the bordering ranges, and at jogs in the fault where local extension is to be found.

Most conspicuous of the faults displaying left-lateral slip is the Garlock fault which intersects the San Andreas fault at about lat 35° N. and extends northeastward and eastward from there for 240 km (fig. 1.3; see maps at front of book). On the west side of the San Andreas fault, the southwest- and east-west-trending Big Pine fault joins the San Andreas fault a few kilometers northwest of the point where the Garlock fault joins the San Andreas fault.

The left-lateral Pinto Mountain fault zone joins the San Andreas fault on its east side at about lat 34° N. and extends northeastward, in a pattern not unlike that of the Garlock fault. The Blue Cut fault is another left-lateral fault in the same general area.

On a broad regional scale, thrust faults and detachments that accommodate subduction of the lower crust are significant, and various interpretations and speculations have been offered (fig. 1.4; Weldon and Humphreys, 1986; Namson and Davis, 1988). Intermediate-scale thrust faults that border the Transverse Ranges on the south side are characterized by such faults as the San Fernando fault zone (Grantz, 1971) and the Cucamonga fault zone (fig. 1.5). At the north end of the San Andreas fault system, where it joins the Mendocino Fracture Zone, such thrust faults as the Kings Range fault similarly accommodate crustal shortening. Smaller thrust faults that flank the San Andreas fault and dip toward it are common along many parts of the fault zone.

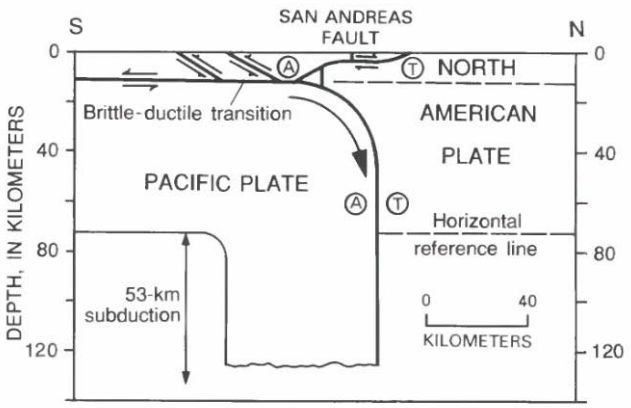

FIGURE 1.4.—Some interpretations suggest that the San Andreas fault bottoms at a detachment fault and that numerous thrust faults, as well as the San Andreas fault itself, are important elements which accommodate the relative displacements between the North American and Pacific plates (from Namson and Davis, 1988). Heavy lines, faults; arrows indicate direction of relative movement: A, away from observer; T, toward observer.

A range of fault types, and the complexities that typify much of the fault zone, are well illustrated near Cajon Pass and southeast of there (fig. 1.5), where the San Andreas fault zone splits into a northern and a southern branch. The strike of the San Gorgonio Pass fault zone in the east-central part of figure 1.5 changes in several places, and depending on the trend of a given segment, strike or dip slip may predominate. In this same area, the San Andreas fault, which to the northwest is relatively continuous and linear, ends as a surface feature, and the style of deformation changes from strike slip to primarily dip slip at the surface. Left-lateral slip characterizes the Pinto Mountain fault in the eastern part of figure 1.5, and small normal faults can be found throughout this area.

SEGMENTATION

Different behavior patterns along different parts of the fault began to be recognized when Steinbrugge and Zacher (1960) found that continuous slip or "creep" occurred along the fault in central California. Allen (1968) delineated five different regions along the San Andreas fault, three displaying seismic activity and two displaying little or no current activity. Wallace (1970) described in more detail major differences in behavior along different segments.

Large segments of the fault system that are believed to produce damaging earthquakes are illustrated in figure 1.6, which also shows an evaluation of the probabilities of earthquakes of different magnitude along these major segments of the San Andreas fault and three of its branches, the Hayward, San Jacinto, and Imperial faults. Both historical seismicity and paleoseismic evidence of large earthquakes and slip rates that characterize these different segments have been used in this assessment (Working Group on California Earthquake Probabilities, 1988).

Segmentation at a scale of a few to several kilometers is shown in figure 1.7, and a cumulative plot of the segment lengths in figure 1.8. The maximum length of these segments is about 18 km, but a more significant upper range appears to be near 10 km. These mappable segments are based on relatively fresh geomorphic features considered to be "young," that is, probably less than several thousand years old.

Both left (fig. 1.7)- and right-stepping echelon patterns are displayed, and combinations or transition zones are also present. Complex patterns are common.

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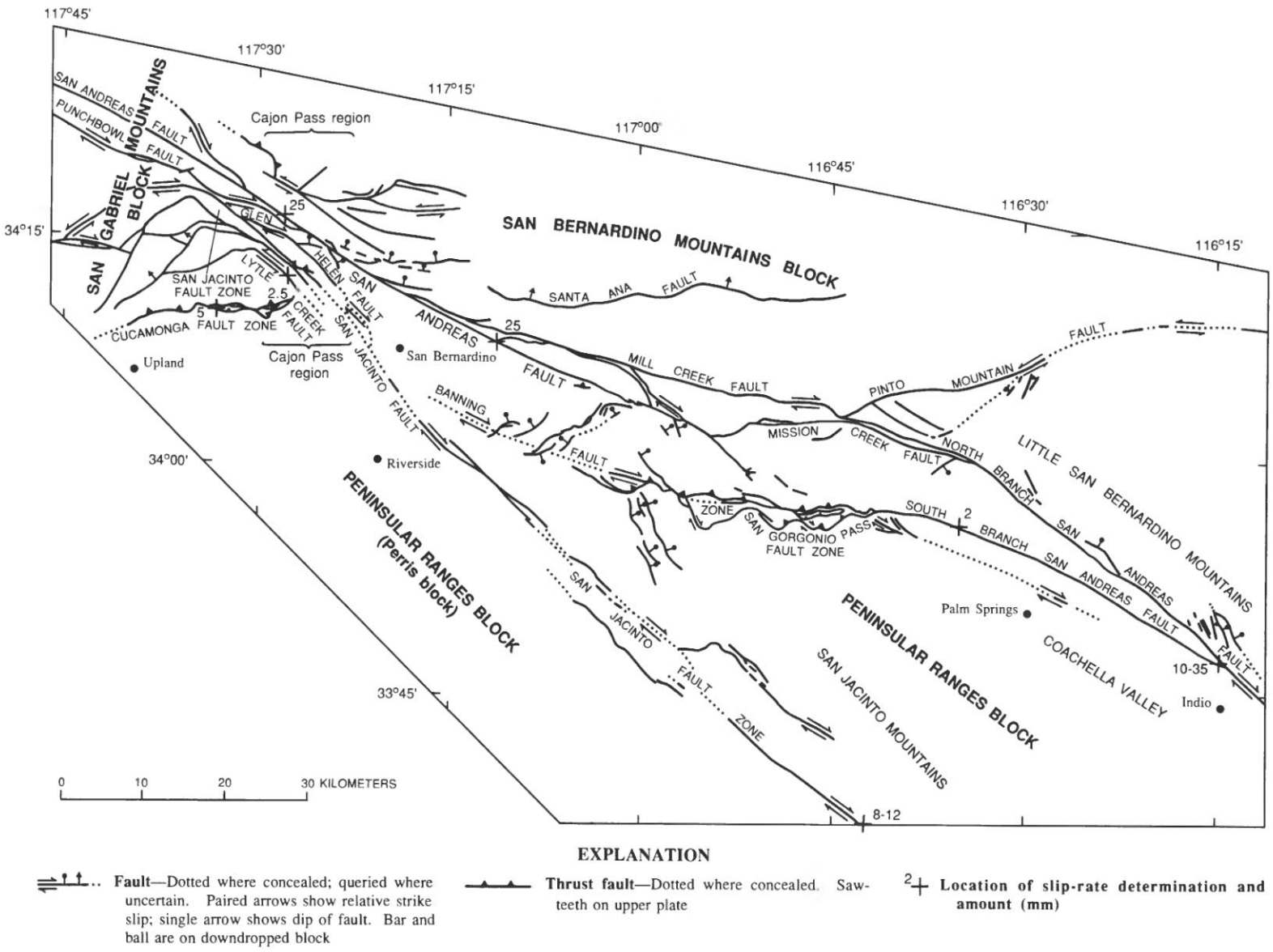

FIGURE 1.5.—Complex branching and changes in the style of faulting characterize the eastern branch of the San Andreas fault system in southern California. Although right-lateral strike slip characterizes the main San Andreas fault and its major branches, thrust faults, normal faults, and left-lateral faults are also present (modified from Matti and others, 1985).

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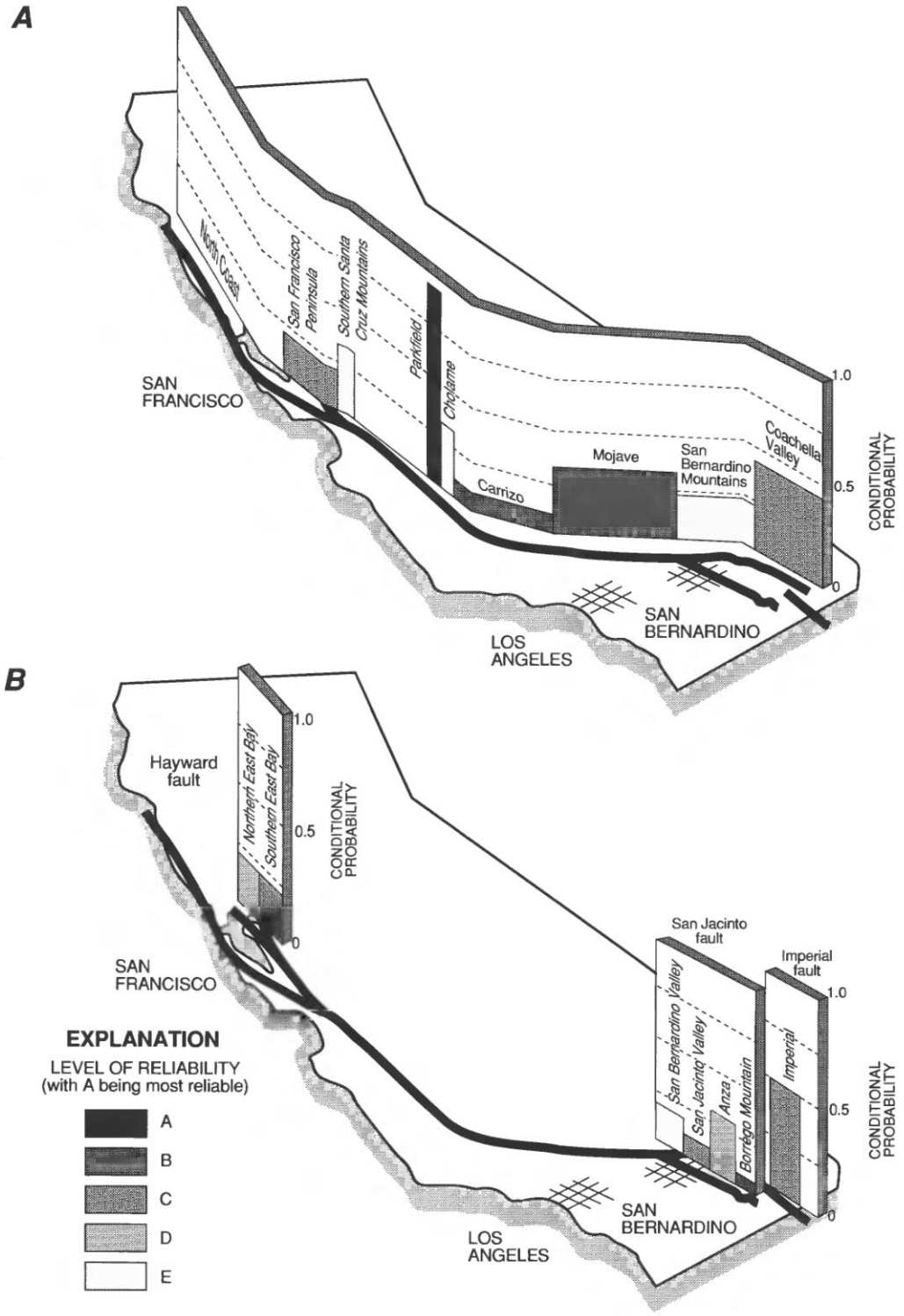

FIGURE 1.6.—Segments of the San Andreas fault system display different behavior. Here are shown conditional probabilities for the occurrence of major earthquakes along segments of the San Andreas (*A*) and the Hayward, San Jacinto, and Imperial faults (*B*) for the 30-year interval from 1988 to 2018. From Working Group on California Earthquake Probabilities (1988).

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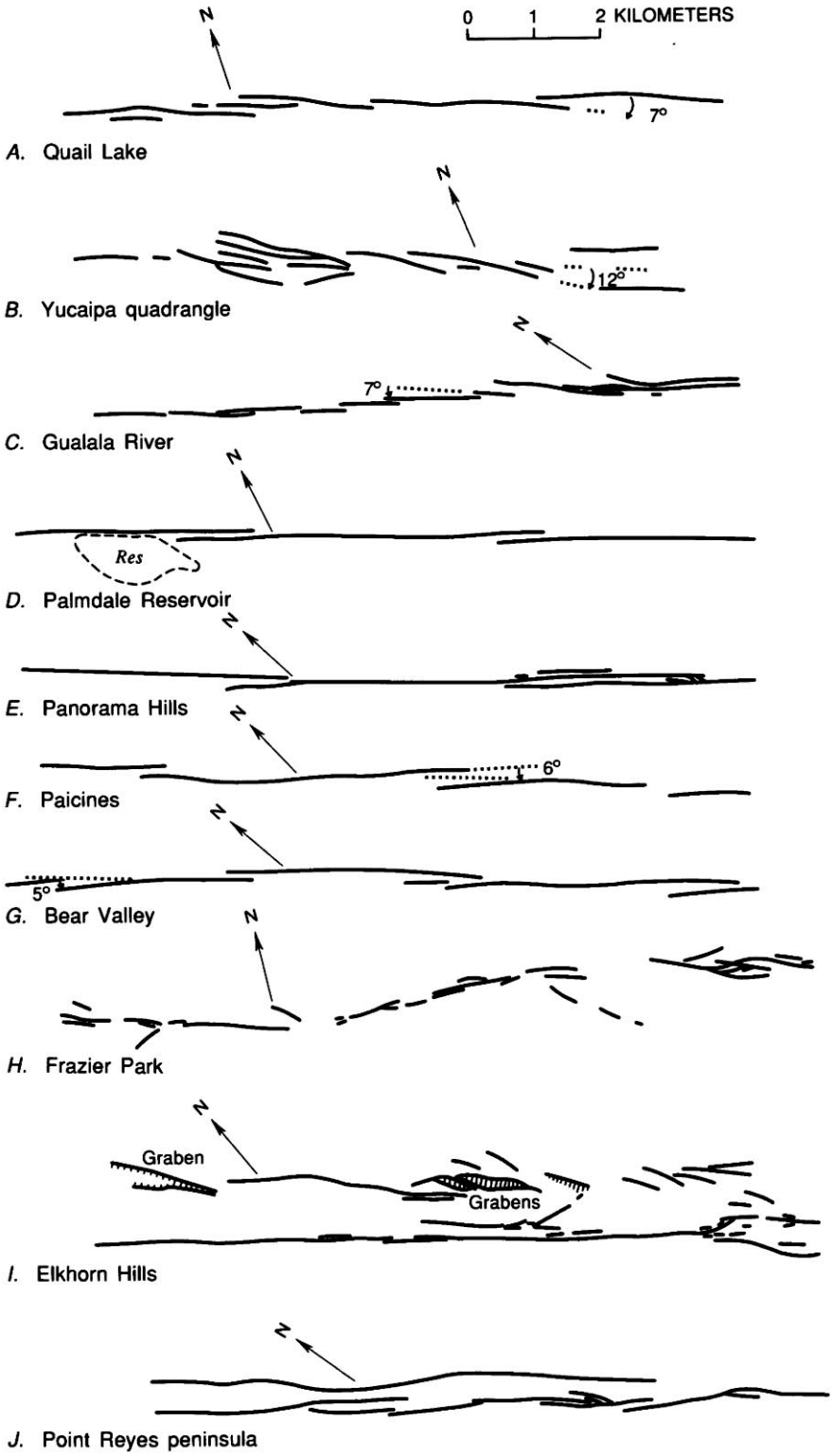

FIGURE 1.7.—Individual branches and strands of surface trace of the San Andreas fault are arranged in various patterns: *A–C*, left-stepping echelon arrangement; *D–F*, right-stepping echelon arrangement; *G*, both left- and right-stepping arrangements; *H–J*, complex arrangements of individual strands. Note that individual strands may be at an angle of as much as 12° to general trend of fault zone. Sources: *A*, *D* (Ross, 1969); *B* (Hope, 1969; see references in this chapter); *C*, *J* (Brown and Wolfe, 1972); *E*, *H*, *I* (Vedder and Wallace, 1970); *F*, *G* (Brown, 1970; see references in chap. 2).

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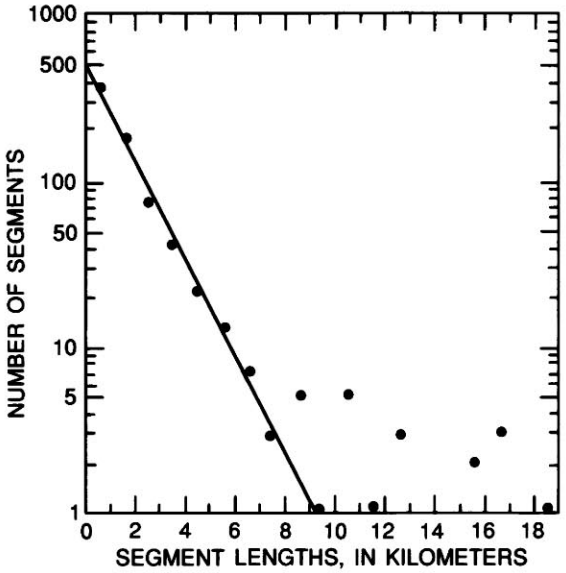

FIGURE 1.8.—Census of lengths of individual segments of the San Andreas fault. Maximum lengths are in the range 10–18 km. Line is fitted by eye to show trend of values. From Wallace (1973).

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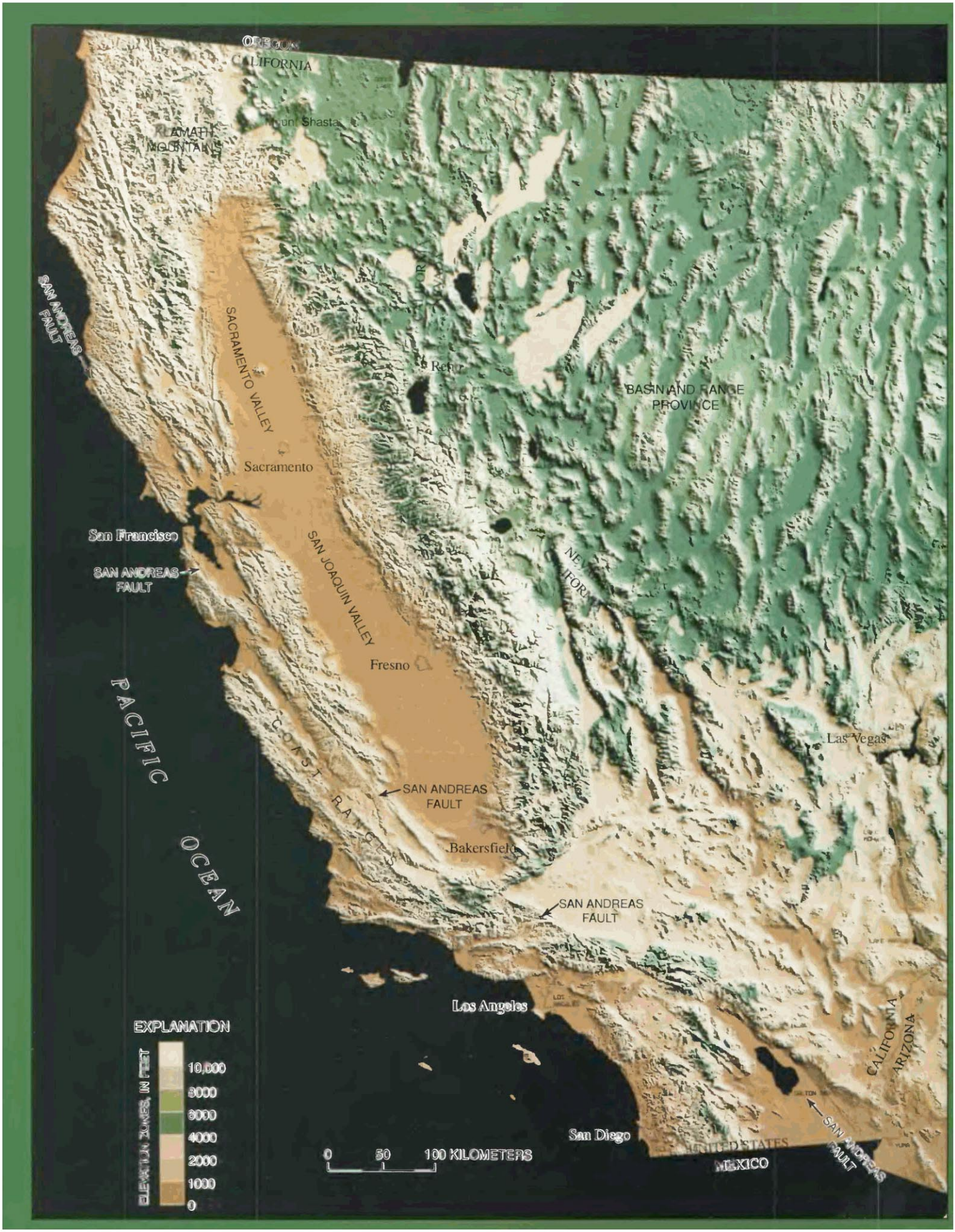

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The San Andreas fault is marked in the landscape by a series of linear valleys and mountain fronts, aligned lakes and bays, elongate ridges, and disrupted or offset stream channels.

2. GEOMORPHIC EXPRESSION

By Robert E. Wallace

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Local geomorphic features within the fault zone	16
Detailed maps of the fault system	19
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Supplementary section: A photographic album of fault features	23

REGIONAL FEATURES

On maps, aerial photographs, or satellite images, at almost any scale, the San Andreas fault zone appears as a linear scar across the landscape. At scales small enough to display the entire fault length, valleys, bays, chains of lakes and ponds, linear flanks of mountain ranges, and elongate ridges bounding one side or the other of the fault are the principal features that reveal its location.

Erosion of the softer broken and sheared rocks in the several-hundred-meters- to l-km-wide fault zone accounts for much of the valley-like expression of the fault, but differential vertical displacements also play a major role. The ratio of local horizontal to vertical displacement may be about 10 or 20 to 1. Differential erosion of the various rock types juxtaposed by faulting also influences the geomorphic expression of the fault.

The San Andreas fault separates some mountain masses from adjacent broad regions of low relief, creating pronounced linear topographic discontinuities. Considering the large lateral displacements that have occurred, juxtaposition of some mountains against flatter, lower areas probably has come about by lateral slip. Some range-size blocks bounded by the fault, however, have risen or dropped hundreds of meters to create the linear topographic features. Elongate blocks of the crust bounded by branches and subparallel strands of the fault have been created and shuffled one block against another by both upward, downward, and lateral differential displacement within the broad shear zone. Such movements are reflected in the topography as elongate ridges and depressions. Whether lateral or vertical block displacement, or warping or folding, has dominated in the development of a specific landform, and what role erosion has played, have yet to be well analyzed for most topographic features within the fault system. Evidently, a complex interaction of tectonic, erosional and depositional processes has influenced the development of each feature, and the result is a linearity of topographic features along and parallel to the San Andreas fault.

From Point Arena southeastward to the vicinity of San Jose, Calif., the trace of the San Andreas fault is topographically conspicuous on regional maps and images as a series of linear valleys (see fig. 2.1 and maps at front of book for locations). Aligned linear valleys also mark the fault trace throughout central California between San Jose and the Carrizo Plain, but along that reach another important characteristic is that the fault trace crosses mountain ranges and major ridges at a low angle. These

◀ FIGURE 2.1.—Shaded-relief map of California and western Nevada, showing the San Andreas fault as a series of linear valleys and ridges passing through a mountainous region, the Coast Ranges, the trends of which are a low angle to the fault. To the east, between the massive Sierra Nevada and the Coast Ranges, lie the broad, flat valleys of the Sacramento and San Joaquin Rivers. Farther east, in the Basin and Range province, are myriad block-faulted mountains separated by intervening basins. Synthesized from digital terrain models of a 1:250,000-scale map series originally prepared by the U.S. Defense Mapping Agency, now maintained by the U.S. Geological Survey; compiler, Ray Batson, U.S. Geological Survey. Illumination is from north at elevation of 30°.

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mountain ranges and ridges, many of which are antiformal structures, trend from 5° to 10° more westerly than the strike of the fault. Thus, the altitude of the surface trace of the fault alternately rises and falls along strike.

In the Carrizo Plain-Temblor Range area, the surface trace of the fault does not lie at the base of the range but more within the Carrizo Plain, where the surface expression of the fault is narrowest, clearest, and best defined. Offset streams are especially well preserved here; individual strands of the fault reach a maximum length, from 9 to 18 km, anywhere along the fault.

In the Big Bend area at the south end of the San Joaquin Valley, the fault trace rises to a high altitude as it passes through mountainous terrain. Along the Mojave segment to the northwest and southeast of Palmdale (see maps at front of book for locations), the fault trace is again marked by a distinct narrow, linear valley. In addition, a gross contrast between the high, rugged mountain masses of the Transverse Ranges and the relatively flat Mojave Desert block is apparent (fig. 2.1). The surface of the Mojave Desert itself stands 700 m or more above sea level and above the San Joaquin Valley. Clearly, the Mojave block has been uplifted, even though the adjacent mountain masses have risen more.

To the southeast of the Mojave segment, the San Andreas fault crosses the Transverse Ranges at a low angle and separates the high San Gabriel Mountains from the San Bernardino Mountains. An extremely complex structural knot, formed by branching of the San Jacinto fault and numerous other faults (fig. 2.1; see fig. 1.5) is reflected as a complex topographic region surrounding the Cajon Pass area, through which the San Andreas fault passes.

Southwest of the Cajon Pass area, the fault divides into a northern and a southern branch and numerous other smaller faults of different tectonic style. Each fault has its own distinctive geomorphic expression.

Southeast of the zone of major branching, the fault again is less conspicuously marked by contrasts of large topographic features, but it is readily visible on aerial photographs at scales of 1:50,000 and larger (see section below entitled "A Photographic Album of Fault Features").

LOCAL GEOMORPHIC FEATURES WITHIN THE FAULT ZONE

Within the fault zone, various geomorphic features are found that have their origin in both the lateral and vertical shuffling of fault-bounded slices, as well as in the persistent, large strike slip. These features include sag depressions and sag ponds, shutter ridges and medial ridges, offset and deflected stream channels, linear benches along valley walls, aligned notches and saddles on spurs, offset marine and river terraces, scarps, fault-controlled drainage, and folds and pressure ridges (fig. 2.2).

Along its entire length, the fault zone exhibits peculiar, anomalous drainage patterns. In regions where tectonic activity is less pronounced, streams generally flow more or less perpendicular to mountain blocks and highlands, and grade more or less regularly to the lowlands; not so along an active fault like the San Andreas. When drainage flowing from highlands meets the San Andreas fault, it is diverted subparallel to the trends of the highlands or is interrupted or blocked completely. In less active areas, erosion generally is the dominant factor in carving geomorphic forms, but displacements are so rapid within the fault zone that tectonic effects overwhelm erosion, and so the geomorphic features directly express fault movement.

Movement within the network of branching and anastomosing fault strands jostles the intervening blocks, compressing some, rotating some, or causing extension across others. Because the principal slip is horizontal and lateral, the blocks tend to be elongate parallel to the trend of the fault. Blocks under compression tend to be squeezed upward to form elongate ridges, whereas blocks under extension may drop downward to form sags, and laterally displaced slices or ridge spurs create shutters across drainage channels.

The dominantly lateral slip across the fault zone and the rate of slip, from 1 cm to a few centimeters per year, make stream channels that are offset right laterally, a common and characteristic geomorphic feature. Stream channels can be completely beheaded or merely offset while maintaining continuity of flow.

In addition to the effects of lateral slip, streams are extremely sensitive to vertical slip on faults and warping of the land surface. For example, only a small upward movement of a block on the downstream side of a fault crossing a stream may divert the stream either to the left or right, thus mimicking lateral slip on the fault. Similarly, warping of the land surface over folds adjacent to the fault or on pressure ridges within the fault zone can distort the patterns of streams. Combinations of these different tectonic processes can produce many unusual features. Both the tectonic and the erosional changes at times may occur almost instantaneously, and so the dominance of one or the other process suddenly may change. Between such periods of sudden change, very little may happen for decades or even centuries. The relative rates of erosional and tectonic processes, and the timing of sudden events, are critical to the landforms created. Some of the patterns of streams found in the Carrizo Plain area are illustrated in figure 2.3, and an example is shown in figure 2.5.

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The geomorphic forms created represent the results of a continuing contest between erosional changes and changes related to fault slip, folding, and warping. Where streams are large and rainfall is greater, only displacements of hundreds of meters or more are preserved for longer than a few centuries. In desert climates, however, as in the Carrizo Plain, the rate of fault slip outruns erosion, and the effects of only a few meters of fault slip may be preserved for hundreds of years, if not millennia, where small channels cross the fault (fig. 2.4).

As an example of how erosion and sedimentation interact with the faulting process, a straight channel that formerly crossed the fault at right angles is shown after having been offset by right-lateral strike slip (fig. 2.5). The strike slip partly or temporarily dams the stream, causing upstream alluviation at C. A fresh fault scarp is formed in the vicinity of A, and successive offsets expose new scarp areas to the left of A. The dam at B is eroded, and the alluvium deposited earlier at C is dissected. As offset progresses further, the channel segment along the fault trace, between B and A, continually elongates, thus lowering the channel gradient more and more. Because of this decreasing gradient, alluvium is deposited upstream from A to and beyond C, and eventually the stream, having difficulty maintaining a channel along that elongate course, spills across the fault trace and creates a new channel more nearly in alignment with the segment upstream from the fault.

After fault movement has progressed sufficiently, the downstream segments of other channels are brought into alignment, or nearly so, with the original channel. For example, in the vicinity of D in figure 2.5, drainage flowing to the right in an adjacent channel would tend to erode headward toward C, and capture of the original

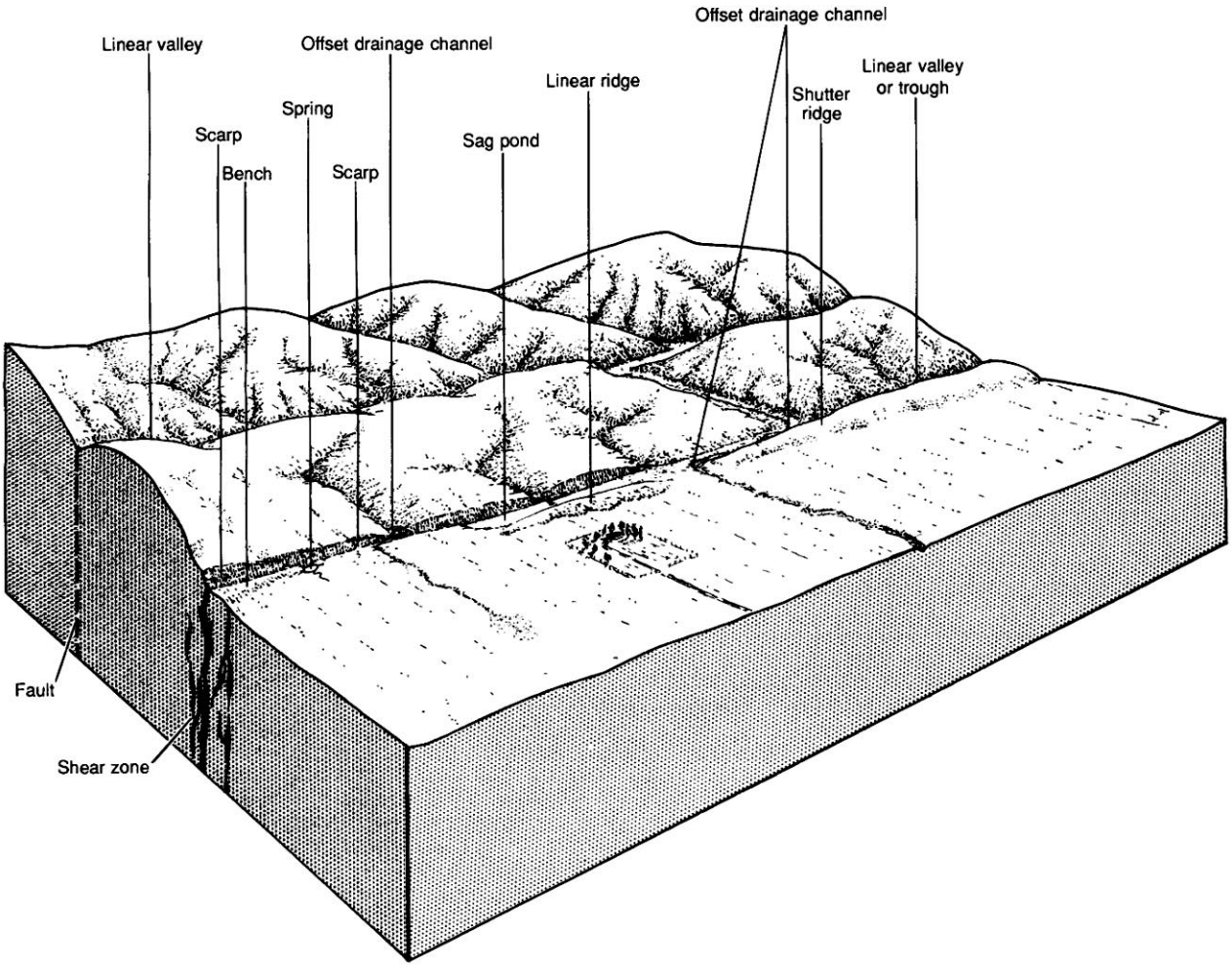

FIGURE 2.2.—Common landforms along the San Andreas fault system (from Vedder and Wallace, 1970).

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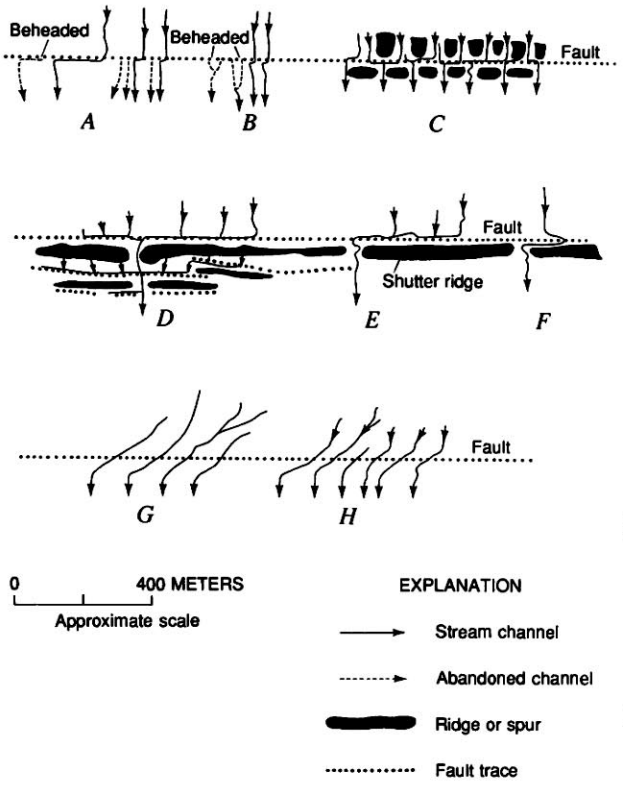
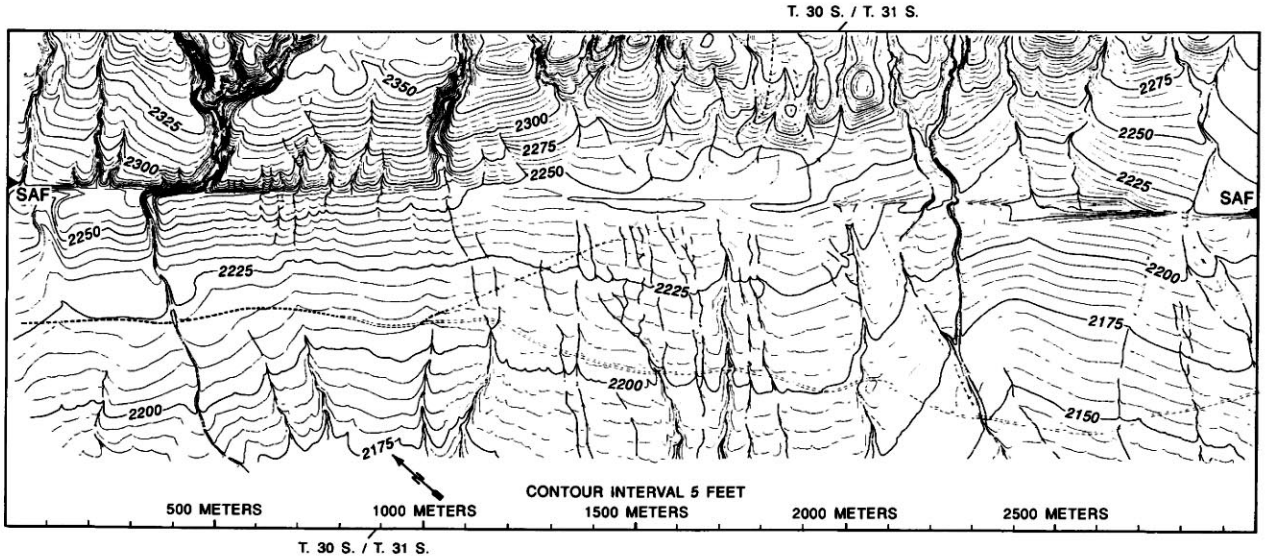


FIGURE 2.3.—Diagrammatic representation of patterns of fault-related stream channels found in the Carrizo Plain area (from Wallace, 1975): *A*, misalignment of single channels directly related to amount of fault displacement and age of channel—no ridge on downslope side of fault, beheading common; *B*, paired stream channels misaligned; *C*, compound offsets of ridge spurs, and offset and deflection of channels, both right and left deflection; *D*, trellis drainage produced by multiple fault strands, sliver ridges, and shutter ridges; *E*, exaggerated or reversed apparent offset, caused by offset plus deflection by shutter ridge; *F*, "Z" pattern, caused by capture by adjacent channel followed by right-lateral slip; *G*, false offset caused by differential uplift or warping; *H*, false offset caused by echelon fractures over fault zone, followed by subsequent streamflow.

FIGURE 2.4.—Topographic map of a segment of the San Andreas fault in the Carrizo Plain area, showing some characteristic small-scale geomorphic features. Markers (SAF) at the left and right margins indicate main fault trace. Between 300 and 500 m (see scale at bottom) is one of the best examples of a stream offset by right-lateral slip on the San Andreas fault (see fig. 2.20). To the northwest, between 100 and 300 m, is an abandoned channel of the same stream. To the southeast, between 600 and 700 m, small streams are offset about 10 m; a few of these streams record multiple offsets of about 8 to 10 m. The last offset presumably was during the great Fort Tejon earthquake of 1857. Between 2,150 and and 2,250 m is a pair of streams that has been offset a few tens of meters. At 2,000 m, the downstream segments of those two streams have been beheaded completely, and at 2,100 m is another possible beheaded segment of the streams (see fig. 2.21). Between 2,300 and 2,700 m is a sag depression about 7 m deep, resulting from downdrop of a narrow block into the San Andreas fault zone. From Sieh and Wallace (1987); map prepared by U.S. Geological Survey from aerial photographs taken January 13, 1966.



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stream would take place. The gradient of this capturing segment, in which flow is to the right, progressively increases because right-lateral slip shortens the channel, thus accelerating erosion; at the same time, the channel flowing to the left elongates, gradient decreases, and erosion decelerates. An example of some geomorphic features that result is shown in figure 2.5.

DETAILED MAPS OF THE FAULT SYSTEM

The U.S. Geological Survey and the California Division of Mines and Geology have prepared numerous detailed maps of the faults within the San Andreas fault system. Maps prepared by the California Division of Mines and Geology address the problem of "active faults" as defined under the Alquist-Priolo Special Studies Zones Act of 1972. These maps, too numerous to list here, were indexed and described by Hart (1985); they constitute a rich data set about the San Andreas and other faults in California. Those readers interested in examining the features of the fault system in more detail or in the field are referred to the published "strip" maps and special fault maps, an index map of which is in figure 2.6.

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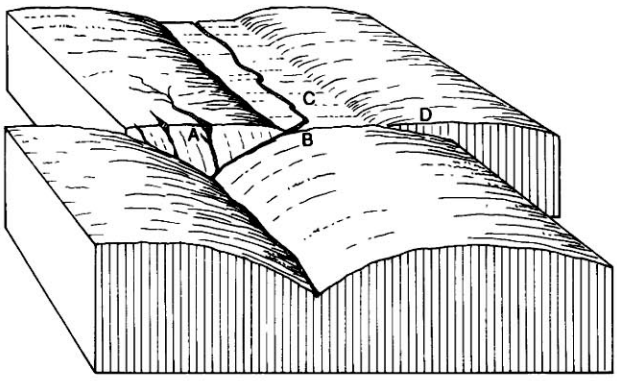

FIGURE 2.5.—General features and conditions produced where a stream channel is offset by strike slip on a fault. See text for discussion of A–D.

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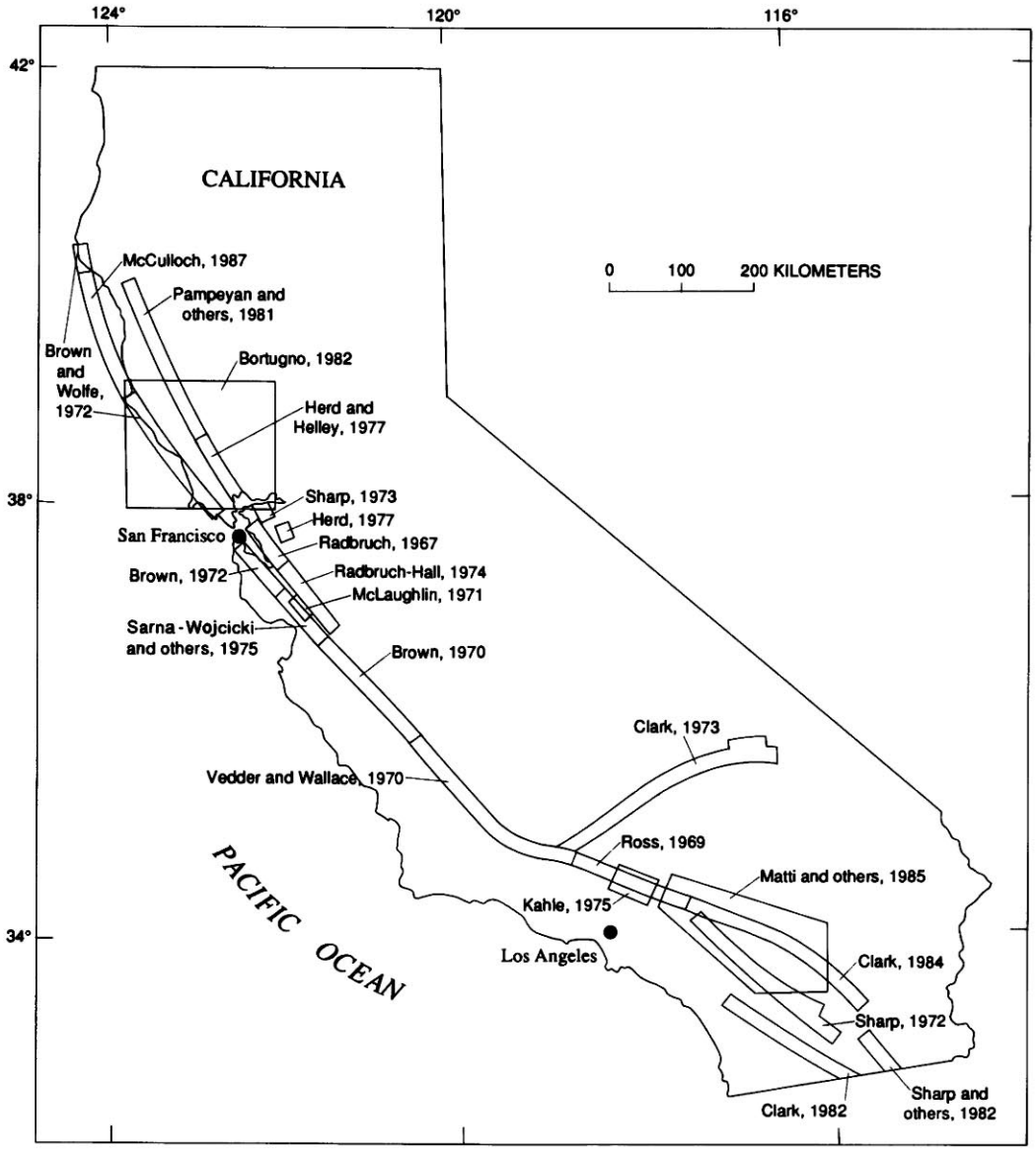

FIGURE 2.6.—Index map of California, showing locations of selected maps of surface traces of the San Andreas fault system.

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A PHOTOGRAPHIC ALBUM OF FAULT FEATURES

The characteristics of the landforms along the San Andreas fault system can be conveyed most vividly and completely by photographs, here arranged geographically from northwest to southeast (figs. 2.8–2.41). Photographs of branch faults are the last in the set. An accompanying map (fig. 2.7) shows the locations of the photographs. All photographs are my own except as otherwise credited in the captions.

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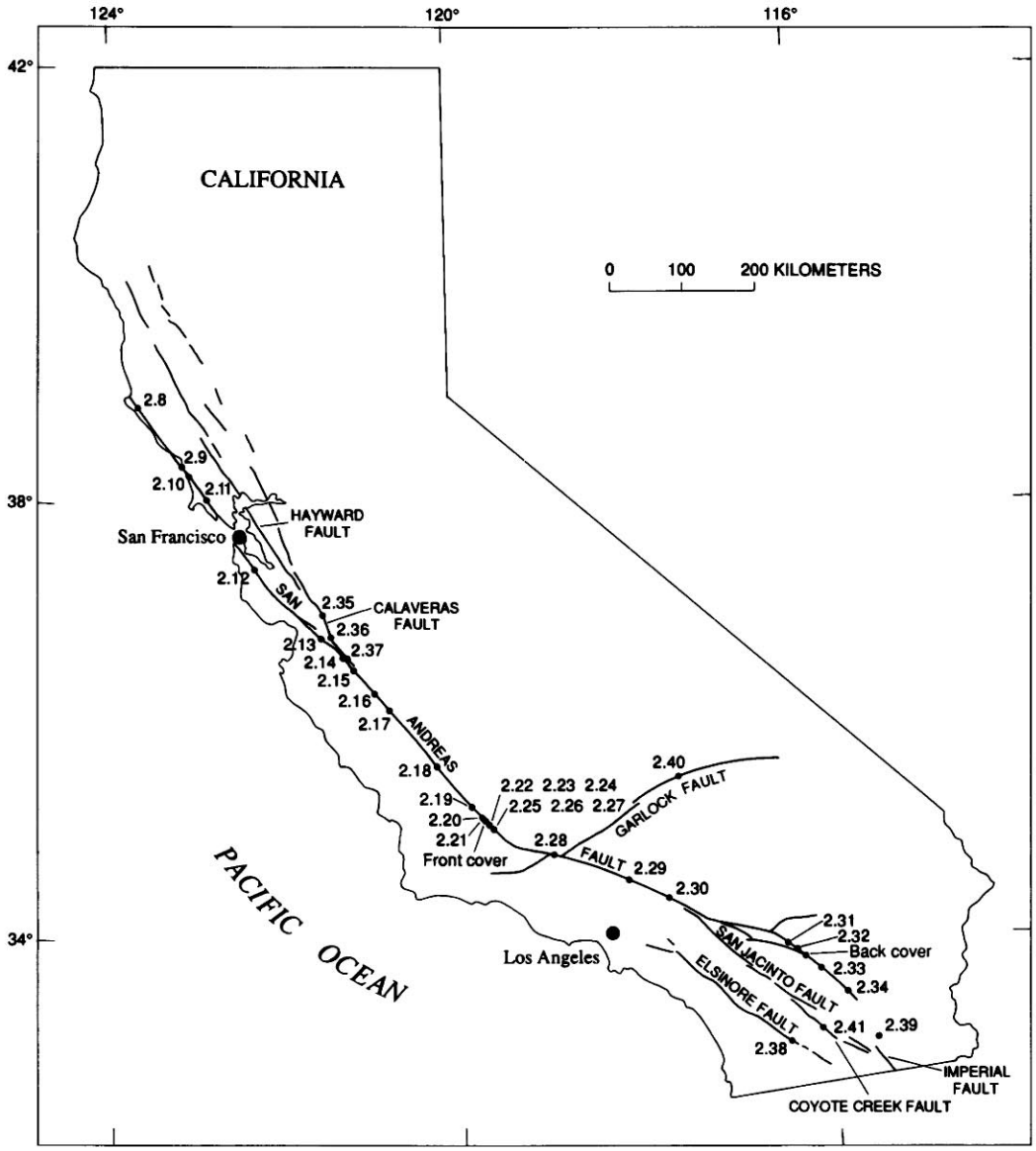

FIGURE 2.7.—Index map of the San Andreas fault system, showing locations of photographs in "photographic album" and locations of cover photographs.

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FIGURE 2.8.—Valley of Garcia Creek follows trace of the San Andreas fault near Point Arena. Most recently active trace lies on west (left) valley flank in foreground. View northwestward, with the Pacific Ocean in background.

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FIGURE 2.9.—A scarp facing the Pacific Ocean, with marine terraces above, marks trace of the San Andreas fault at Bodega Bay, 70 km north of San Francisco. View northwestward.

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FIGURE 2.10.—Tomales Bay lies in an elongate depression along the San Andreas fault. In 1906, a maximum strike slip of 6 m on the fault was reported at the head of Tomales Bay, mid-distance in view; however, some of this slip may have been related to shifting of marshy sediment. The Point Reyes peninsula is to right (west); Mount Tamalpais is high-point in skyline at top left. View southeastward toward San Francisco, 55 km away.

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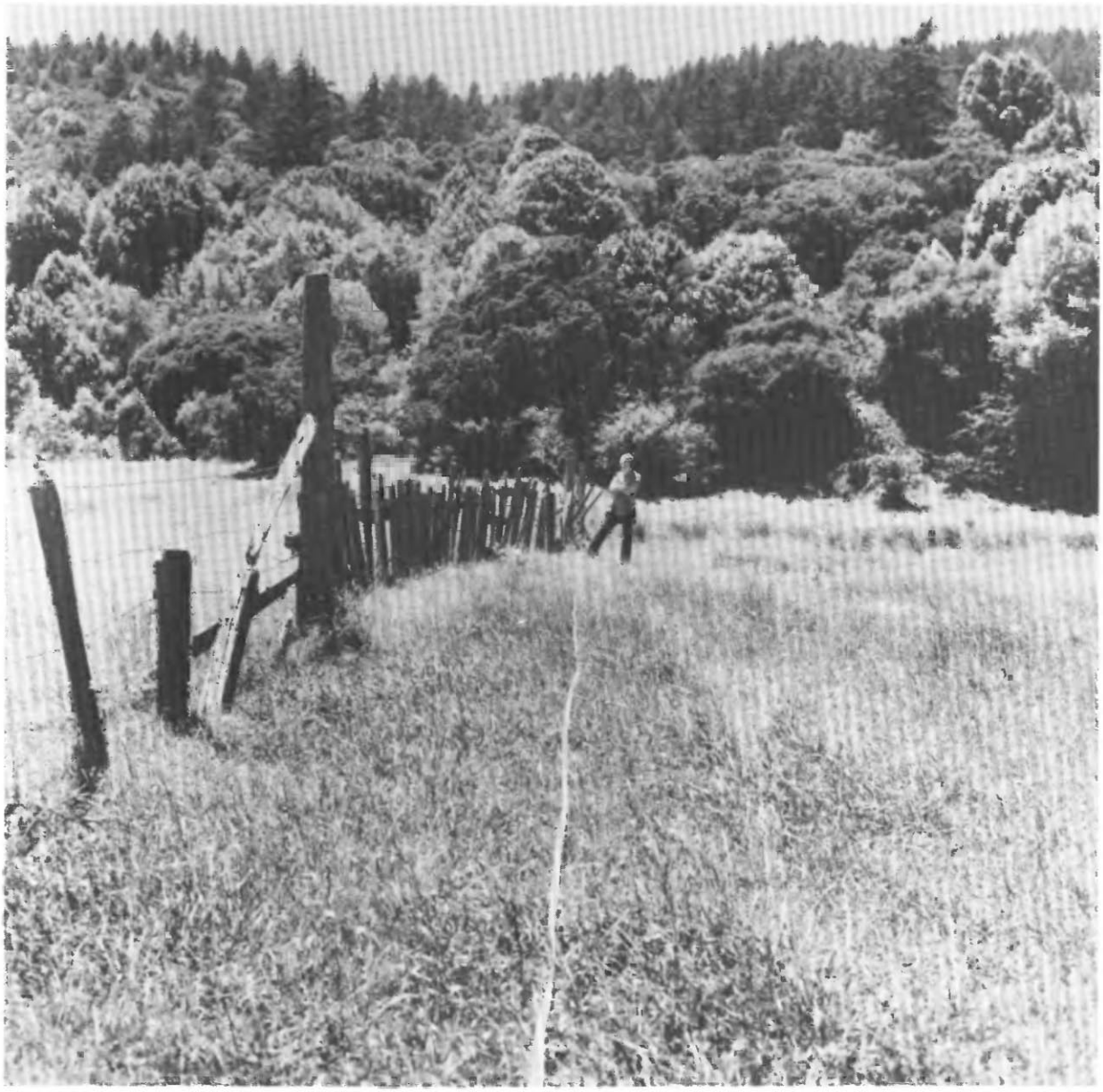

FIGURE 2.11.—A broad valley marks trace of the San Andreas fault on the Point Reyes peninsula. During the great San Francisco earthquake of 1906 , slip on one strand of the fault offset a fence about 2.5 m. Fence beyond break (west side) is relatively straight and aligned with line of view and with tape in foreground; fence on near (east) side bows gradually to meet the fault. View southwestward along fence in southern part of the Strain Ranch (Lawson, 1908, p. 70–71; Brown and Wolfe, 1972).

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FIGURE 2.12.—Along the San Andreas fault zone near San Francisco. Displacement in 1906 was along linear trace on left (west) side of the Crystal Springs Reservoir (foreground). To northwest, active trace of fault bends to east side of the San Andreas Reservoir, which lies just beyond the Crystal Springs Reservoir. View northwestward.

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FIGURE 2.13.—The San Andreas fault at San Juan Bautista. In 1906, southeast end of surface rupture was just north of here. Northwest limit of creeping segment of fault is now at about the same point. Active trace of fault lies along scarp at northeast (right) edge of town, which is located on a tectonic upwarp along the fault. View northwestward.

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FIGURE 2.14.—Fault creep on the San Andreas fault was first reported at the Paicines Winery south of San Juan Bautista in 1960 by Steinbrugge and Zacher (1960). Fault trace (between arrows) passes under winery building, and walls of building are continually being displaced. View northwestward.

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FIGURE 2.15.—The San Andreas fault about 40 km south of San Juan Bautista. Here, the Calaveras and San Andreas faults join. The Gabilan Range is on left; the San Benito River meanders across fault zone. View northwestward.

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FIGURE 2.16.—The San Andreas fault about 70 km south of San Juan Bautista. The Diablo Range is on right (east); the Gabilan Range, displaying a broad, arched upland surface, is on skyline at upper left. View northwestward.

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FIGURE 2.17.—From 65 to 80 km northwest of Cholame, trace of the San Andreas fault follows crest of a ridge. Fault trace is marked by a series of sag ponds, in seemingly anomalous position near crest of a major elongate topographic high. View southeastward from California Highway 198.

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FIGURE 2.18.—Trace of the San Andreas fault in the Palo Prieta Pass, about 13 km southeast of Cholame. A sag pond is in foreground. View southeastward.

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FIGURE 2.19.—A graben locally marks trace of the San Andreas fault near north end of the Carrizo Plain. The Caliente Range is on horizon in upper right. View southeastward.

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FIGURE 2.20.—Stream offsets are well displayed along the Carrizo Plain reach of the San Andreas fault. Here, Wallace Creek, center (named by Sieh and Jahns, 1984), is offset about 130 m. To right (southeast) of the creek, small gulches are offset about 9.5 m as a result of fault slip accompanying the great Fort Tejon earthquake of 1857. See figure 2.4 for a detailed topographic map of this reach of the fault.

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FIGURE 2.21.—A pair of streams that has been offset by right-lateral slip on the San Andreas fault (lineament extending from left to right edge of photograph). View northeastward across fault toward the Temblor Range. Photograph by Sandra Schultz Burford, U.S. Geological Survey.

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FIGURE 2.22.—Stream channel offset by the San Andreas fault. Southwest (far) side is raised along a fault sliver, which tends to preserve incised position of stream. Mound topography is believed to be ancient modified ground-squirrel burrows. View southwestward toward the Carrizo Plain.

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FIGURE 2.23.—A sigmoidal pattern of stream channel results from right-lateral offset, followed by stream capture producing left deflection, followed by further right-lateral offset. Fault extends from right to left; stream flows from bottom to top. View southwestward toward the Carrizo Plain.

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FIGURE 2.24.—Multiple fault strands are common along the San Andreas fault. Four parallel strands are reflected geomorphically here in the Carrizo Plain area. Nearest, most recently active strand (latest displacement in 1857) displays deflection of streams both to right and left. Although right-lateral slip causes displacement, either stream capture, surface warping, or uplift of downstream side can deflect drainage to either right or left. View southwestward.

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FIGURE 2.25.—Linear scar marks trace of the San Andreas fault in the Carrizo Plain area. Large stream entering fault zone from left has been displaced by movement on fault to debouch on right (southwest) side into the Carrizo Plain, thus displaying right-lateral slip. View southeastward.

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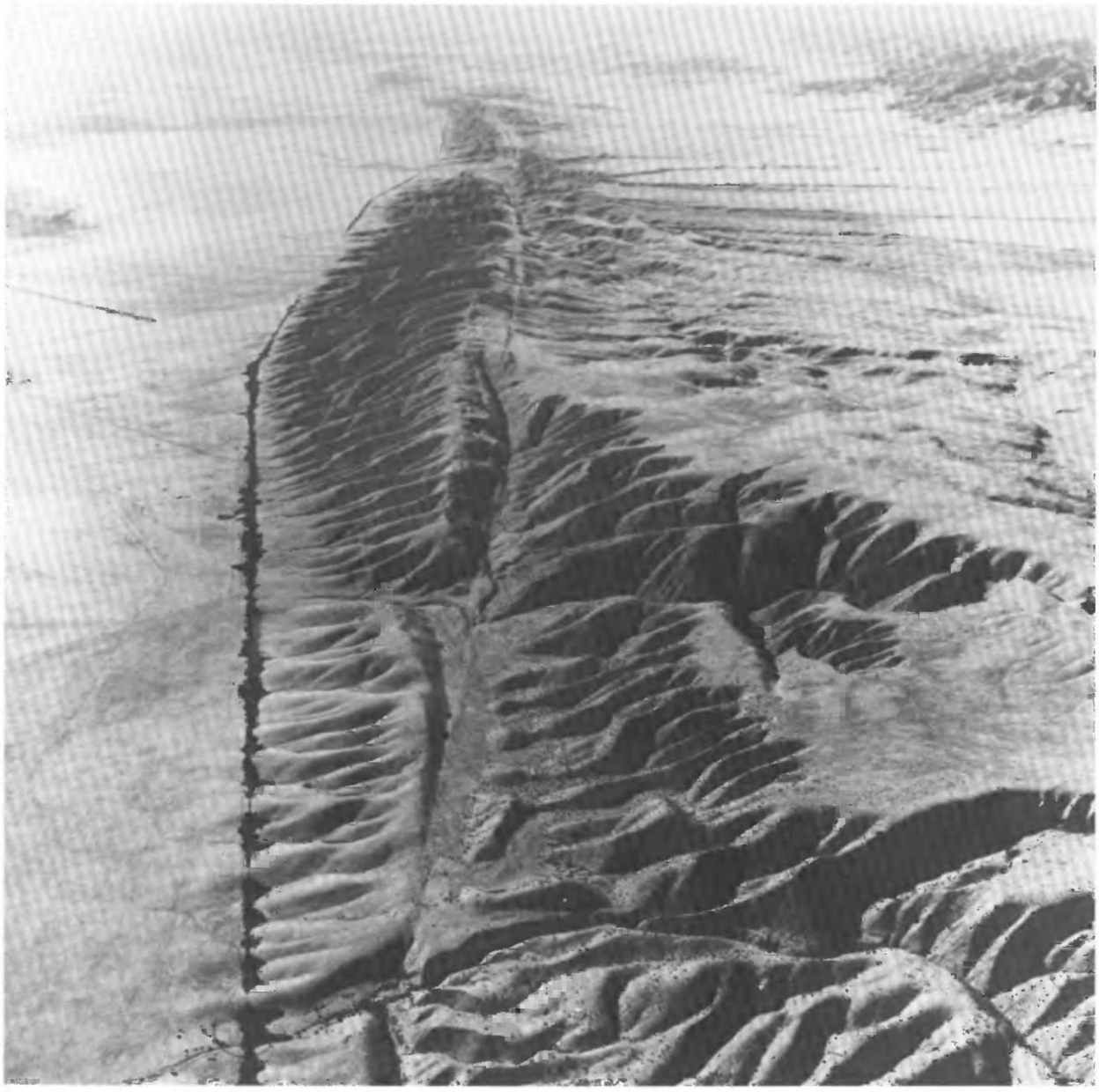

FIGURE 2.26.—The San Andreas fault on east edge of the Carrizo Plain. Rugged, dissected terrain west (left) of fault trace is the Elkhorn scarp. The Elkhorn Plain is to right in distance (see Vedder and Wallace, 1970).

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FIGURE 2.27.—A complex expression of the San Andreas fault forms west flank of the Elkhorn Hills. Upwarping of hills, in combination with echelon fractures along the San Andreas fault zone, helped control drainage. View southeastward.

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FIGURE 2.28.—In the Big Bend region of the San Andreas fault, the Garlock fault, which has left-lateral slip, branches eastward. Junction of these two great faults is near center (circle); trace of the Garlock fault extends to left (east), and that of the San Andreas fault (between arrows) extends east-southeastward from lower right to upper left corner of photograph. Light-colored mountain just west of fault junction is Fraser Mountain, an isolated thrust block placed there by compression across the Big Bend. U.S. Air Force photograph, taken November 27, 1967.

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FIGURE 2.29.—The Palmdale Reservoir lies along the San Andreas fault north of the San Gabriel Mountains. The Mojave Desert is to northeast (right), and a series of ridges lies between the fault and the desert basin. View northwestward.

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FIGURE 2.30.—The San Andreas fault on northeast flank of the San Gabriel Mountains. View northwestward from Jackson Lake (foreground) toward Palmdale.

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FIGURE 2.31.—Northern branch of the San Andreas fault in northern Coachella Valley. The San Gorgonio Pass is at left horizon, and the San Bernardino Mountains are at center of horizon. View northwestward.

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FIGURE 2.32.—The San Andreas fault (between arrows) in northern Coachella Valley, disrupts drainage, offsetting and beheading many channels. Mount San Jacinto is in center distance; the San Gorgonio Pass, a fault-controlled pass, is at right in the distance. View westward; U.S. Geological Survey photograph, taken November 15, 1956.

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FIGURE 2.33.—The San Andreas fault in badlands of the Mecca Hills, Coachella Valley. Sympathetic slip of as much as 1+ cm occurred here during the Borrego Mountain and Imperial Valley earthquakes of 1968 and 1979, respectively.

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FIGURE 2.34.—The San Andreas fault near the Salton Sea, Imperial Valley. Salt Creek is in foreground; Bat Cave Buttes are dark hills at left, and the Salton Sea is in distance. View southeastward.

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FIGURE 2.35.—The Coyote Lake Reservoir lies in a topographic trough along the Calaveras fault a few kilometers east of Morgan Hill, Calif. View eastward across fault.

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FIGURE 2.36.—Creep of about 1 cm/yr on the Calaveras fault in Hollister, Calif., has bowed walls, sidewalks, streets, and houses. View eastward at Sixth Street.

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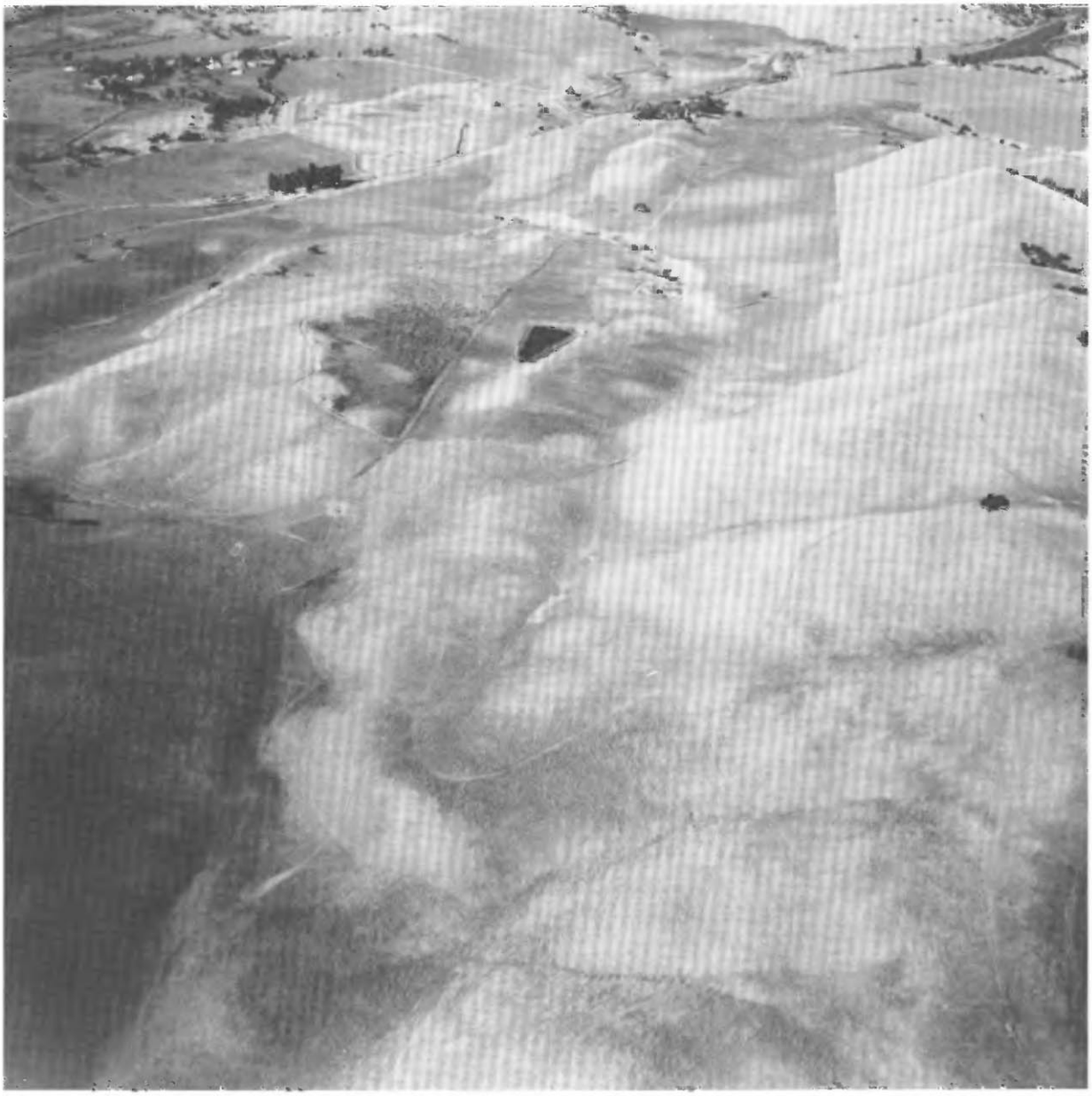

FIGURE 2.37.—Valleys and ponds mark trace of the Calaveras fault (first referred to at this location as the Paicines fault). View northwestward toward village of Paicines (top).

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FIGURE 2.38.—The Elsinore fault just north of the United States-Mexican border is not as conspicuously displayed as the San Andreas and San Jacinto faults; however, this fault markedly influences the topography. Here, a major valley is eroded in the general fault zone, but traces of late Quaternary displacement are not as obvious as farther northwest along fault. U.S. Geological Survey photograph, taken October 13, 1956.

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FIGURE 2.39.—Imperial fault south of the Salton Sea, southern California. During the Imperial Valley earthquake of October 15, 1979, surface rupture occurred along fault trace (black-and-white line). Bull's-eye denotes epicenter. From U.S. Geological Survey (1982, cover). U.S. Air Force photograph, taken July 17, 1968.

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FIGURE 2.40.—Linear ridges and undrained sags mark trace of the Garlock fault along north edge of the Mojave Desert. Note left-lateral offset of gulches. View southwestward.

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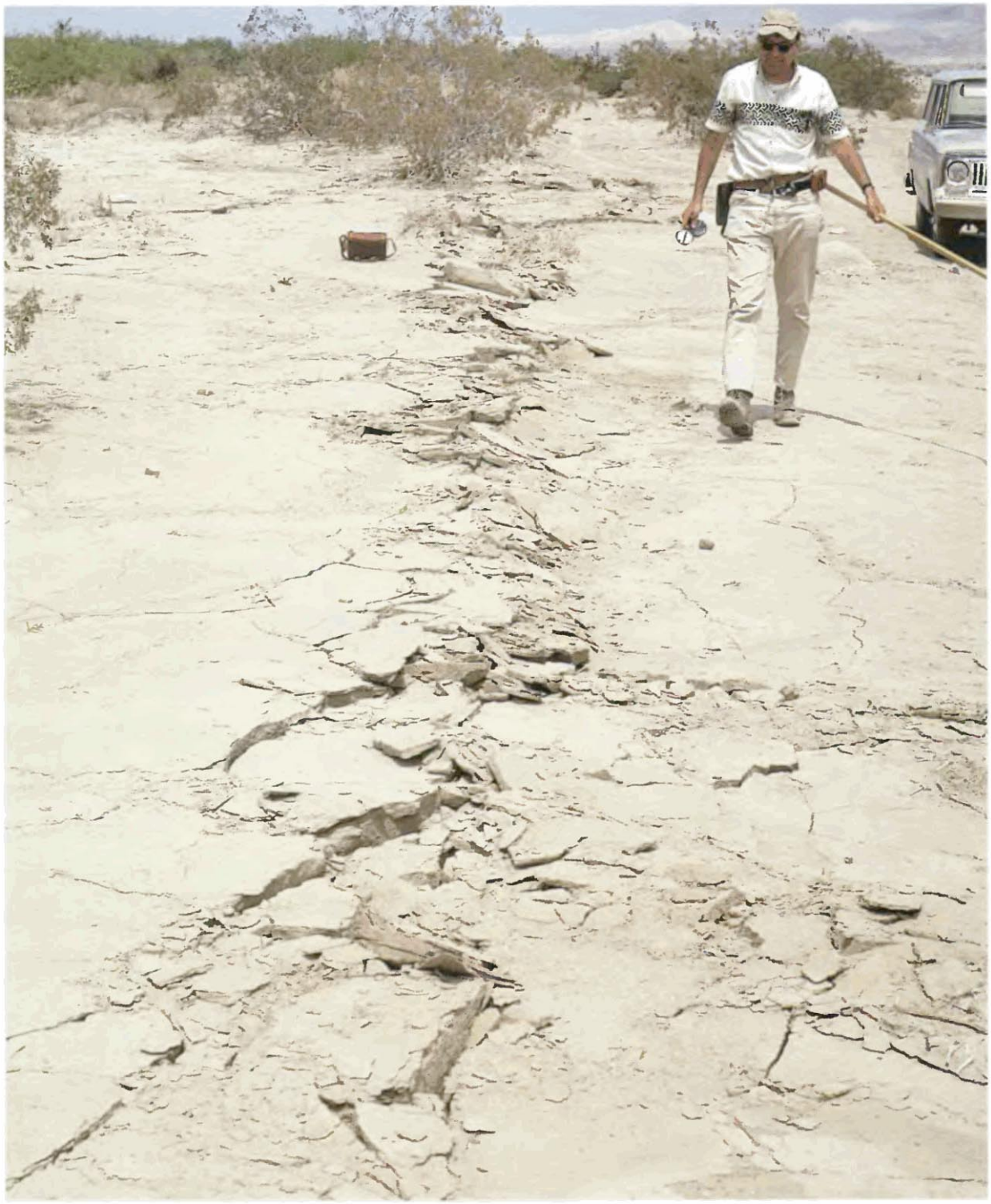

FIGURE 2.41.—Right-lateral slip accompanying an earthquake creates characteristic echelon fractures and zones of compression that produce a "mole track." This mole track formed along the Coyote Creek fault during the Borrego Mountain earthquake of 1968.

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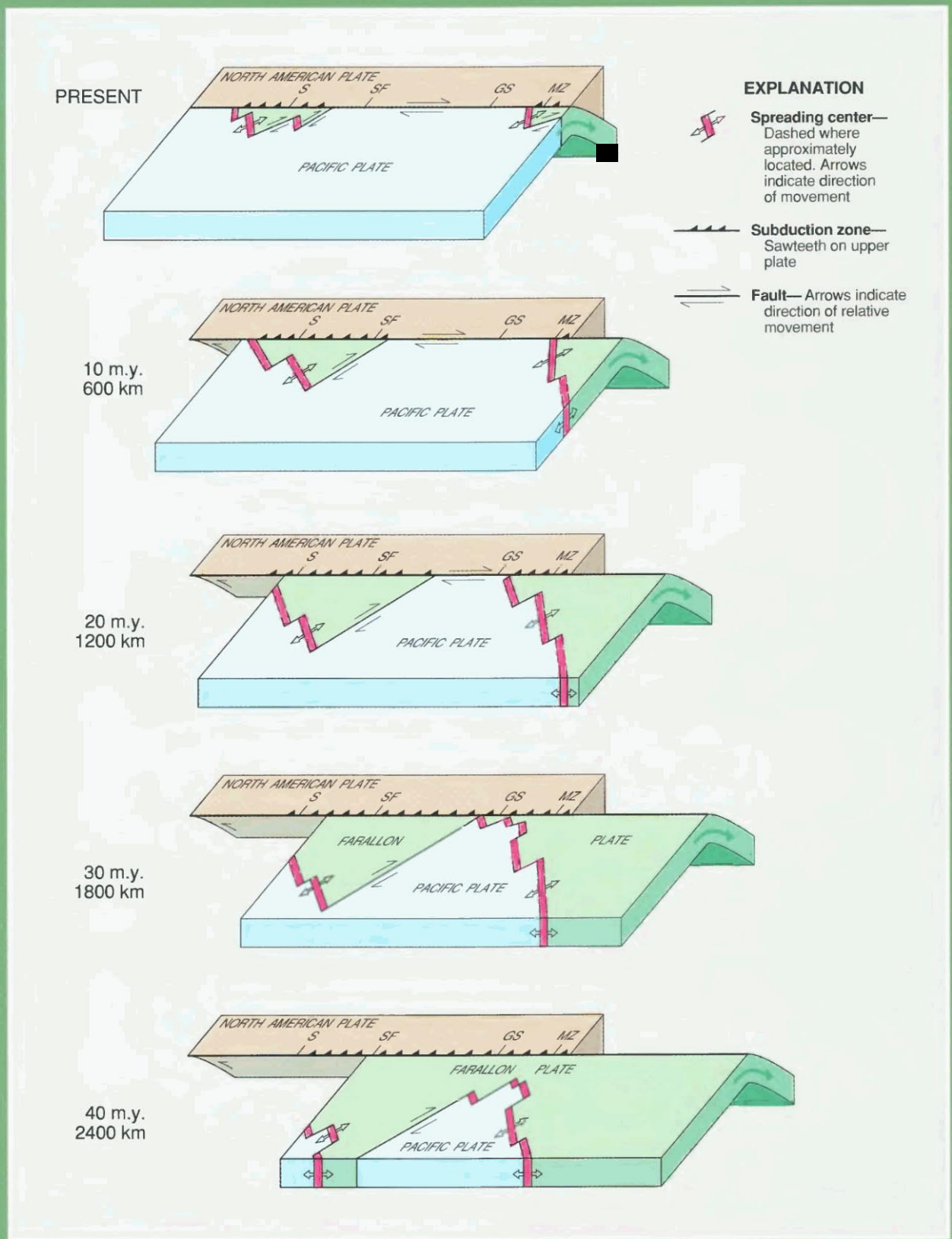

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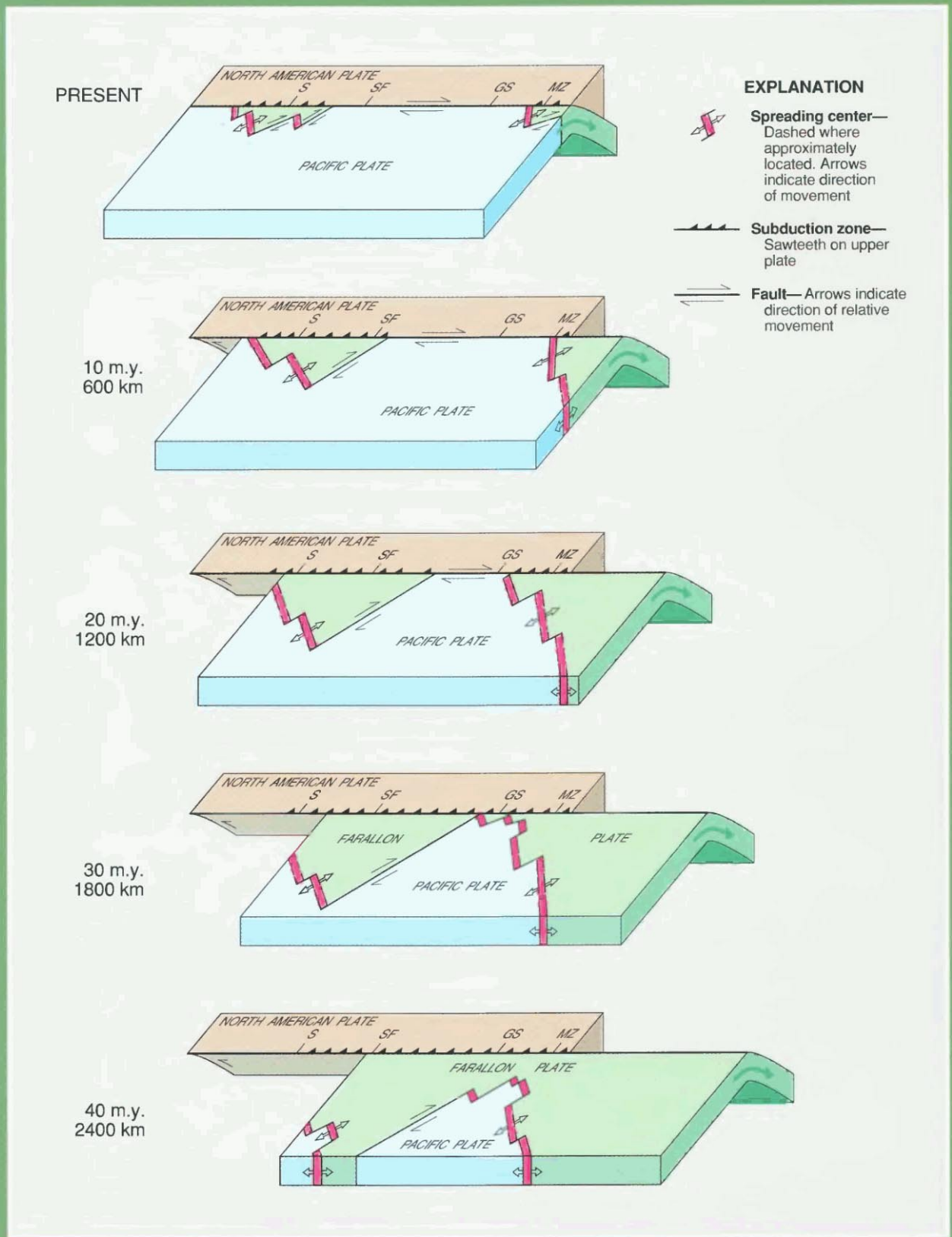

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The San Andreas fault is a transform fault along the boundary between the Pacific and North American plates. Bedrock along the fault includes various lithologic units that range in age from Precambrian to Tertiary and younger. Some bedrock units that can be matched across the fault suggest strike-slip displacement of as much as 560 km.

3. GEOLOGY AND PLATE-TECTONIC DEVELOPMENT

By WILLIAM P. IRWIN

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INTRODUCTION

The great scar across the land of California, extending from the Gulf of California to Point Arena on the north coast, was recognized as a major fault during early geologic study of the San Francisco peninsula; it was named for San Andreas Valley, which lies a few kilometers south of San Francisco. Interest in the San Andreas fault was heightened as a result of movement on the fault, in some places as much as 5 m of strike-slip displacement, that occurred during the great San Francisco earthquake of 1906. Because of this earthquake, a concerted study was carried out by several leading geologists of that time (Lawson, 1908) that dramatically increased our knowledge of the regional extent and general features of the fault. Much controversy ensued during the following decades as to the time of origin of the fault, the magnitude of cumulative displacement along it, and, indeed, even whether the displacement might be principally dip slip rather than strike slip. An early proponent of substantial lateral movement on the San Andreas fault was Levi Noble (1927) of the U.S. Geological Survey, who suggested a 38-km right-lateral displacement based on the similarity of Tertiary strata on opposite sides of the San Andreas fault at Cajon Pass and Rock Creek (lat 34°26' N., long 117°50' W.). Substantial lateral offset of Quaternary terraces along the Mojave segment of the fault was recognized by R.E. Wallace (1949) while working on his Ph.D. thesis at the California Institute of Technology. He estimated a slip rate of 0.4 cm/yr, which he extrapolated to 120 km of right-lateral slip since mid-Tertiary time (approx 30 Ma). In 1953, a benchmark

◀ FIGURE 3.1.—Sequential diagrams showing interactions between the North American, Farallon, and Pacific plates, assuming a constant relative motion of 6 cm/yr parallel to the San Andreas fault (modified from Atwater, 1970). Position of the North American plate in each time frame is relative to those of the Farallon and Pacific plates rather than to outlines of diagram. Lengthening interface between the North American and Pacific plates, shown in three upper diagrams, represents the San Andreas transform fault. Captions for each step indicate amount of time and lateral movement necessary for the North American plate to reach its present position relative to the Pacific plate. GS, Guaymas; MZ, Mazatlán; S, Seattle; SF, San Francisco.

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paper by M.L. Hill and T.W. Dibblee, Jr., of the Richfield Oil Corp. cited various evidence for great right-lateral offset along the San Andreas fault and speculated that the total offset amounts to 560 km or more since Jurassic time.

During middle and late 1960's, a time of great ferment of concepts regarding the plate-tectonic development of the planet Earth, the foundation was laid for much of the present view of the tectonics of California and the San Andreas fault. A highly significant breakthrough to our understanding of the development of the fault system was the brilliantly simple construction by J. Tuzo Wilson (1965, fig. 9), who showed the San Andreas fault as a transform fault connecting two spreading oceanic ridges (figs. 3.1, 3.2). This view was soon modified by McKenzie and Morgan (1969) and Atwater (1970) to account for the effects of migrating triple junctions and for the timing, rates, and vectors of plate movement. Their plate-tectonic analysis of the San Andreas fault was based on calculations of plate motions between North America, Africa, India, Antarctica, and the Pacific, and many land-based geologists of the time would have agreed that it seemed "outrageous" to be "studying the San Andreas fault by using data that is no closer to California than 7,000 km" (Atwater and Molnar, 1973).

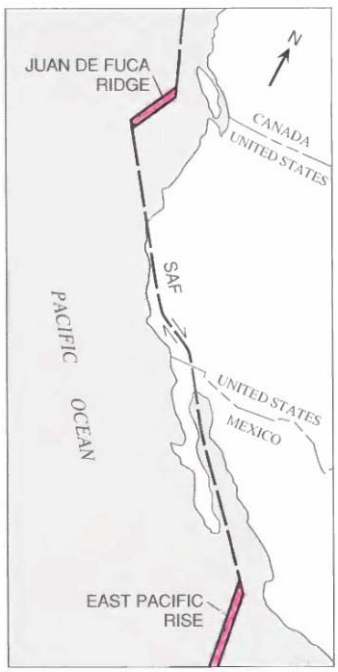

FIGURE 3.2.—Sketch map of part of the Pacific coast of North America, showing J. Tuzo Wilson's early idea of the San Andreas fault (SAF) as a right-lateral (arrows) transform fault connecting the termination of two spreading centers represented by the East Pacific Rise and the Juan de Fuca Ridge (modified from Wilson, 1965).

GEOLOGIC FORMATIONS

On its path through nearly the length of California, the San Andreas fault separates major crustal blocks (fig. 3.3). In much of northern and central California, the fault is a southeast-trending boundary between the Salinian block of granitic and metamorphic rocks on the west and the Franciscan assemblage and overlying strata of the Great Valley sequence on the east. In its southerly course the fault abruptly curves eastward to cut diagonally across the Transverse Ranges, and then splays into several auxiliary faults before the main strand terminates near the Gulf of California. In southern California the basement rocks cut by the San Andreas fault are mostly Precambrian and younger metamorphic and plutonic rocks, and the crustal blocks on either side of the fault generally do not show the distinctive lithologic contrast that is so striking in central and northern California.

FIGURE 3.3.—Geologic sketch map of California, showing distribution of principal basement rocks. Cenozoic cover not shown except for the Modoc Plateau, northeastern Sierra Nevada, Great Valley, and Santa Barbara-Ventura Basin. Based on U.S. Geological Survey (1966), Jennings and others (1977), and Ross (1984). Units: 1, Quaternary alluvium—shown only in Great Valley; 2, basement rocks concealed by thick Upper Cretaceous and Tertiary deposits in the Santa Barbara, Ventura, and Los Angeles Basins; 3, Cenozoic volcanic rocks of the Modoc Plateau; 4, Great Valley sequence—Lower Jurassic to Upper Cretaceous strata, including Coast Range ophiolite at base; 5, Franciscan assemblage of Lower Jurassic to Tertiary oceanic rocks; 6, Sierra Nevada batholith—dominantly Cretaceous granitic rocks; 7, Sierra Nevada metamorphic belt—early Paleozoic to Late Jurassic rocks, including fragments of ophiolites, island arcs, and melanges, intruded by Mesozoic plutons; 8, Klamath Mountains—early Paleozoic to Late Jurassic ophiolites, island arcs, and melanges, intruded by early Paleozoic to Cretaceous plutons; 9, Salinian block—dominantly Cretaceous plutons intruding metamorphic rocks of questionable age (Barrett Ridge slice [BRS], commonly shown as part of the Salinian block, is here shown as part of unit 11); 10, southern California batholith—dominantly Cretaceous plutons intruding sedimentary and volcanic rocks of Jurassic age and metamorphic rocks of mostly unknown age; 11, mainly Precambrian metamorphic and plutonic rocks, in part overlain by Paleozoic continental shelf deposits and intruded by Mesozoic plutons, locally underthrust in southwestern part of region by schist (similar in lithology to the Pelona Schist) of probable Cretaceous age.

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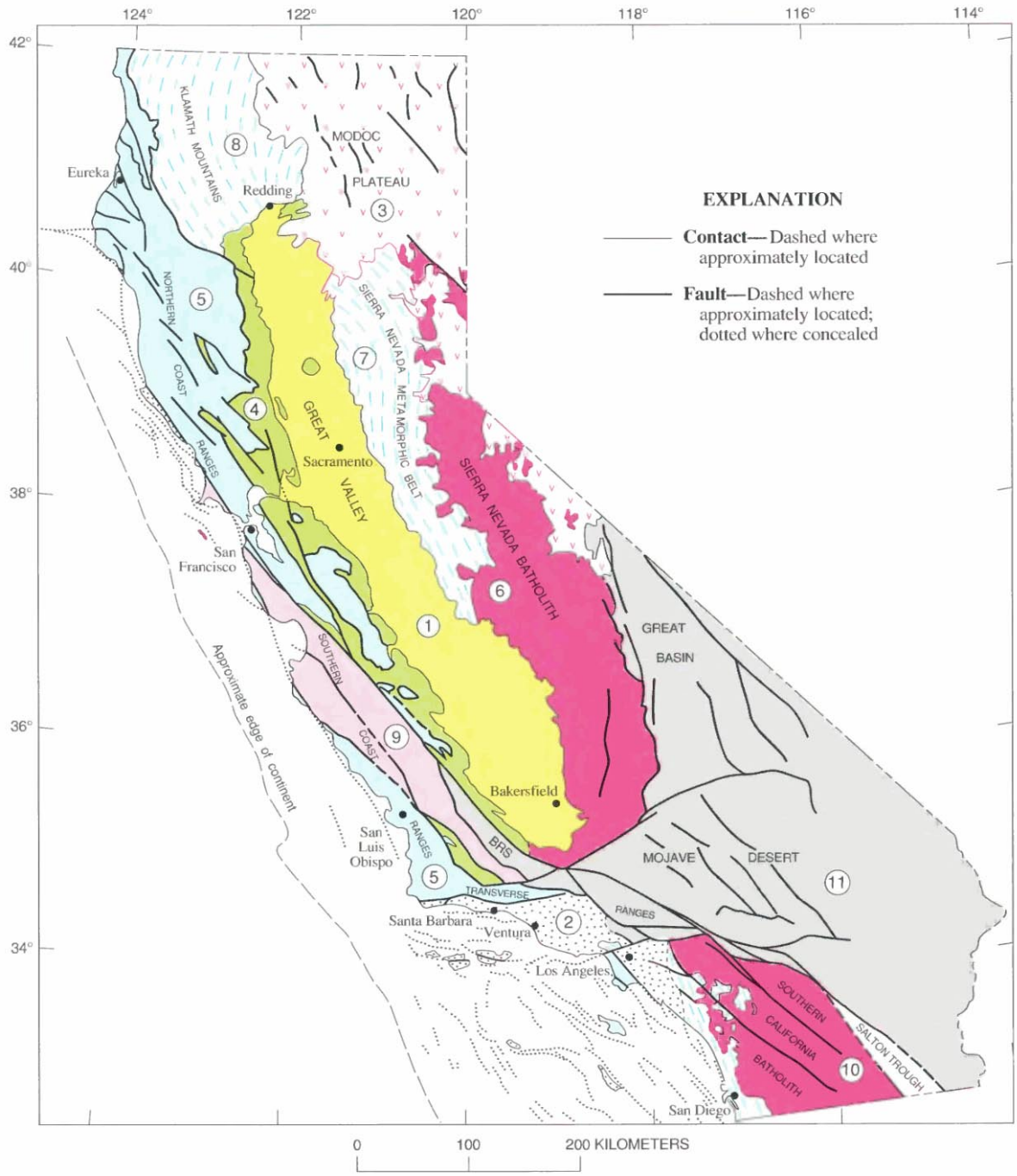
NORTHERN AND CENTRAL CALIFORNIA

FRANCISCAN ROCKS

Franciscan rocks form the east wall of the San Andreas fault for virtually its entire course through the Coast Ranges of central and northern California, although the Franciscan is concealed along some reaches of the fault by overlying rocks. The Franciscan is a heterogeneous assemblage that consists largely of dismembered sequences of graywacke, shale, and lesser amounts of mafic volcanic rocks, thin-bedded chert, and rare limestone.



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These rocks also occur with serpentinite and tectonic pods of blueschist in melange zones that are the locus of much shearing within the Franciscan and that generally separate blocks of the more coherent sequences. The sedimentary and volcanic Franciscan rocks were formed in a marine environment, as attested by the abundance of foraminifers in the limestone and by radiolarians in the chert. Most of these rocks are probably Late Jurassic and Cretaceous in age (Bailey and others, 1964), but some of the chert and associated volcanic rocks are as old as Early Jurassic (Pliensbachian) (Irwin and others, 1977; Blome and Irwin, 1983). In the northern Coast Ranges, some of the rocks assigned to the coastal belt of the Franciscan assemblage are as young as late Tertiary and are thought to have accreted to North America during post-middle Miocene time (McLaughlin and others, 1982). The age and origin of Franciscan melange is problematic. Mid-Cretaceous limestone in melange near Laytonville in the northern Coast Ranges, 225 km northwest of San Francisco, has a paleomagnetic inclination that indicates an origin several thousand kilometers to the south (Alvarez and others, 1980). Similarly, Franciscan pillow basalt about 45 km northwest of San Francisco is thought to have moved northward 19° of latitude (approx 2,000 km) from its site of origin (Grommé, 1984). These and other features indicate that some, possibly much, of the Franciscan has been transported great distances northward along the Pacific margin relative to a stable North America.

The Franciscan rocks are locally overlain structurally by the Coast Range ophiolite and the Great Valley sequence, and are separated from them by the Coast Range thrust (Bailey and others, 1970). The original extent of the Coast Range thrust is not clearly known because most of the ophiolite and Great Valley sequence that formed the upper plate of the thrust has been removed from the top of the Franciscan except in the general area of the Diablo antiform, which is marked by a line of windows from Mount Diablo to Parkfield, and along the west edge of the Great Valley (figs. 3.3, 3.4). A few small outliers of upper-plate rocks are present elsewhere east of the San Andreas fault as far north as Pillsbury Lake, 35 km east of Willits, and the Camp Meeker area, 17 km northeast of Bodega Head, and at several localities west of the Salinian block as far south as the Santa Ynez fault in the Transverse Ranges (see maps at front of book). Much of the serpentinite in Franciscan melange may well be sheared-in fragments of dismembered Coast Range ophiolite.

COAST RANGE OPHIOLITE

The Coast Range ophiolite represents oceanic crust on which much of the sedimentary rock of the Great Valley sequence was deposited. A complete ophiolite sequence consists of serpentinized harzburgite tectonite at the base, overlain by cumulate ultramafic and gabbroic rocks, passing upward into noncumulate gabbroic and related plutonic rocks, then into diabase dikes, and finally into pillow lavas. The Coast Range ophiolite, however, generally is highly sheared, dismembered, thinned, and locally missing, presumably as a result of faulting, at many places along the fault contact between Franciscan and Great Valley rocks. Only in a few places is a nearly complete lithologic sequence of Coast Range ophiolite preserved, and there the total stratigraphic thickness of the ophiolite is about 3 to 5 km (Hopson and others, 1981). Isotopic ages ranging from about 165 to 153 Ma (Hopson and others, 1981) indicate that the Coast Range ophiolite is Middle and Late Jurassic in age. Paleontologic and paleomagnetic evidence suggests that the Coast Range ophiolite formed in an equatorial setting and was transported great distances northward before being accreted to North America and overlain by the Great Valley sequence (Pessagno and others, 1984; Hopson and others, 1986; McLaughlin and others, 1988).

GREAT VALLEY SEQUENCE

The Great Valley sequence consists of interbedded marine mudstone, sandstone, and conglomerate that range from Late Jurassic to Cretaceous in age (Bailey and others, 1964). It crops out as thick, monotonously bedded sections of strata that generally are markedly less deformed and more coherent than sedimentary sections of the Franciscan and also have greater lateral continuity. Where most fully developed, such as along the west side of the northern Great Valley, the aggregate stratigraphic thickness of Great Valley sequence is at least 12 km. The strata normally lie depositionally on Coast Range ophiolite except where disrupted by faults, but at the north end and along the east side of the Great Valley they onlap the Nevadan and older basement terranes of the Klamath Mountains and Sierra Nevada. This enormous thickness of clastic detrital material probably represents submarine fans and turbidity deposits that formed as a result of rapid erosion of the ancestral Klamath Mountains and Sierra Nevada.

FIGURE 3.4.—Schematic block diagram of part of the Coast Ranges of California, showing gross structural relations between principal lithotectonic units cut by the San Andreas fault (modified from Irwin, 1977). The Coast Range ophiolite lies at base of the Great Valley sequence and is separated from underlying Franciscan rocks by the Coast Range thrust. Blueschist-facies metasedimentary and metavolcanic rocks that form border zone in the Franciscan immediately below the thrust are not shown. View southeastward along the San Andreas fault.

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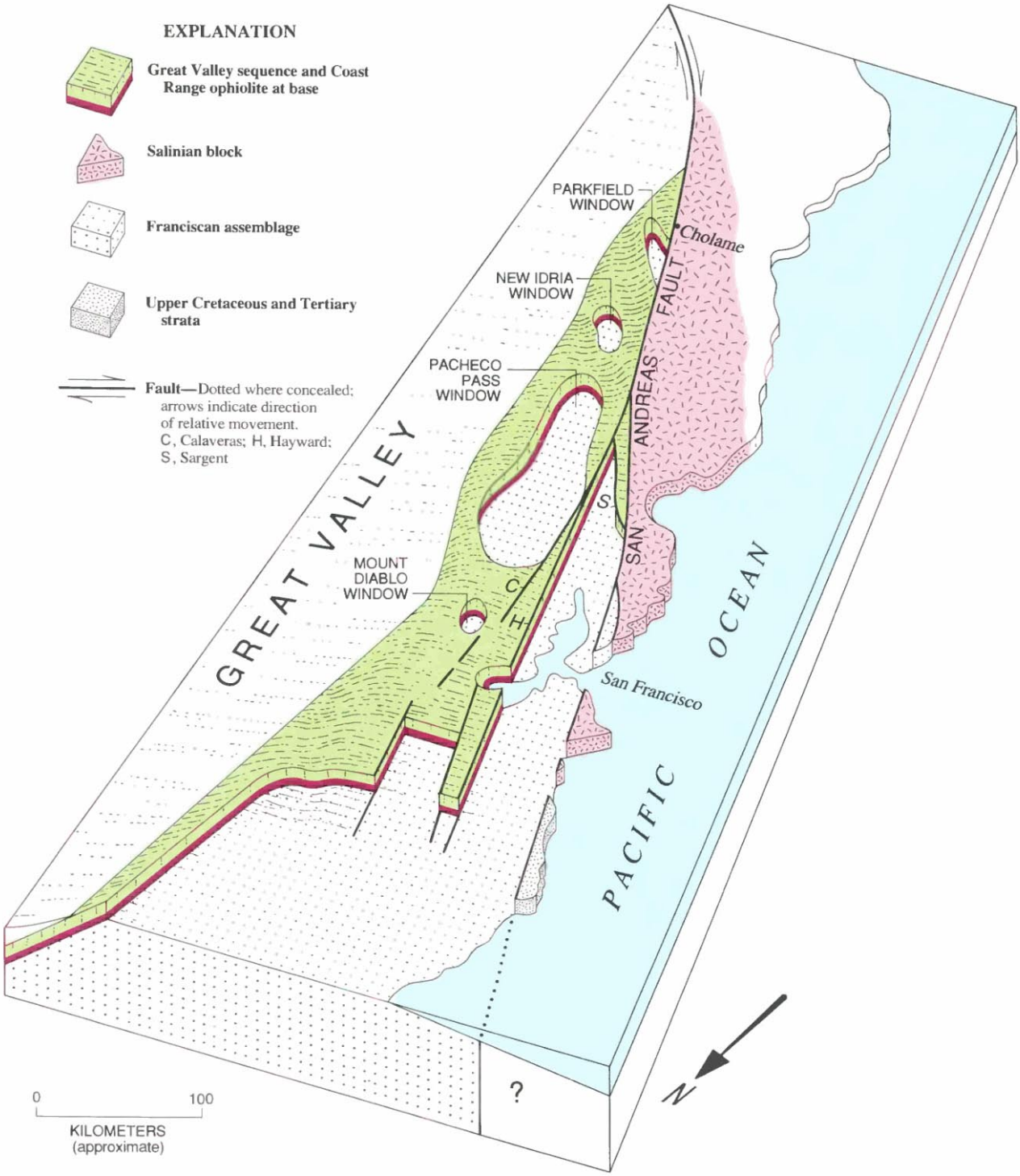
COAST RANGE THRUST

The upper plate of the Coast Range thrust, consisting of Great Valley sequence with Coast Range ophiolite at the base, is cut by the San Andreas fault only along the west side of the Diablo Range in central California. There, the upper plate of the Coast Range thrust forms a broad blanket over the Franciscan rocks except in



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several places along the length of the Diablo Range where windows, or piercement structures, in the upper plate expose Franciscan rocks of the lower plate (fig. 3.4): at Mount Diablo, Pacheco Pass, New Idria, and Parkfield. This deformed antiformal structure (Bailey and others, 1964) is truncated on the west by the Hayward and Calaveras faults in its northern part and by the San Andreas fault in its southern part, and narrows to the southeast as the San Andreas fault converges with the south end of the Great Valley. The ophiolitic rocks are generally thinned and highly discontinuous along the faults that bound the windows except for the New Idria window, which is occupied mostly by serpentinite. South of the Pacheco Pass window, the structure is complicated by a series of west-northwest-trending synforms that cross the axis of the Diablo Range antiform at a low angle, and by multiple strands of the San Andreas fault. In the Parkfield area, the western part of the antiform has been virtually destroyed by its proximity to the San Andreas fault. The Franciscan rocks of the Parkfield window, and the associated serpentinite and Great Valley sequence of the highly dissected upper plate, now are mostly elongate fault slices that form part of the San Andreas fault zone (see Dibblee, 1980).

Most of the serpentinite of the Coast Ranges of California is related to the ultramafic parts of the Coast Range ophiolite. Serpentinite is strikingly absent along the San Andreas fault north of San Francisco, a situation that reflects the absence of the upper plate of the Coast Range thrust in that area. Although many elongate fault-bounded bodies of serpentinized ultramafic rocks in the Coast Ranges traditionally have been mapped and described as part of the Franciscan, most are probably dismembered and dislocated parts of the Coast Range ophiolite or equivalent. Recognition that the ultramafic rocks in most places belong to the Coast Range ophiolite rather than to the Franciscan assemblage is important to a tectonic analysis of the region. The common presence and possible seismotectonic significance of serpentinite along creeping segments of the San Andreas and related faults were described by Allen (1968) and Irwin and Barnes (1975).

SALINIAN BLOCK

The west wall of the San Andreas fault consists mainly of rocks of the Salinian block from the Transverse Ranges northward to Bodega Head. At the latitude of the San Francisco peninsula, the Salinian block is separated from the San Andreas fault by a narrow fault slice of Franciscan rocks (fig. 3.3). Northward, from just beyond Bodega Head to Point Arena, the rocks that crop out along the fault are chiefly Upper Cretaceous and Tertiary sedimentary strata, but because of the presence of a relatively small exposure of spilitic volcanic rocks that may be Franciscan, it is questionable whether these sedimentary rocks overlie granitic and metamorphic rocks of the Salinian block or whether they are separated from the Salinian block by another fault just off shore (Wentworth, 1968). The north end of the Salinian block off shore is thought to be at about the latitude of Point Arena (see McCulloch, 1987). At Point Delgada (see maps at front of book), which many workers consider to be the location of the northernmost onland trace of the San Andreas fault, the rocks on both sides of the fault are Franciscan.

The Salinian block is composite, consisting of central, western, and northern belts, and commonly is considered to include the Barrett Ridge slice (fig. 3.3; Ross, 1984). The basement rocks of the Barrett Ridge slice, though poorly exposed, are thought likely to be a northward continuation of the rocks of the San Gabriel Mountain area because they include similar-appearing metamorphic and granitic rocks, as well as schist similar to the Pelona Schist, along a possible exposure of the Vincent(?) thrust (Ross, 1984). The principal formations of these central, western, and northern belts are granitic and metamorphic rocks, locally overlain by Upper Cretaceous and younger strata. The metamorphic rocks, which commonly are moderate- to high-grade gneiss, granofels, impure quartzite, and minor schist and marble, probably represent a metamorphosed thin-bedded sequence of siltstone and sandstone, with lesser amounts of shaly, marly, and calcareous strata (Ross, 1978). The metamorphic rocks of the western belt are higher in metamorphic grade than those of the central and northern belts. The stratigraphic age of the protoliths of the metamorphic rocks is not known. The plutonic rocks are mostly granite and tonalite, but they range in composition to gabbro. U-Pb-isotopic measurements on zircon in the plutonic rocks indicate that plutonic activity began about 120–105 Ma in the northwestern part of the Salinian block and migrated southeastward over a period of 40 m.y., with the youngest plutons intruding the Barrett Ridge slice about 80–75 Ma (Mattinson and James, 1985).

The basement rocks of much of the Salinian block do not clearly differ from those of the Sierra Nevada, and so many workers have speculated that the Salinian block may be a displaced part of the Sierra Nevada (for example King, 1959; Page, 1981). According to Ross (1984), who compared the two terranes in considerable detail, the similarities are so great that strong data would be required to support an alternative origin. Paleomagnetic data, however, indicate that the Salinian block may have been displaced 2,500 km northward since Cretaceous time (Champion and others, 1984) and that it may have originated near the latitude of Central America or Mexico in the axial part of the Cordilleran Cretaceous plutonic arc (Page, 1982).

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DISPLACEMENT OF PRE-QUATERNARY ROCKS BY THE SAN ANDREAS FAULT

The largest offset on the San Andreas fault postulated by Hill and Dibblee (1953) is 560 km, on the basis of the speculation that a contact between Sierran basement and Franciscan rocks near the south end of the Great Valley was cut by the fault and that the contact on the west side of the fault was offset northward to a point at sea north of Point Arena. This concept, however, is questionable not only because of the uncertain correlation of the Salinian block with rocks of the Sierra Nevada but also because the northernmost exposure of granitic rocks along the west side of the fault is at Bodega Head, about 90 km southeast of Point Arena, and neither the presence nor the type of a contact between Sierran-type basement and Franciscan rocks is known off shore north of Point Arena (see McCulloch, 1987). Nor is the significance clearly known of the possibly substantial lateral offset along the San Gregorio fault, which intersects the San Andreas at a low angle just west of the entrance to the San Francisco Bay. However, Upper Cretaceous strata that crop out near Gualala, on the west side of the San Andreas fault between Bodega Head and Point Arena, were thought by Ross and others (1973) also to have been offset 560 km, consistent with Hill and Dibblee's concept. The strata near Gualala include quartz-plagioclase arkose and a conglomerate characterized by unusual quartz-bearing mafic clasts, including volcanic rocks, diabase, and diorite to gabbro. Paleocurrent features indicate a source to the east of the fault. The source of the unusual gabbroic clasts is thought to be the Eagle Rest Peak area in the San Emigdio Mountains, just east of the San Andreas fault in the Transverse Ranges (fig. 3.5). This area may also be the source of relatively small fault slivers of similar mafic rocks that now lie 160 km northwest along the San Andreas fault at Gold Hill and 320 km northwest at Logan (Ross and others, 1973).

Other features that suggested substantial right-lateral offset to Hill and Dibblee (1953) include (1) the south limit of Cretaceous strata near Fort Ross, offset 512 km from

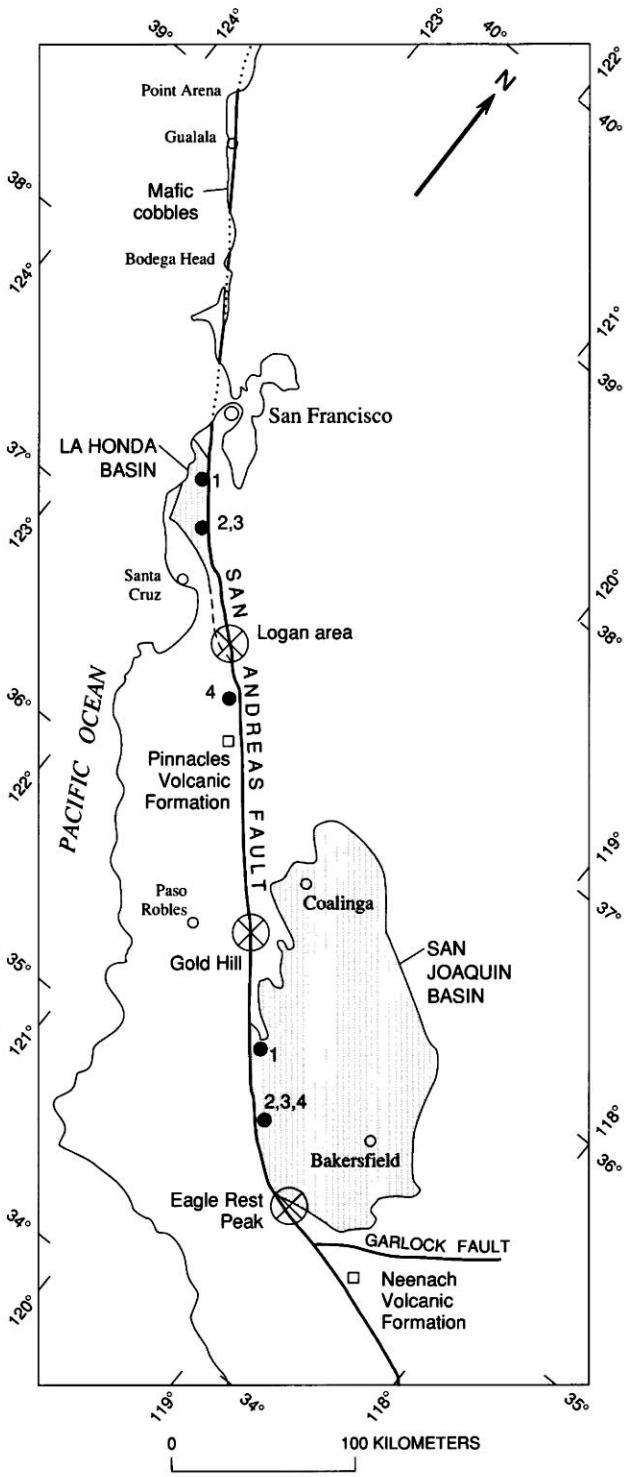

FIGURE 3.5.—Locations of some pre-Quaternary features offset by the San Andreas fault in the California Coast Ranges. The La Honda Basin is an offset segment of the San Joaquin sedimentary basin (Stanley, 1987); boundary dashed where approximately located. Circled x's, bedrock exposures of unusual quartz-bearing mafic rocks at Logan, Gold Hill, and Eagle Rest Peak (Ross and others, 1973); squares, locations of the Pinnacles and Neenach Volcanic Formations (see fig. 3.6) (Matthews, 1976). Numbered dots: 1, Butano Sandstone and Point of Rocks Sandstone Member (of Kreyenhagen Formation), representing offset parts of an Eocene deep-sea fan (Clarke and Nilsen, 1973); 2, steeply southwest-dipping slopes of the San Joaquin and La Honda Basins during late Zemorrian time (Stanley, 1987); 3, deepest parts of the San Joaquin and La Honda Basins adjacent to the San Andreas fault during Saucesian time (Stanley, 1987); 4, unusual clasts in upper Miocene conglomerate in the Temblor Range east of fault and their postulated source area in the Gabilan Range west of fault (Huffman, 1972).

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their south limit in the Temblor Range; (2) Eocene formations in the Santa Cruz Mountains, offset 360 km from lithologically and faunally similar formations in the Temblor-San Emigdio Mountains; (3) sequences of lower Miocene volcanic rocks, red beds, and Oligocene and lower Miocene marine deposits of the Gabilan Range, offset 280 km from similar sequences in the San Emigdio Mountains; (4) a facies transition from marine to continental middle and upper Miocene beds of the Carrizo Plain, offset 104 km from a similar transition projected from the south end of the Great Valley; and (5) 16 km of offset based on the juxtaposition of two facies of Pleistocene gravel south of the Temblor Range.

Offset of the Eocene formations was described in more detail by Clarke and Nilsen (1973), who considered the lower to upper Eocene sedimentary sequences to represent parts of a single deep-sea fan that have been offset 305 km along the San Andreas fault. These sequences are (1) the Twobar Shale Member of the San Lorenzo Formation and the Butano Sandstone, exposed in the Santa Cruz Mountains on the west side of the fault; and (2) the shale member and Point of Rocks Sandstone Member of the Kreyenhagen Formation, exposed along the southwest boundary of the Great Valley on the east side of the fault (fig. 3.5). Both sandstone units, which consist chiefly of detritus from the Salinian block, are thought to have been deposited as a submarine fan on the west side of a deep, northwest-trending offshore basin. The Eocene fan deposits on the east side of the fault are in a structurally complex area at the south end of the Diablo antiform. If they overlie Franciscan basement there and Salinian basement on the west side of the fault, they indicate that the Franciscan and Salinian basements had already been juxtaposed by Eocene time when the fan was deposited, as noted by Page and Engebretson (1984).

The strongest evidence for measuring the large amount of right-lateral displacement along the trace of the San Andreas fault through the Coast Ranges may be the correlation of the Pinnacles and Neenach Volcanic Formations (Matthews, 1976), which are exposed on opposite sides of the fault about 315 km apart (fig. 3.5). The Pinnacles Volcanic Formation is in the central Coast Ranges, on the west side of the Chalone fault, a parallel strand that is several kilometers west of the San Andreas. The Neenach Volcanic Formation is in the Mojave Desert, adjacent to the San Andreas fault on the northeast side, about 20 km southeast of its intersection with the Garlock fault. The volcanic rocks at both exposures rest on granitic basement rocks that are petrographically and chemically similar (Ross, 1984). As described by Matthews (1976), the volcanic rocks form stratigraphic sections that are remarkably similar in composition, lithologic sequence, and age; they consist of calc-alkaline andesite, dacite, and rhyolite flows interbedded with pyroclastic and volcaniclastic rocks (fig. 3.6). K-Ar-isotopic analyses of the volcanic rocks indicate an early Miocene age (23.5 Ma; Turner, 1970). The similarity of the 315-km offset of the volcanic formations and the 305-km offset ascribed to the previously mentioned Eocene fan deposits suggests that little movement occurred along that section of the San Andreas fault during intervening Oligocene time (Clarke and Nilsen, 1973).

Paleobathymetric contour maps of middle Tertiary (late Oligocene to early Miocene) topographic features of the San Joaquin sedimentary basin match similar features across the fault in the La Honda Basin (fig. 3.5), according to Stanley (1987). The paleobathymetry is based on studies of the distribution of fossil foraminifers. In both basins, (1) the southwestern margins were bounded by shelf areas and steep north-facing slopes, (2) maximum water depth was about 2,000 m, (3) the deepest part was truncated by the San Andreas fault, and (4) the paleobathymetric contours generally trend at large angles to the fault and are truncated by it. These features indicate a post-late Zemorrian (late Oligocene to early Miocene) displacement of 325 to 330 km and a post-Saucesian (early Miocene) displacement of 320 to 325 km.

Large offset along the San Andreas fault is also indicated by an anomalous distribution of upper Miocene sedimentary deposits that occur on both sides of the fault for more than 300 km in the central Coast Ranges. According to Huffman (1972), the clast composition of upper Miocene sedimentary rocks of the Temblor Range lying east of the fault in the southern Coast Ranges indicates that they were deposited adjacent to the Gabilan Range, which lies to the northwest on the opposite side of the fault, and that they subsequently have been displaced approximately 240 km (fig. 3.5).

The various aforementioned features that have been used to measure lateral offsets along the San Andreas fault are all situated near the present-day trace of the fault. They do not measure the substantial displacements that probably occurred along presently inactive older faults of the system, nor do they measure the large lateral movement (described below) that is thought to have occurred along the interface between continental and oceanic crust during the early plate-tectonic development of the fault system.

RELATION OF GEOLOGIC STRUCTURE TO SEISMIC BEHAVIOR

From the preceding descriptions, the San Andreas fault evidently cuts through many different types of rocks and regional structures along its traverse from the Transverse Ranges to the Mendocino triple junction, and the patterns of seismicity differ strikingly along various

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segments of the fault. These differences in seismic behavior coincide so closely with certain geologic situations along the San Andreas fault in central California as to suggest a causal relation.

Certain segments of the San Andreas fault in central California are characterized by frequent small-magnitude earthquakes and aseismic slippage (creep); creep also occurs along the San Andreas fault in Coachella Valley, the Imperial fault, and the Superstition Hills fault. Other segments, said to be "locked," are characterized by infrequent earthquakes, some of which have been historically of large magnitude, and by an absence of creep. The occurrence of creep has been described by Allen (1968), Wallace (1970), Nason and Tocher (1970), and Thatcher (see chap. 7), among others. The creep is mainly on faults along the west side of the Diablo antiform. The creeping segment of the San Andreas fault extends from Cholame to near San Juan Bautista. Other faults known to creep include segments of the Calaveras, Hayward, Concord, Green Valley, and Sargent faults (fig. 3.7). The locked segments of the San Andreas fault in central California extend northward from near San Juan Bautista and southward from Cholame. Though of no recognized significance, the creeping segment of the San Andreas fault terminates near the north end of the Barrett Ridge slice of the Salinian block.

The creeping segments in central California occur where the faults regionally cut the upper plate of the Coast Range thrust (figs. 3.4, 3.7; Irwin and Barnes, 1975). This position accounts for the common presence of serpentinite along the creeping segments of the San Andreas fault, because the serpentiniferous Coast Range ophiolite in the upper plate of the thrust is at the fault interface along these segments. The lower-plate Franciscan rocks form a geochemical province characterized by carbon dioxide-rich springs. Where the upper plate of the thrust is present, it may act as a hydraulic cap that helps to maintain high pore pressure caused by carbon dioxide in the underlying Franciscan rocks, and to direct fluid flow into the fault (Irwin and Barnes, 1975). The importance of pore pressure in relation to creep is its ability to reduce the frictional strength of rocks by lowering the effective confining pressure, as demonstrated by Byerlee and Brace (1972). The tectonic relations between carbon dioxide springs and seismicity were described by Irwin and Barnes (1980).

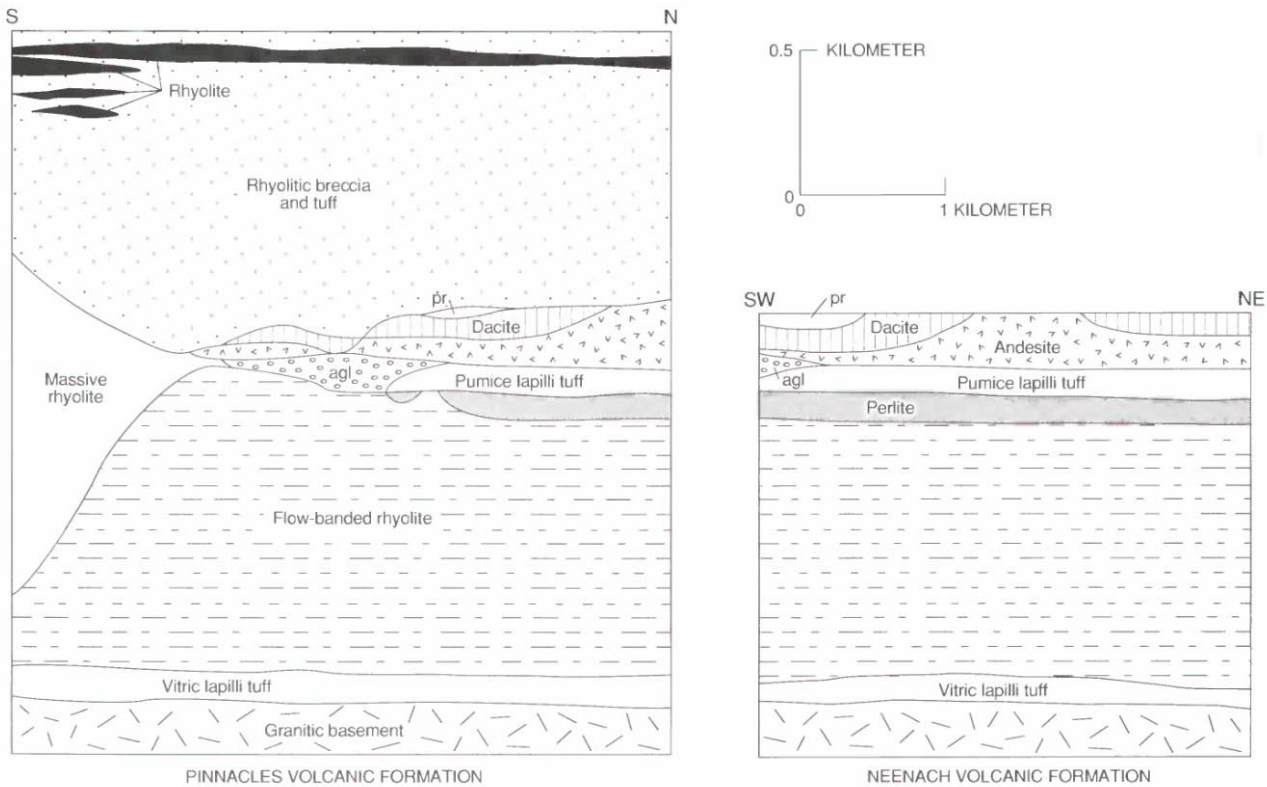

FIGURE 3.6.—Idealized cross sections showing stratigraphic and lithologic similarity of the Neenach Volcanic Formation, on northeast side of the San Andreas fault in southern California, to lower half of northern part of the Pinnacles Volcanic Formation several kilometers west of fault in central California (modified from Matthews, 1976) (see fig. 3.5 for locations). agl, agglomerate; pr, porphyritic rhyolite.

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SOUTHERN CALIFORNIA

TRANSVERSE RANGES AND THE SALTON TROUGH

Where the San Andreas fault bends eastward, near the south end of the Great Valley, it forms the boundary between the southern "tail" of the Sierra Nevada and rocks of the Transverse Ranges (fig. 3.3). Continuing southeastward along the Transverse Ranges, the fault trends along the north slope of the San Gabriel Mountains and the edge of the Mojave Desert for about 100 km, and then cuts diagonally between the San Gabriel and San Bernardino Mountains, where a major strand (San Jacinto fault) splits off to the south. The rocks traversed by the San Andreas fault in the Transverse Ranges are mainly Mesozoic plutons and their Precambrian metamorphic and plutonic host rocks.

South of the Transverse Ranges, the bedrock along the fault is concealed by Quaternary deposits of the Salton Trough for a length of more than 200 km. The Salton Trough, which includes the Coachella and Imperial Valleys, widens toward the southeast, and the number of faults and complexity of the zone increase. The east wall of the trough is at the San Andreas fault, where it consists of Precambrian rocks and Mesozoic plutons and of schists like those exposed in the Orocopia and Chocolate Mountains (fig. 3.8). The west wall consists of Cretaceous plutonic rocks of the Southern California batholith and their metamorphic host rocks, similar to rocks exposed in the nearby San Jacinto Mountains. As shown by Fuis and others (1982), the trough is a gap in the crystalline basement that is filled with Quaternary and older Cenozoic sedimentary rocks. The gap increases irregularly in width from 20 km at the north end of the Salton Sea to 60 km at the United States-Mexican border. The enormous thickness of the sedimentary fill is indicated by a drill hole that bottoms in Pleistocene(?) sedimentary rocks at a depth of about 4 km (Muffler and Doe, 1968). Seismic-refraction studies show an interface with "basement" rocks at a depth of 5 to 6 km, and the "basement" rocks below the 5- to 6-km-deep interface are thought actually to be metamorphosed Cenozoic fill (Fuis and others, 1982). Near the south end of the Salton Sea, the San Andreas appears to terminate as a transform fault at a spreading center, or pullapart zone, that is the most northerly in a series of spreading centers distributed along the length of the Gulf of California which form part of the East Pacific Rift. The proximity of this pullapart zone accounts for the abundant young volcanic and geothermal features in the area (Elders and others, 1972).

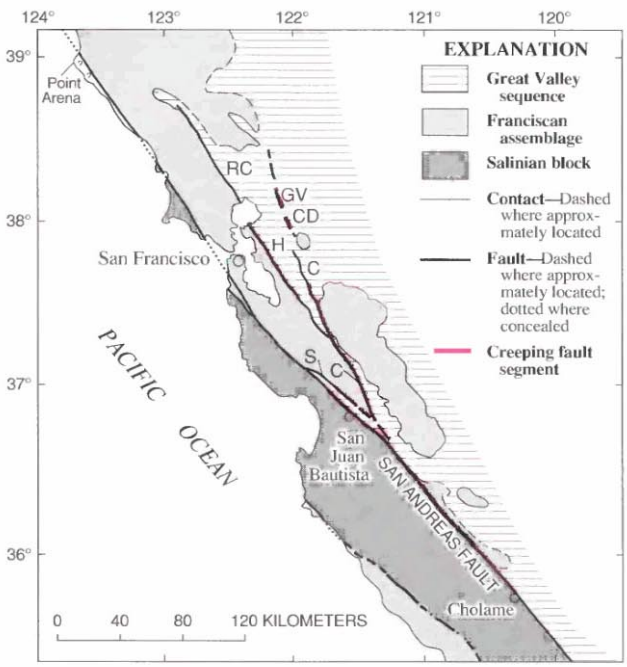

FIGURE 3.7.—Known creeping segments of the San Andreas and related faults in central and northern California. Data from Nason (1973), Frizzell and Brown (1976), Prescott and Burford (1976), Burford and Sharp (1982), and Harsh and Burford (1982). Faults: C, Calaveras; CD, Concord; GV, Green Valley; H, Hayward; RC, Rodgers Creek; S, Sargent. Compare creeping segments with concentrations of small earthquakes shown in figures 5.4 and 5.5.

The Precambrian rocks and associated Mesozoic plutons that constitute much of the crystalline basement cut by the San Andreas in southern California are locally seen to lie in thrust-fault contact on relatively younger metamorphic rocks. In the San Gabriel Mountains, on the southwest side of the San Andreas fault, the principal country rocks are divided into two plates by the Vincent thrust (lat 34°19' N., long 117°45' W.). As described by Ehlig (1981), the upper plate of this thrust is a Precambrian gneiss-amphibolite-granite complex (U-Pb age, approx 1,700 Ma; Silver, 1966) intruded by a Precambrian anorthosite-syenite-gabbro complex (U-Pb age, 1,220 Ma; Silver, 1971), all of which are intruded by the Late Triassic Lowe Granodiorite (U-Pb age, 220 Ma; Silver, 1971), by mid-Mesozoic rhyolitic to basaltic dikes, and, finally, by granitic plutons of probable Late Cretaceous age (U-Pb age, 80 Ma; Carter and Silver, 1971). The oldest rocks in the upper plate are thought to be a remnant of a Precambrian craton. Northeast of the fault, in the Mojave Desert and San Bernardino Mountains, some Precambrian rocks are unconformably overlain by lower Paleozoic miogeoclinal strata that are thought to represent an essentially autochthonous part of the North American craton (Burchfiel and Davis, 1981; Ehlig, 1981).

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The lower plate of the Vincent thrust consists of the Pelona Schist, which is largely a sedimentary section of arkosic sandstone, siltstone, and shale that has been metamorphosed to white mica-quartz-albite schist and locally includes metavolcanic rocks, metachert, marble, and serpentinite (Ehlig, 1981). The section in the San Gabriel Mountains has an exposed thickness of 3.5 km. The metamorphism decreases downward, away from the fault, and so sedimentary structures, including graded bedding, are well preserved in the lowest 1 km of section. This "upside down" metamorphism and other features indicate that the metamorphism of the lower-plate rocks occurred during thrusting. Pelona-type schist also occurs beneath Precambrian rocks of the Barrett Ridge slice west of the Tejon Pass and crops out in places along the Garlock fault (fig. 3.9). On the northeast side of the San Andreas fault in the Orocopia-Chocolate Mountains area, just east of the Salton Sea, the schist, there known as the Orocopia Schist, lies below the Orocopia thrust. Scattered exposures of Pelona-type schist and the Vincent-Orocopia thrust continue into southwesternmost Arizona (Haxel and Dillon, 1978).

The protoliths of the Pelona-type schist are thought to be deep-marine sedimentary rocks deposited on oceanic crust, possibly representing mostly the distal parts of turbidite fans. They probably were Jurassic or Cretaceous in age and are thought to have been metamorphosed by the thrusting that probably occurred no later than Late Cretaceous time (Haxel and others, 1985). The tectonics of the Pelona and Orocopia Schists is controversial. The Vincent-Orocopia thrust may have dipped southwest, and the Precambrian and other rocks of the upper plate been thrust northeastward over backarc-basin protoliths of the Pelona and Orocopia Schists (Haxel and Dillon, 1978). Conversely, the thrust relation may represent a gently north-northeast dipping subduction zone in which the protoliths of the schists were trench deposits similar to the Franciscan rocks and were thrust north-northeastward under the sialic North American plate (Burchfiel and Davis, 1981; Crowell, 1981). The Pelona-type schist is reminiscent of the Franciscan-derived South Fork Mountain Schist and related semischists of northern California that form a narrow, virtually continuous selvage for hundreds of kilometers along the west edge of the Klamath Mountains and the west side of the Great Valley, where they form the lower plate of the Coast Range thrust (Blake and others, 1967).

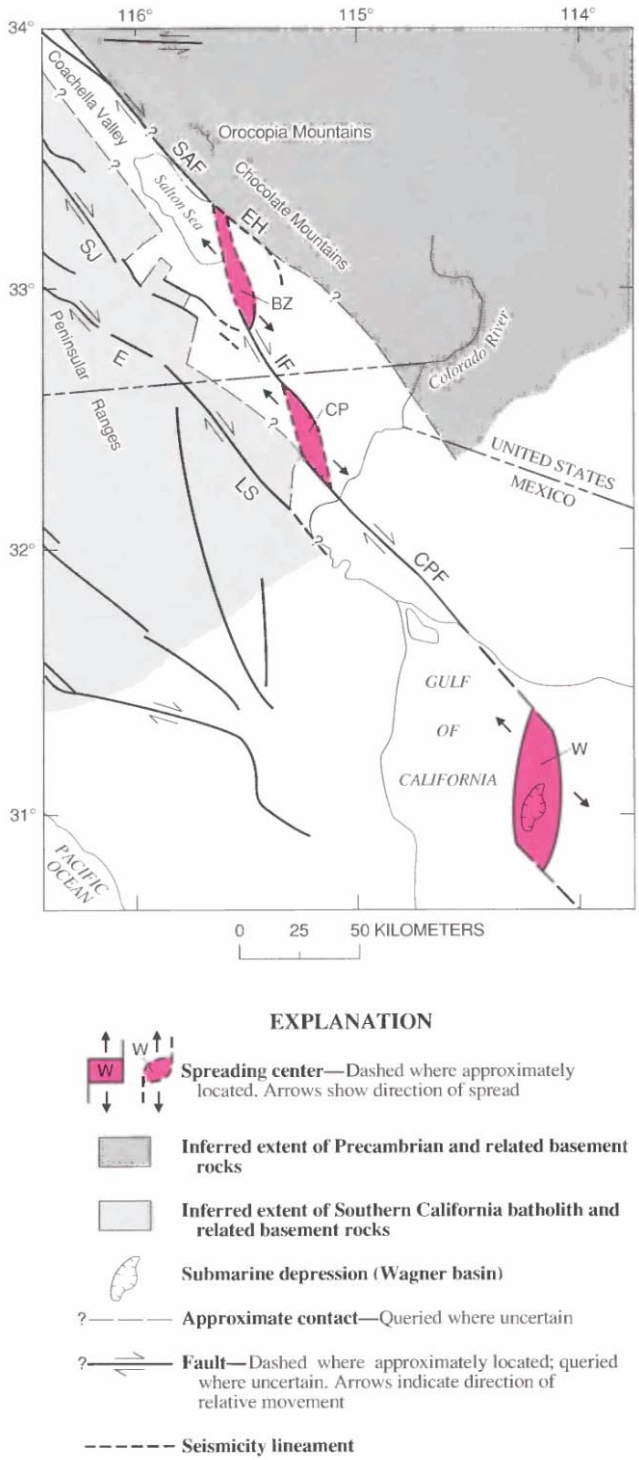

FIGURE 3.8.—Salton Trough and north end of the Gulf of California, showing major spreading centers and termination of the San Andreas fault (modified from Fuis and others, 1982). Spreading centers: BZ, Brawley seismic zone; CP, Cerro Prieto geothermal area; W, Wagner Basin. Major transform faults: CPF, Cerro Prieto; IF, Imperial; SAF, San Andreas. Other major faults: E, Elsinore; EH, East Highland Canal seismicity lineament; LS, Laguna Salada; SJ, San Jacinto.

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DISPLACEMENT OF BASEMENT ROCKS BY THE SAN ANDREAS FAULT

The distribution of the Pelona-type schist (fig. 3.9) has played an important role in many attempts to measure the slip on the San Andreas fault in southern California. In their classic report, Hill and Dibblee (1953) recognized the similarity of the Pelona Schist of the San Gabriel Mountains area to the Orocopia Schist east of the Salton Sea and postulated that these schists are offset 257 km from one another by the San Andreas fault. Crowell (1962) noted that the Precambrian rocks and Pelona-type schist of the Tejon area are separated from those of the San Gabriel Mountains area by the San Gabriel fault and that the Tejon, San Gabriel Mountains (Soledad), and Orocopia Mountains areas contain not only similar Precambrian rocks and Pelona-type schist but also similar Oligocene and other Tertiary strata. The similar lithologies and geologic histories of the rocks of these three areas indicated to him that these rocks once formed an east-west-trending belt which has been segmented and displaced by right-lateral slip of approximately 50 km on the San Gabriel fault and 210 km on the San Andreas fault. However, the validity of the concept that the Tertiary rocks of the San Gabriel (Soledad) and Orocopia Mountains areas once were parts of a single basin was questioned by Spittler and Arthur (1973), who believed that the Tertiary strata of these two areas were deposited in separate basins, consist of distinctly different flow rocks, and are dissimilar in age.

More recent schemes for measuring offset along the San Andreas fault in southern California have been proposed. Among them, Powell (1981) postulated that all major exposures of the Pelona-type schist are in the core of an antiformal fold and that they once formed a nearly continuous structure which subsequently has been disrupted by Cenozoic strike-slip faults (fig. 3.10). An important part of Powell's palinspastic reconstruction of the antiform is an old east-west-trending fault that is a composite of the San Francisquito, Fenner, and Clemens Well faults. This fault is thought to have had 80 km of right-lateral slip, cutting the antiform, and later was cut diagonally by the San Andreas fault. The axis of the antiformal structure is a linear feature that can be used as a "piercing point" in measuring offset where the axis appears on opposite sides of a fault. On this basis, the axis in the San Gabriel Mountains (Sierra Pelona) area is offset 220 km along the San Andreas fault from the axis in the Orocopia Mountains area (Powell, 1981). The Transverse Ranges segment of the San Andreas fault was described by Matti and others (1985) as consisting of several old strands (Wilson Creek, Mission Creek, and

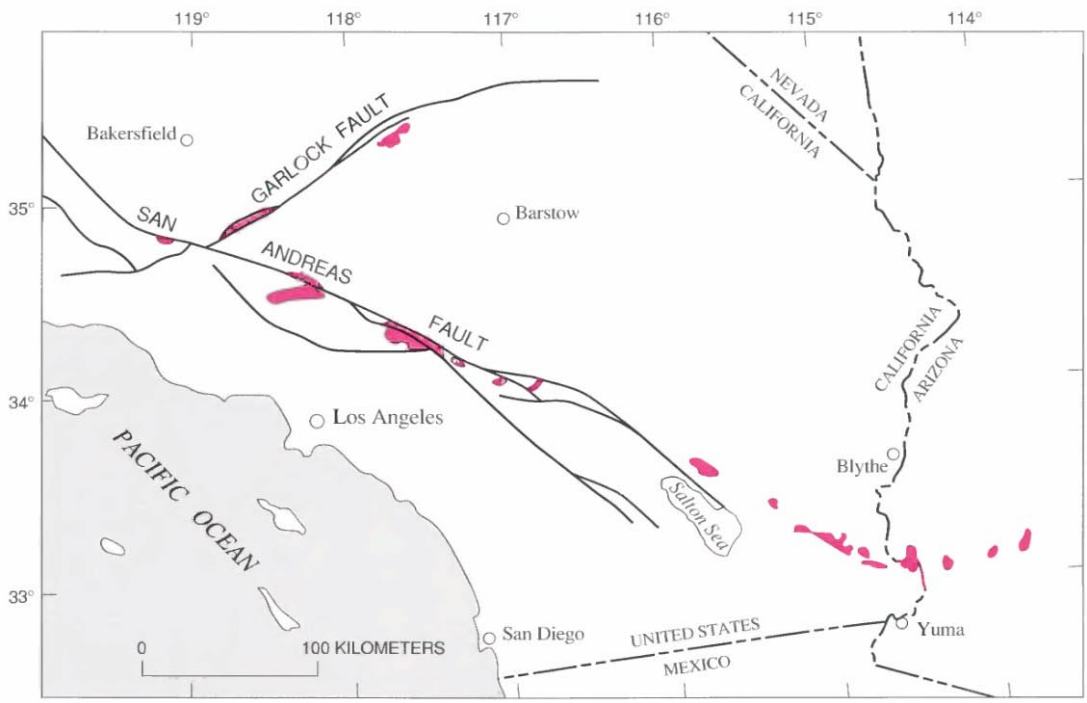

FIGURE 3.9.—Distribution of the Pelona Schist and lithologically similar schists in southern California and southwestern Arizona (modified from Haxel and Dillon, 1978). Northernmost occurrence along the San Andreas fault is in Barrett Ridge slice of the Salinian block.

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Mill Creek faults) and a young strand (San Bernardino strand). The total displacement across all of these strands is thought to be 160±10 km (Matti and others, 1986), on the basis of exposures of a distinctive Triassic megaphyric monzogranite. The exposures of this monzogranite, which are on the northeast side of the San Andreas fault in the San Bernardino Mountains but on the opposite side of the fault in Liebre Mountain (lat 34°43' N., long 118°40' W.), are thought to represent displaced parts of the same pluton.

PLATE-TECTONIC DEVELOPMENT OF THE SAN ANDREAS FAULT

The Pacific coast of North America is a highly mobile zone of tectonic interaction between continental crust on the east and oceanic crust on the west. At some times and places, the relative movements of these contrasting crustal domains have been sufficiently convergent that the oceanic crust has underthrust the continental crust and swept island arcs and other crustal materials into the zone of interaction (Hamilton, 1969). However, much of the movement along this zone of interaction seems to have been oblique or lateral in an overall northwest-southeast direction, and so as the two types of crust moved past one another, fragments of all sizes were sliced or pulled from them and carried various distances away from their source. By these processes of convergence and lateral translation, large crustal fragments referred to as "terranes" (Irwin, 1972; Coney and others, 1980; Schermer and others, 1984) are juxtaposed against others that may differ strikingly in lithology, age, genetic environment, stratigraphy, metamorphic facies, plutonism, and mineral deposits.

The general directions and rates of movement of the major crustal domains that converged along the western margin of North America are amenable to explanation by the theory of global plate tectonics as far back in time to

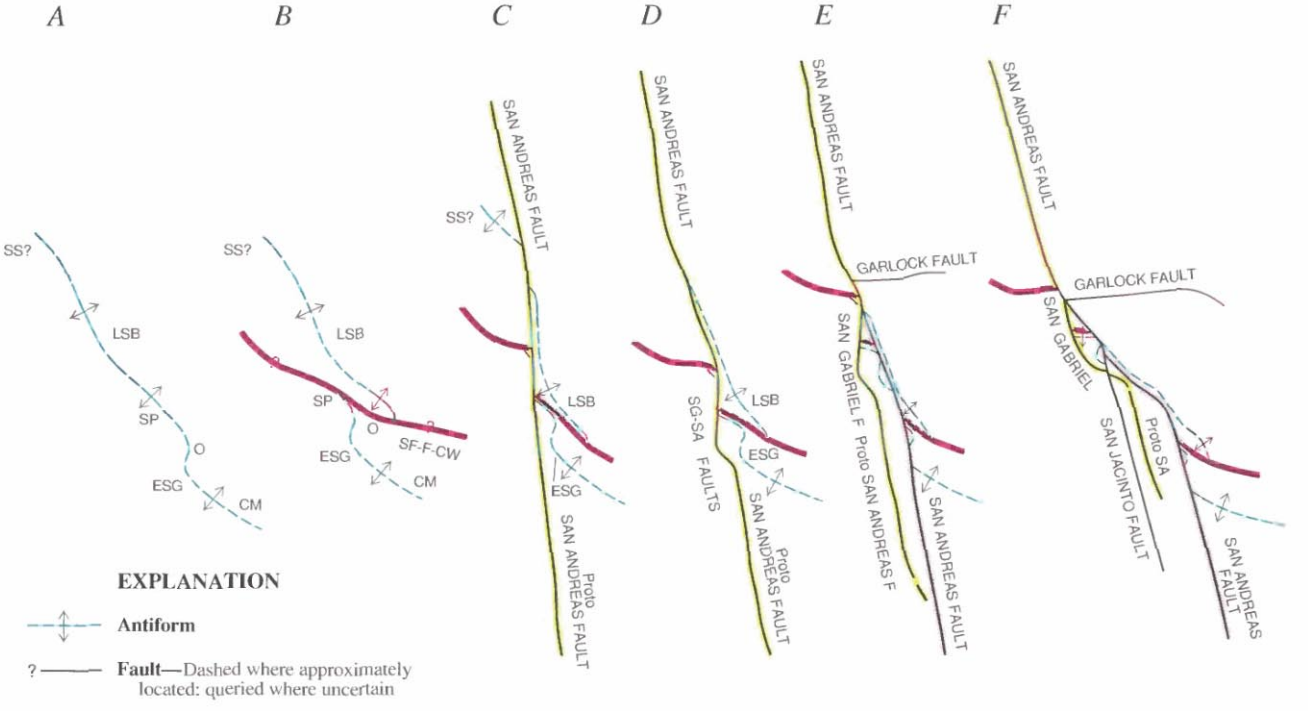

FIGURE 3.10.—Sequential diagrams showing evolution of the San Andreas fault system in southern California as proposed by Powell (1981). *A*, Approximately 30–15 Ma—formation of regional antiform cored by schist lithologically similar to the Pelona Schist. *B*, Approximately 20–10 Ma—displacement of antiform by the San Francisquito-Fenner-Clemens Well fault. *C*, Approximately 10–2 Ma—inception of San Andreas-San Gabriel strand of the San Andreas fault, displaying approximately 60 km of right-lateral displacement. *D*, Approximately 5–0 Ma—left-lateral bending of San Gabriel segment and possible inception of the Garlock fault. *E*, Approximately 2–0 Ma—inception of modern southern-California segment of the San Andreas fault, displaying 220 km of right-lateral displacement. *F*, Approximately 2–0 Ma—left-lateral bending of Transverse Ranges segment of the San Andreas fault and development of the San Jacinto fault. Faults: CW, Clemens Well; F, Fenner; SA, San Andreas; SF, San Francisquito; SG, San Gabriel. Antiform segments: CM, Chocolate Mountains; ESG, Eastern San Gabriel Mountains; LSB, Little San Bernardino Mountains; O, Orocopia Mountains; SP, Sierra Pelona; SS, Sierra de Salinas.

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at least the Mesozoic (Engebretson and others, 1985). According to this theory, the crust of Earth is a mosaic of interacting rigid plates. Boundaries between the plates are spreading ridges where the plates pull apart, oceanic trenches above subduction zones where the plates converge, and transform faults where the plates slide laterally past one another. These boundaries are the loci of seismic activity. The corollaries of the theory of global plate tectonics have been enormously valuable as an aid in recognizing the genetic environments of the various terranes, whether oceanic or continental crust, volcanic island arc, or oceanic trench. The presence of multiple ophiolite and blueschist belts along parts of the western margin of North America (Irwin, 1977) indicates that some of these terranes were subduction related during Paleozoic and Mesozoic time. Although much has been learned of the relative motions between the oceanic and continental rocks for the past 180 m.y. (for example, Engebretson and others, 1985), the tectonics of the zone of allochthonous terranes is so complex, and the sites of origin of the various terranes generally so obscure, that much painstaking research remains to be done before the Paleozoic and Mesozoic margins of western North America can be palinspastically reassembled.

The tectonic setting of the continental margin during late Mesozoic time, before development of the San Andreas fault, is highly controversial. Some geologists (for example Dickinson, 1981) favor a model of highly convergent plate interaction to develop a continental margin of the Andean type (fig. 3.11). Others, however, interpret certain paleontologic and paleomagnetic evidence to indicate that some late Mesozoic rocks of the Coast Ranges were translated great distances northward from equatorial sites of origin during Late Jurassic time, before accretion to North America and deposition of the Great Valley sequence (Hopson and others, 1986). This movement is thought to have been followed in Late Cretaceous and early Tertiary time by a second episode of dextral translation during which part of the Franciscan assemblage was accreted and parts of the Coast Range ophiolite and overlying Great Valley sequence moved northward for distances as great as 1,120 km (McLaughlin and others, 1988).

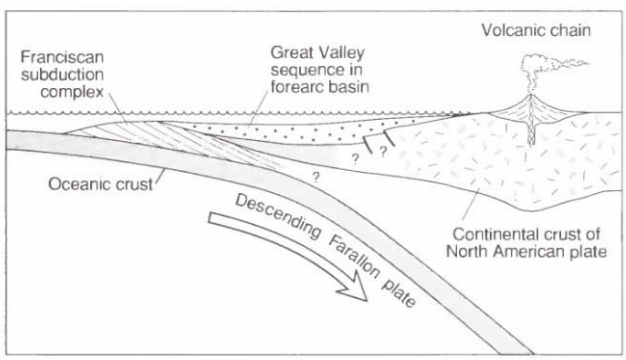

FIGURE 3.11.—Schematic diagram showing California as an Andean-type continental margin during late Mesozoic time (modified from Dickinson, 1981).

The rates and relative directions of motion of the principal tectonic plates are based mainly on patterns of magnetic anomalies in the oceanic crust. These patterns indicate that a subduction-related trench lay offshore of western North America during early Tertiary time because of the convergence of the Farallon plate (see fig. 3.1), and that strike-slip movement on faults of the San Andreas system began no earlier than approximately 30 Ma (late Oligocene), when the Pacific plate first impinged on the North American plate (McKenzie and Morgan, 1969; Atwater, 1970). Triple junctions formed at the point of contact of the Pacific plate with the North American plate and migrated to the northwest and southeast as subduction of the Farallon plate continued. These triple junctions are now approximately 2,500 km apart: The Mendocino triple junction is off the coast of northern California, and the Rivera triple junction is at the mouth of the Gulf of California. The relative motion along the transform fault that formed the lengthening boundary between the Pacific and North American plates was right lateral. This early transform movement probably was not along the modern trace of the San Andreas fault but must have been along other faults of the system that now lie mostly to the west and at the edge of the continent (fig. 3.12). The modern San Andreas fault apparently did not come into being in southern California until the opening of the Gulf of California during Pliocene time, about 4 Ma, since which time Baja California has moved 260 km away from mainland Mexico (Larson and others, 1968). The San Andreas fault is commonly referred to as the boundary between the Pacific and North American plates, which is true in the sense that the rocks on the west side of the fault are moving somewhat in concert with the Pacific plate, although those rocks actually are displaced fragments that once were part of the North American plate (fig. 3.13).

During the early development of the San Andreas fault system, the principal movement must have been along a transform fault that formed the boundary between rocks of the North American plate and newly formed oceanic crust of the Pacific plate as the triple junction migrated southward. At some point during southward migration of this triple junction, the transform apparently jumped eastward one or more times to positions within the North American plate, to become the northern section of the modern San Andreas fault. The modern trace of the San Andreas fault in central California probably had only minor slip until about 12.5–10 Ma and probably was not

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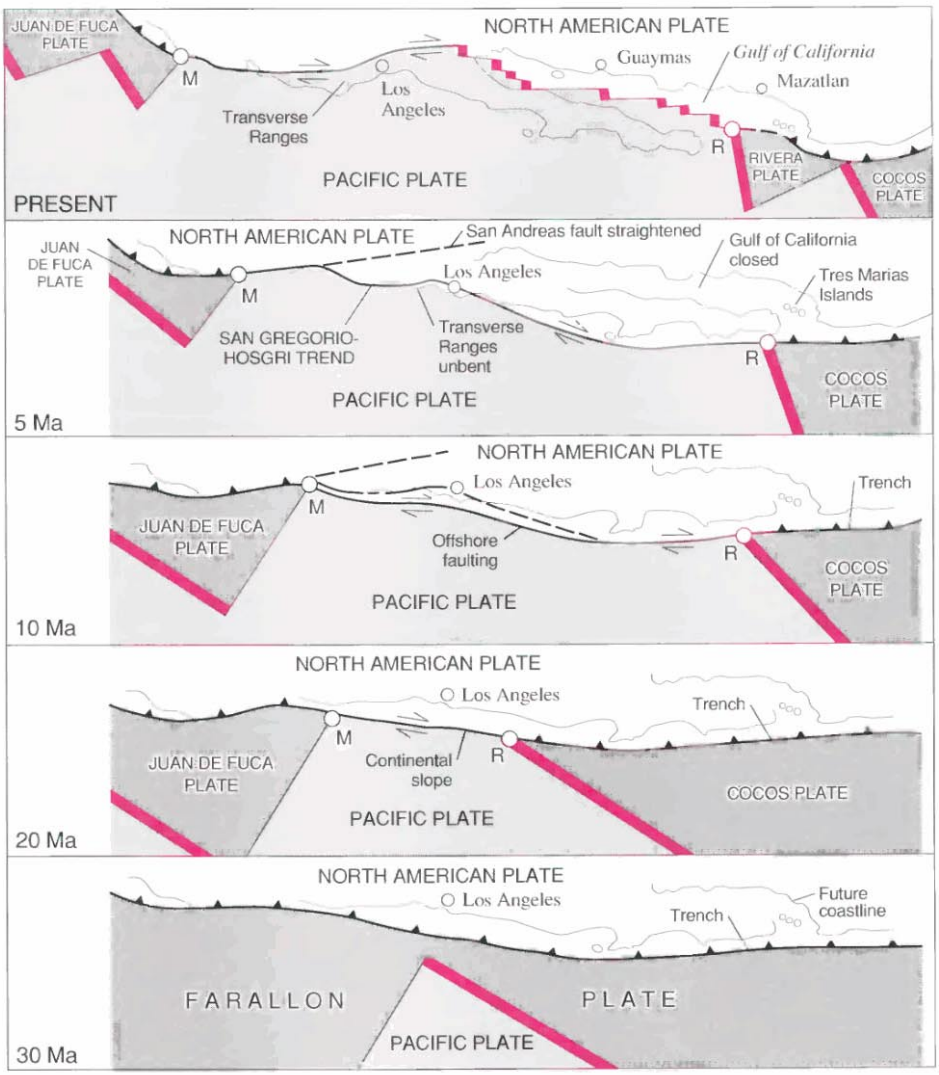

EXPLANATION

Spreading center

Subduction zone—Dashed where approximately located. Sawteeth on upper plate

Fault—Dashed where approximately located. Arrows indicate direction of relative movement

M **Mendocino triple junction**

R **Rivera triple junction**

FIGURE 3.12.—Sequential diagrams showing plate-tectonic evolution of the San Andreas transform fault system (modified from Dickinson, 1981). Note that early transform faulting was west of the present-day San Andreas fault and presumably separated young oceanic rocks of the Pacific plate from rocks of the North American plate. Over time, the transform faulting has stepped eastward, and so virtually all the presently most active element, the present-day San Andreas fault, is now in rocks of North American plate aspect. In earlier diagrams, partial outline of the Gulf of California, which did not exist before 5 Ma, is shown for reference only.

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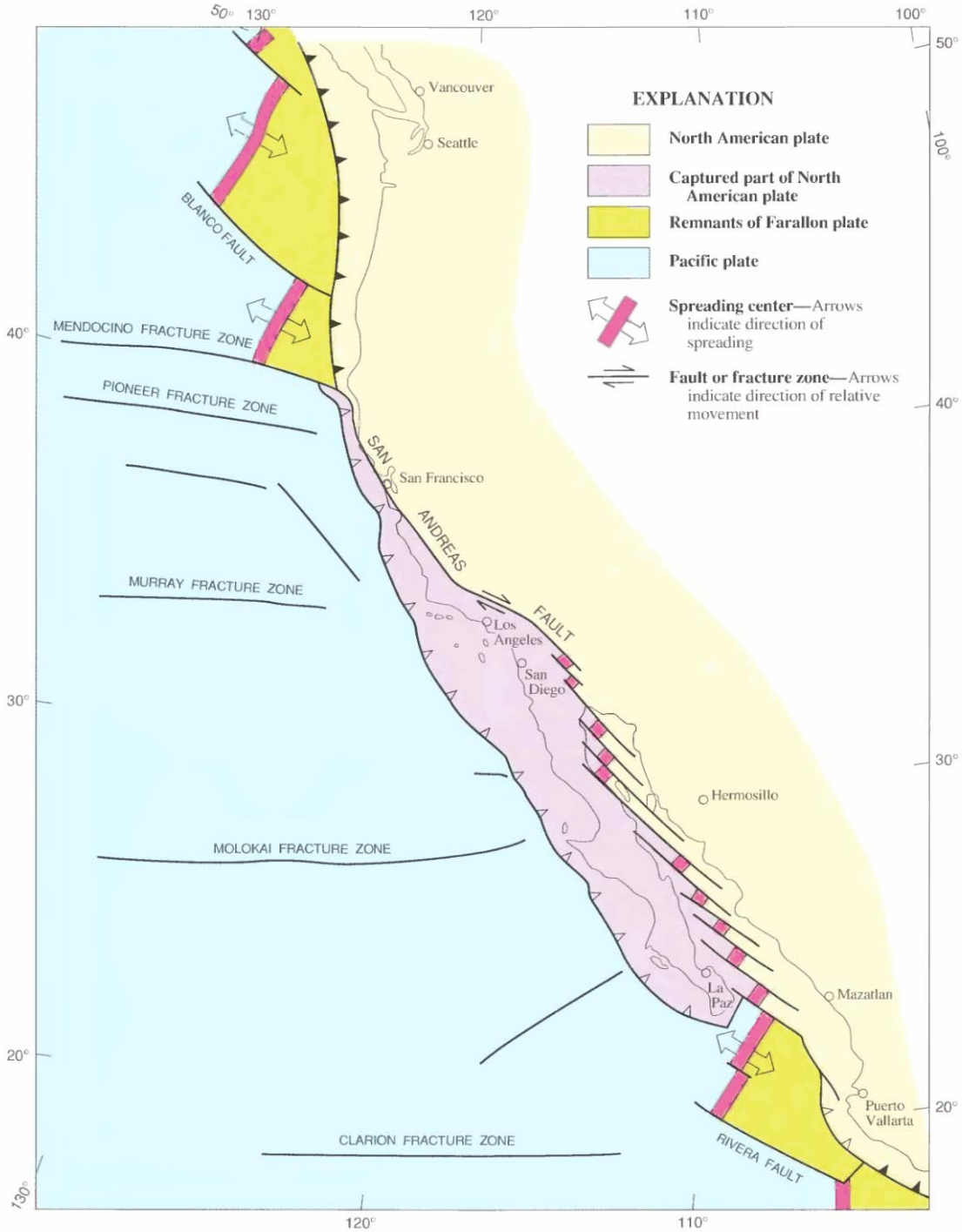
the strand of dominant slip before 7.5–5 Ma (Dickinson and Snyder, 1979). The southern section of the modern San Andreas fault was formed by similar eastward jumps of the transform fault, resulting in opening of the Gulf of



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California. Some of the major faults that lie between the San Andreas fault and the continental margin may represent these earlier positions of the transform, and some of these faults are still active. Possible candidates for such early intermediate faults include, among others, the San Gregorio-Hosgri fault in central and northern California and the Elsinore and offshore faults in southern California. With our present state of knowledge, however, it is unclear which of the many faults in the Coast Ranges are early faults of the San Andreas system and which may have formed before mid-Tertiary initiation of the San Andreas system.

The models of McKenzie and Morgan (1969) and Atwater (1970) have been widely used in relating Pacific plate interactions to the tectonics and geology of California and other parts of western North America (fig. 3.1). A more actualistic developmental sequence of diagrams was drawn by Dickinson (1981), in which the position of an early San Andreas fault is shown before the opening of the Gulf of California (fig. 3.12). In figures 3.1 and 3.12, the boundary between the Pacific and North American plates is shown as a transform fault that was formed by the passage of migrating triple junctions. However, marine geologic studies offshore of California between Point Conception and Cape Mendocino indicate that this old interface between the Pacific and North American plates is an inactive east-dipping low-angle fault which is interpreted to be a fossil subduction zone (McCulloch, 1987). There, magnetic stripes of the oceanic (Pacific) plate can be traced some distance eastward—locally as much as 30 km—beneath the leading edge of the upper (North American) plate, and both plates are covered along the suture by a thin veneer of undeformed Miocene strata. The presence of a Miocene or older subduction zone rather than a transform fault at the ocean-continent interface is difficult to reconcile with a strict interpretation of McKenzie and Morgan's (1969) and related models, although it is interpreted to indicate that the transform motion was accompanied by oblique convergence (McCulloch, 1987).

The present overall rate of relative movement between the Pacific and North American plates, earlier thought to be about 6 cm/yr (Atwater, 1970) or 5.6 cm/yr (Minster and Jordan, 1978), is now thought to be more likely about 4.8 cm/yr (DeMets and others, 1987). This rate probably has varied over time (Atwater and Molnar, 1973); however, the rate of relative motion between the two plates is substantially greater than the slip rates based on measured offsets of geologic features along the San Andreas fault. For example, the 315-km offset of the lower Miocene Pinnacles and Neenach Volcanic Formations indicates a minimum overall slip rate of 1.3 to 1.4 cm/yr (Matthews, 1976), and the offset of the channel of Wallace Creek by the San Andreas fault in central California indicates a slip rate of about 3.4 cm/yr for the past 3,700 yr and of 3.6 cm/yr for the past 13,250 yr (Sieh and Jahns, 1984). Geodetic-survey measurements indicate that slip rates during the past 90 yr in central California average 2.9 cm/yr for the upper 15 km of crust but 3.7 cm/yr below 15 km (Thatcher, 1977). The discrepancy between the rate of relative motion between the Pacific and North American plates and the much smaller slip rate on the San Andreas fault has been noted by many workers (for example, Atwater, 1970; Minster and Jordan, 1978; Weldon and Humphreys, 1986). Part of the total slip along the boundary between the Pacific and North American plates probably is occurring in small increments along other faults in a broad zone of interaction that may extend from the continental margin eastward even as far as the Basin and Range province.

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FIGURE 3.13.—Western margin of North America, showing tectonic capture of part of the North American plate by the Pacific plate (plate-tectonic base modified from Moore, 1981). Captured part of the North American plate is now moving northwesterly with the Pacific plate and is commonly considered to be part of the Pacific plate. West boundary of captured part of the North American plate is inactive early transform fault with component of subduction (open sawteeth; see text); interfaces of the North American plate with remnants of the Farallon plate are active subduction zones (solid sawteeth).

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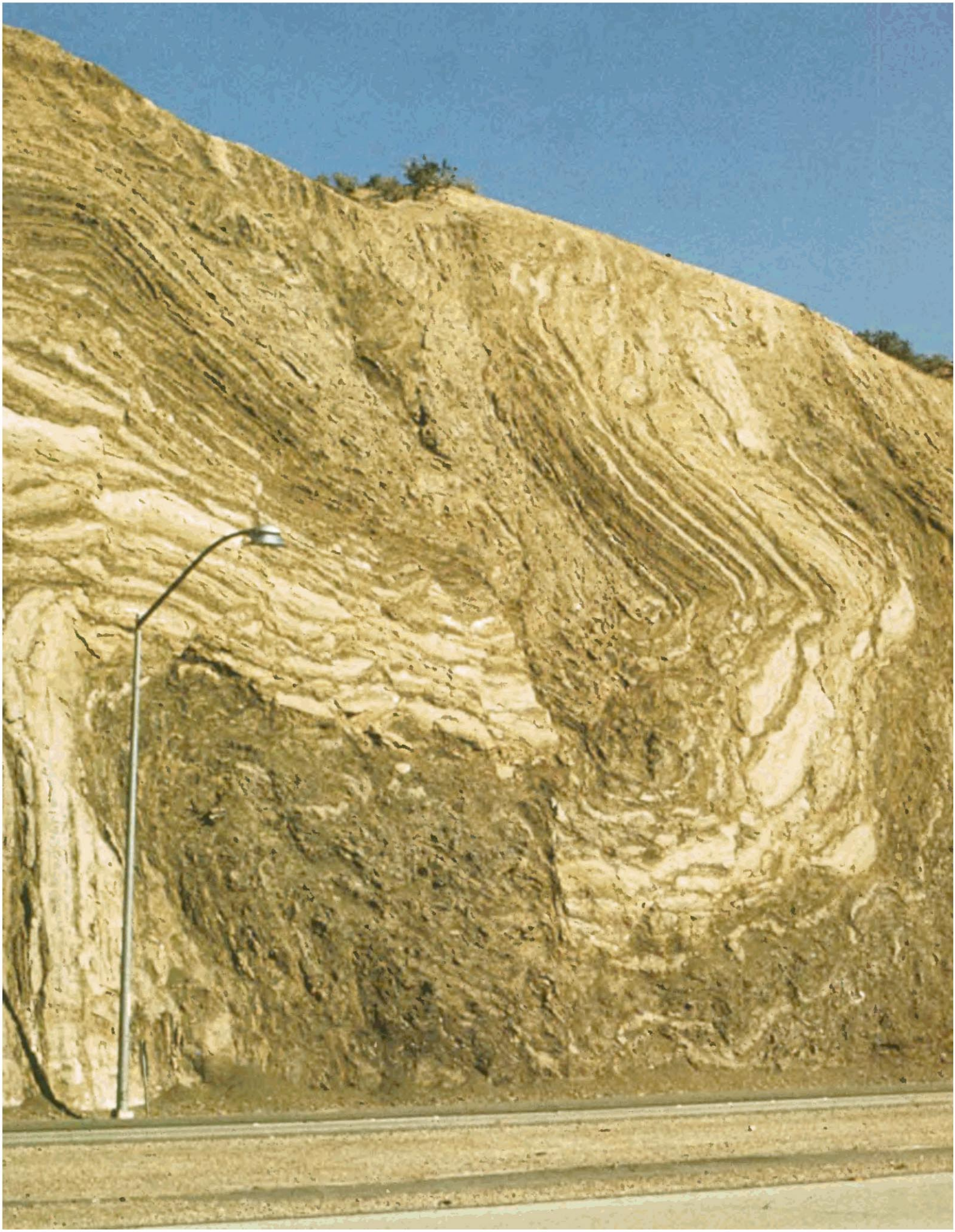

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Displaced or deformed rock units and landforms record the past 2 m.y. of faulting, folding, uplift, and subsidence in California. Properly interpreted, such evidence provides a quantitative basis for predicting future earthquake activity and for relating many diverse structures and landforms to the 5 cm/yr of horizontal motion at the boundary between the North American and Pacific plates.

4. QUATERNARY DEFORMATION

By Robert D. Brown, Jr.

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INTRODUCTION

Modern techniques of geologic dating and expanded research on earthquake hazards have greatly improved our knowledge of the San Andreas fault system. Much of this new knowledge has been gained since 1965, and that part which concerns crustal deformation during the past 2 m.y. is briefly summarized here.

In emphasizing recent work, I cite only a few of those earlier investigators who first recorded the extent and timing of deformation in upper Cenozoic deposits. Their contributions deserve a more complete accounting, and in several works cited herein such credit is given, most thoroughly by Wahrhaftig and Birman (1965). Also especially important in understanding the framework of the fault system are the 1:250,000-scale, 1° by 2° sheets of the "Geologic Atlas of California" published by the California Division of Mines and Geology, the 1:750,000-scale "Geologic Map of California" (Jennings, 1977), and the 1:750,000-scale "Fault Map of California" (Jennings, 1975).

The Quaternary deformation processes—chiefly faulting, folding, and uplift—represent crustal changes that in many places continue today but at barely perceptible rates. The perspective of 2 m.y. of geologic time permits us to detect and measure these processes, and where historical deformation is evident—as shown by seismology, geodetic studies, or geologic investigations of recent earthquakes—the Quaternary record provides an independent check on the reliability of our observations and measurements. More importantly, we also use the Quaternary viewpoint to sketch the outlines of the currently active fault system, its intact crustal elements and major active faults, and how these faults propagate and change over time. From such evidence we can better understand

◀ FIGURE 4.1.—Strata within a few hundred meters of the San Andreas fault are highly deformed. Here, folded and faulted beds of Pliocene age on the north side of the San Andreas fault are exposed in a roadcut along California Highway 14 just south of Palmdale along the southern margin of the Mojave Desert. Photograph by R.E. Wallace, U.S. Geological Survey.

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the pre-Quaternary history of the system and build the predictive kinematic models needed for earthquake hazard assessment.

Evidence of Quaternary deformation comes chiefly from the observed displacement of strata or geomorphic features (fig. 4.1). Where this displacement can be dated or, at least, bracketed in time, the age of deformation can be established, and its rate—generally an average—can be determined. In this report, most deformation rates are converted to units of centimeters per year, in part to facilitate comparison of different data sets but also because the dominant process, strike slip on major faults, is conveniently expressed in such units. Both the amount of displacement and the materials used to determine the age of displaced geologic markers require careful geologic analysis to ensure that field relations are unequivocal and correctly interpreted; the most reliable deformation rates depend on highly detailed analyses of local stratigraphy, which provide multiple measures of displacement over broad timespans, typically thousands to tens of thousands of years.

Deposits of Quaternary age can be dated by several methods, most of which ultimately depend on geochemical analyses that require highly sophisticated laboratory practices and expertise, as well as carefully chosen samples. The principal methods of dating Pleistocene and Holocene deposits within the San Andreas fault system (fig. 4.2) include radiocarbon, soil chronostratigraphy, correlation with standard sea-level stages (chiefly used for uplifted marine terraces), tephrochronology, and mammalian and invertebrate paleontology; supplementary techniques include paleomagnetism, uranium-series analysis, and amino-acid racemization. The underlying theory and limitations of these methods (for example, Pierce, 1986) are beyond the scope of this review. Each method, however, differs in resolving power, the timespan over which it is effective, and applicability to different rock types.

Difficulties in dating deformed Quaternary deposits are not the only deterrent to reconstructing the history of faulting. Large areas within the fault system are nearly devoid of Quaternary deposits; others are masked by landslide deposits, which conceal Quaternary folds and faults. Few published geologic maps differentiate between faults with Quaternary movement and those that have long been inactive, and for even the best known faults our knowledge of Quaternary faulting is still incomplete. Quaternary reverse and thrust faults, more difficult to identify and map than their strike-slip counterparts, are surely underrepresented on published geologic maps and in the literature.

Our knowledge of Quaternary deformation is thus incomplete and biased. We have learned much, and are rapidly learning more, about the Holocene and latest Pleistocene, but the view much beyond the past 100 ka is still poorly resolved. Despite the problems, the results of the past 2 decades of Quaternary research have brought

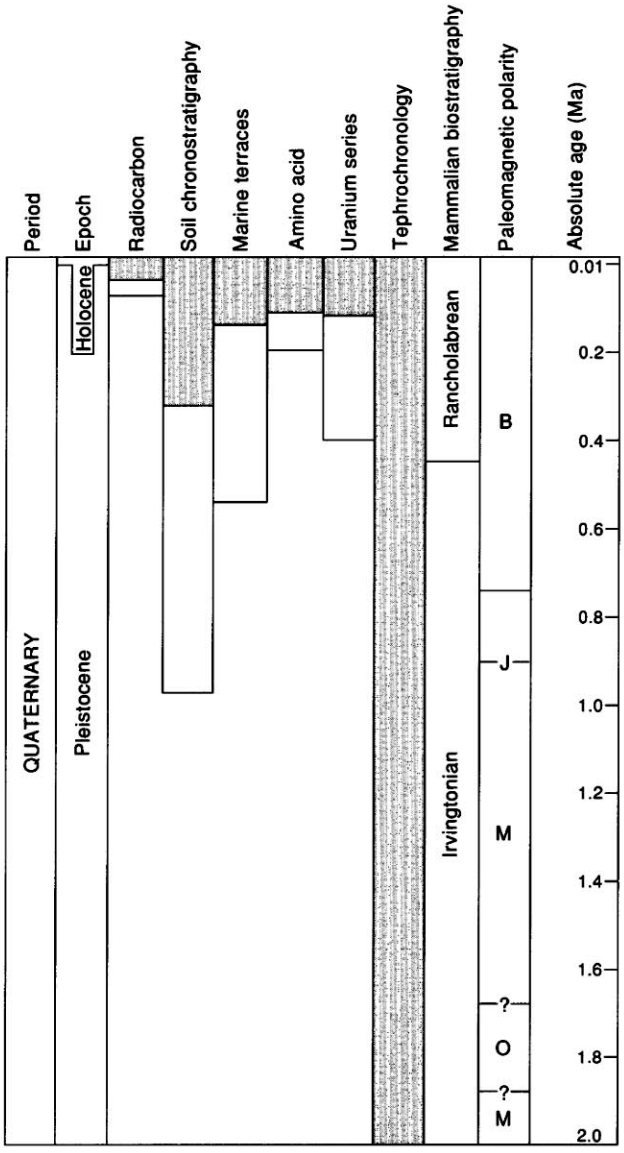

FIGURE 4.2.—Dating methods used in studies of the Quaternary deposits of the San Andreas fault system. Shading shows principal methods and timespans over which they have been most effectively used; open bars indicate potential range of the methods. Other available methods of Quaternary dating, some of which are not shown, either are little used or have produced few or no reported data on Quaternary deformation within the fault system. Paleomagnetic polarities: B, Brunhes Normal-Polarity Chron; J, Jaramillo Normal-Polarity Subchron; M, Matuyama Reversed-Polarity Chron; O, Olduvai Normal-Polarity Subchron.

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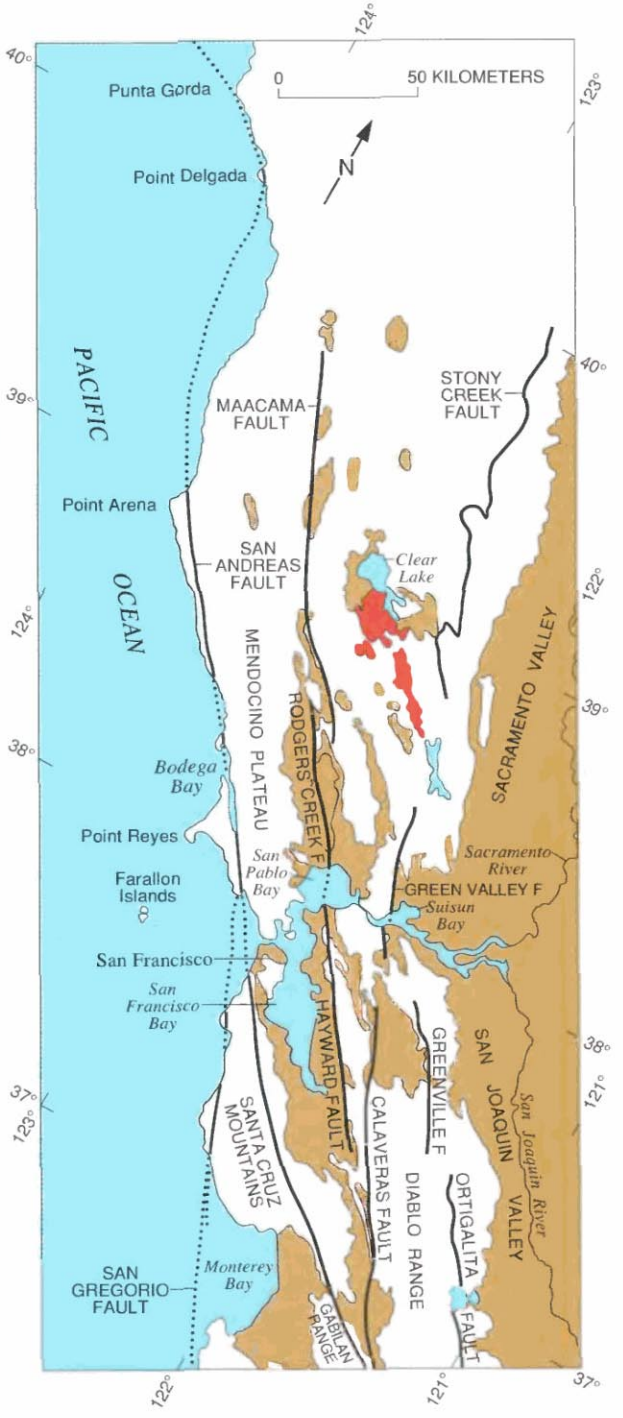
new insights into the mechanics of the fault system and the promise of more discoveries yet to come.

NORTHERN SECTION OF THE SAN ANDREAS FAULT SYSTEM

SAN ANDREAS FAULT

The northern section of the San Andreas fault system, as defined here, extends from Punta Gorda, 40 km southeast of the Mendocino triple junction, to the northern Gabilan Range (fig. 4.3). This belt of Quaternary—and earlier—faulting and folding, about 120 km wide by 500 km long, includes the San Andreas, at least four major related faults, and several smaller faults, 5 to 20 km long. All of these faults displace Quaternary deposits or landforms, and all are seismically active. From west to east, major faults within the system are the San Gregorio, San Andreas, Hayward (and its northern, right-stepping extensions, the Rodgers Creek-Healdsburg and Maacama faults), Calaveras (and its northern, right-stepping extensions, the Concord and Green Valley faults), and an ill-defined, possibly discontinuous fault zone along the eastern margin of the Coast Ranges that includes, from north to south, the Stony Creek, Greenville, and Ortigalita faults.

The offshore counterpart of the main San Andreas fault, which trends seaward and westward from Punta Gorda to the Mendocino triple junction, represents the latest segment of the northward-growing transform. This east-west-trending, offshore segment of the fault is located chiefly on seismic and bathymetric evidence; it follows along the north face of the Gorda Escarpment (along lat 40°23′ N. and west of long 124°39′ W.) and the south wall of Mattole Canyon (from the east end of the Gorda Escarpment southeast to lat 40°17′ N., long 124°27′ W.), but water depths of as much as 2,000 m, high submarine relief, and sea-floor deposits of young sediment (Silver, 1971; McCulloch and others, 1985) obscure details of its Quaternary history.



EXPLANATION

Alluvial and estuarine deposits (Quaternary)—Chiefly basin fill; may also include some Pliocene deposits

Clear Lake Volcanics (Quaternary and Tertiary)—Flows, tuffs, and breccias of dacite and rhyolite and less abundant basalt. Age is late Pliocene to Holocene

Bedrock (Tertiary and older)—Varied rock types

Fault exhibiting evidence of Quaternary displacement—Dotted where concealed by water

FIGURE 4.3.—Geologic sketch map of the northern Coast Ranges, central California, showing faults with Quaternary activity and basin deposits in northern section of the San Andreas fault system. Fault patterns are generalized, and only major faults are shown. Several Quaternary basins are fault bounded and aligned parallel to strike-slip faults, a relation most apparent along the Hayward-Rodgers Creek-Maacama fault trend.

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From Punta Gorda southward to Point Arena the fault is almost entirely off shore; its location is known from sea-floor features, coastal geomorphology, and relations at Point Delgada, where it locally intersects the coastline. A line of coastal bluffs, 350 to 850 m high and sloping 33°–43°, trends N. 50° W. for 20 km northwest of Point Delgada. At the base of the bluffline, Lajoie and others (1982) measured Holocene uplift rates of about 0.5 cm/yr from dated molluscan fossils in beach ridges 30 m above present sea level. Seaward of the bluffs, the Spanish and Delgada Submarine Canyons head near the present coast, 2 to 3 km landward of the 100-m bathymetric contour, which approximately defines the late Wisconsin sea level. Shoreward of this contour, both canyons are linear, and neither they nor the intervening sea floor exhibits evidence of vertical or horizontal displacement. These relations are consistent with a near-shore San Andreas fault, located in or near the surf zone and close to the base of the coastal bluffs. The unusually large component of vertical slip (0.5 cm/yr, northeast side up) for this segment of the fault may result from its more westerly trend than that of segments farther south, which exhibit almost pure strike slip; or, as suggested by Merritts and Bull (1989), it may result from the late Quaternary passage of the Mendocino triple junction along this part of the coast.

The fault intersects the coastline about 6 km northwest of Point Delgada, cuts across the point, and locally separates upper Pleistocene marine terrace gravel and younger alluvium (McLaughlin and others, 1983) along the coast from intensely deformed bedrock inland. Other locations have been suggested (Curry and Nason, 1967; Beutner and others, 1980; McLaughlin and others, 1983) for the fault here, but several lines of independent evidence support this trend, including fault slip during the 1906 earthquake (Lawson and others, 1908, p. 54–58), the alignment of scarps, sags, and saddles along the 1906 fault trend, bedrock faulting colinear with 1906 faulting (Brown and Wolfe, 1972), and continuity to the north and south with offshore and nearshore evidence of recent faulting.

From Point Delgada southward to Point Arena, a distance of 125 km, the fault is defined by aligned, chiefly west-facing scarps on the sea floor, the right-lateral deflection of Noyo Submarine Canyon, straight boundaries of irregular submarine topography, and a 2- to 5-km-wide zone of disturbed reflective layers evident in continuous seismic-reflection profiles (Curray and Nason, 1967). The shapes and dimensions of sea-floor features, as shown by seismic-reflection profiles and modern bathymetric maps, resemble fault-formed features on land and provide similar evidence for right-lateral strike slip. The offshore data, however, are insufficient to determine the amount of Quaternary displacement.

Onland segments of the fault between Point Arena and the Gabilan Range exhibit abundant geomorphic and geologic evidence of Quaternary displacement, some of which can be translated into slip rates. Trunk streams, systematically displaced from their headwaters by at least 10 km, record cumulative strike-slip faulting that must span much of Quaternary time. For example, the fault-deflected, northwest-trending courses of the Garcia and Gualala Rivers follow the fault zone for 50 km between Point Arena and Fort Ross; their present alignment (fig. 4.4) documents a long and complex history of channel extension and stream piracy. Three streams east of the fault—the Garcia River and the Wheatfield and South Forks of the Gualala River—exhibit similar offsets of about 13.5 km from possible former outlets to the sea west of the fault: the Garcia River from its present mouth near Point Arena, the Wheatfield Fork from the present mouth of the Gualala River near Gualala, and the South Fork from a low gap (110-m elevation) in the coastal ridge near the Sea Ranch. The average rate of post-Pliocene slip across the boundary between the North American and Pacific plates, derived from spreading rates at the mouth of the Gulf of California (DeMets and others, 1987, p. 912), is estimated at 5.1 cm/yr. In northern California, this slip is distributed chiefly on the San Andreas and other active faults to the east. On the San Andreas fault at Point Arena, Prentice (1989) obtained a maximum slip rate of 2.6±0.3 cm/yr from a faulted stream channel ^{14}C dated at 2,350 to 2,710 yr. Together with the assumed 13.5-km offsets, this rate implies that the postulated drainage diversions required about 519 ka. Other lines of evidence indicate much greater antiquity for this and nearby parallel strands of the fault.

Despite abundant evidence of Quaternary faulting along the northern section of the San Andreas fault, other examples of measurable fault displacement of dated upper Pliocene and Quaternary deposits are sparse. Much of the fault lies off shore, and most onshore segments cut older, highly deformed rocks of the Franciscan complex, from which the upper Cenozoic deposits have been eroded. Some reliable indicators of Quaternary slip, however, come from geologic and geomorphic relations observed from San Francisco southward.

On the San Francisco peninsula and farther south in the Santa Cruz Mountains, estimates of Quaternary slip on the San Andreas fault have been derived from offset biofacies and lithofacies relations. The fault offsets are in discontinuously exposed upper Cenozoic strata, which

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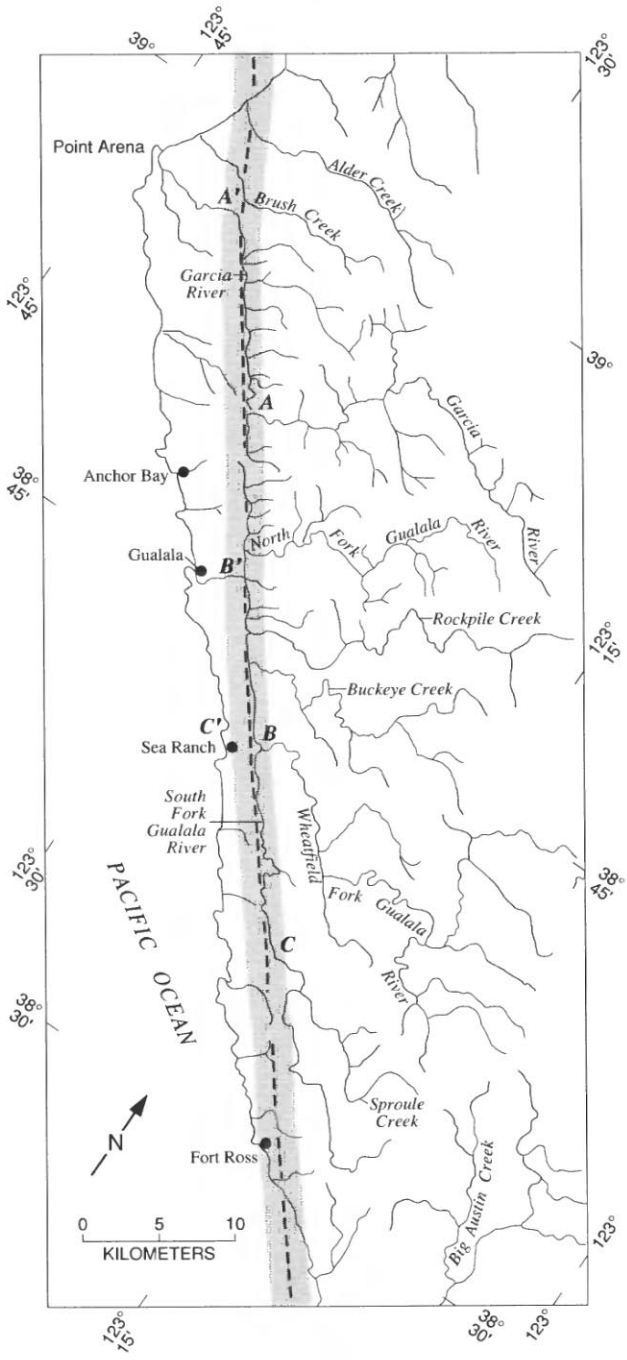

FIGURE 4.4.—Sketch map of part of northern California, showing coastal drainages south of Point Arena, systematically diverted by right-lateral slip on the San Andreas fault (dashed and shaded line). Possible offsets of 13.5 km are indicated for the Garcia River (*A*–*A'*), the Wheatfield Fork of the Gualala River (*B*–*B'*), and the South Fork of the Gualala River (*C*–*C'*).

have been assigned by different investigators to the marine Merced, or Merced(?), Formation and the nonmarine Santa Clara Formation. East of the San Andreas fault, both the Merced and Santa Clara Formations contain, in their upper parts, the 400-ka-old Rockland ash bed of Sarna-Wojcicki and others (1985), thus establishing at least a partial age equivalence of these two units.

The upper, Rockland ash-bearing part of the Merced Formation (Clifton and others, 1988) is fault bounded on the southwest and juxtaposed against a ridge of older rock for 11 km southeast of San Francisco (fig. 4.5). The minimum offset of 11 km from any western counterpart of the Merced outcrop belt and the 0.4- to 2.0-m.y. age of the faulted Merced strata require a minimum slip rate of 1.7±1.0 cm/yr for this section of the San Andreas fault.

A similar rate can be derived from the present distribution of upper Pleistocene marine deposits, which Addicott (1969) interpreted as the faulted remnants of a narrow marine embayment that once extended southeastward across the San Andreas. The fault separation of 35 to 40 km (Addicott, 1969, fig. 2) and an assumed 2- to 3-m.y. age for the embayment yield a geologic slip rate of 1.6±0.4 cm/yr.

Additional evidence for Quaternary strike slip (Dibblee, 1966; Cummings, 1968) comes from the southern Santa Cruz Mountains south and west of San Jose. Distinctive reworked conglomerate clasts in the Corte Madera facies of the Santa Clara Formation west of the San Andreas fault are displaced 28 km from their source, an Upper Cretaceous pebble conglomerate lens on the east side of the fault. The age of the Corte Madera facies is poorly constrained, but Cummings (1968) assumed a probable age range of 1 to 3 m.y., which yields slip rates of about 1 to 3 cm/yr.

These slip rates carry uncertainties as great as ±1 cm/yr, but because they integrate slip over millions of years of geologic time, short-term changes in fault activity influence them only slightly. For comparison, a late Holocene slip rate is available from a site on the San Francisco peninsula, 11 km south of San Francisco. There, displaced and abandoned stream channels and relict alluvial deposits (fig. 4.6) were explored and described by Hall (1984; N.T. Hall, written commun., 1986). The alluvium, ^{14}C dated at 1,130±160 yr, accumulated along a northwest-flowing stream and behind a northwest-trending shutter ridge along the main fault trace. Alluviation ceased when fault slip, unusually high seasonal streamflow, or stream piracy caused the stream to abandon its fault-extended course and to carve a shorter, steeper, southwest-flowing channel across the fault and directly down the slope. This younger channel now exhibits 13.5 m of right-lateral offset where it is

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crossed by the fault; about 2.7 m of this total offset can be attributed to fault displacement during the 1906 earthquake. Hall's (1984) analysis of this sequence of depositional, erosional, and faulting events yields a minimum slip rate for the past 1,200 yr of about 1.25 cm/yr.

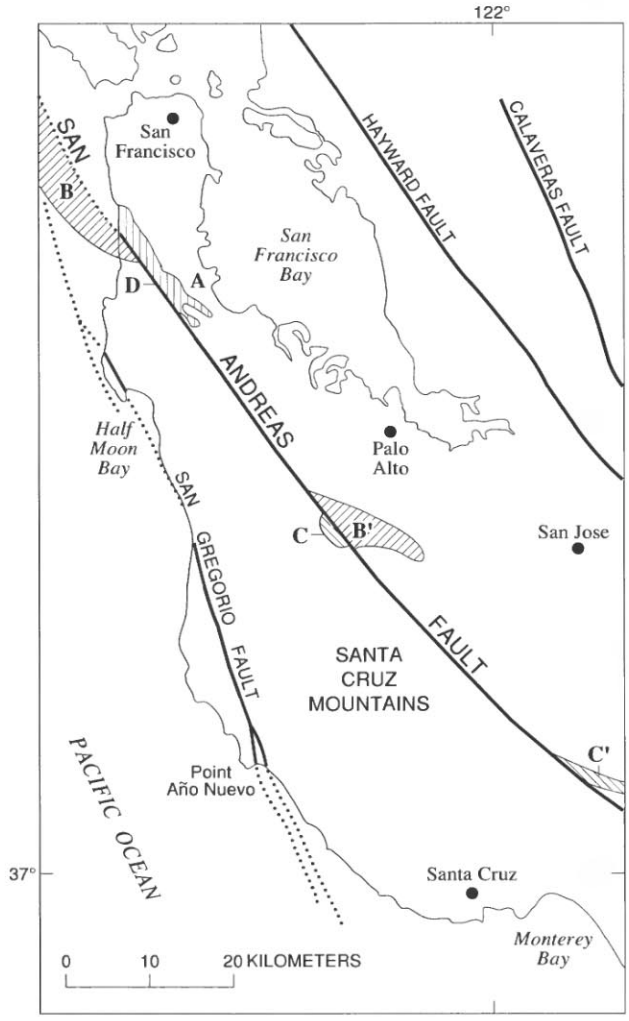

FIGURE 4.5.—Fault-displaced geologic units on the San Francisco peninsula provide a basis for estimating the rate of strike slip on this section of the San Andreas fault—about 1.5 cm/yr for the Quaternary. Critical field relations include: A, outcrop belt of the marine Merced Formation, 2.0–0.4 Ma, truncated and faulted against older rocks for 11 km on the southwest; B–B′, fault-displaced parts of a 3.0- to 2.0-Ma, late Pleistocene marine embayment (Addicott, 1969); C–C′, 3.0- to 1.0-Ma nonmarine conglomerate of the Corte Madera facies of the Santa Clara Formation west of the fault and its source area east of the fault (Cummings, 1968); D, site where 1.2-ka (late Holocene) slip rate of about 1.25 cm/yr (Hall, 1984) was measured. Quaternary slip has also occurred on the San Gregorio, Hayward, and Calaveras faults. Faults dotted where concealed by water.

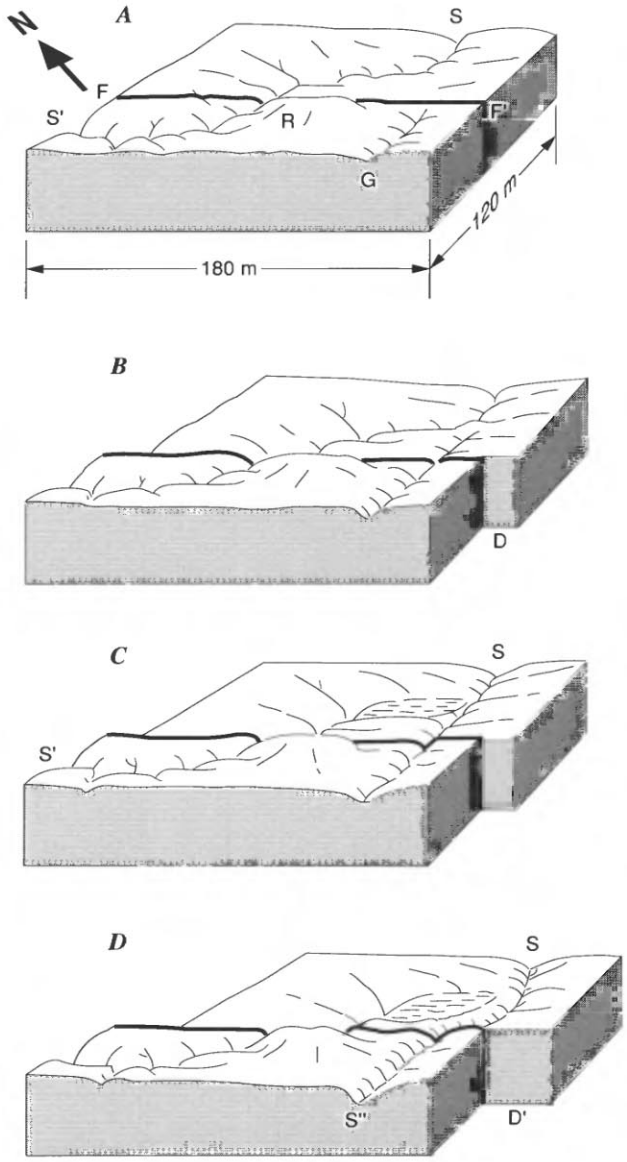

FIGURE 4.6.—Interpretative block diagrams, based on relations described by Hall (1984), for a site on the San Andreas fault 11 km south of San Francisco. Rate of fault slip, about 1.25 cm/yr, is derived from observed 13.5-m stream offset, which postdates alluviation along original (precapture) streamcourse. *A*, Stream, flowing obliquely downslope from S to S′, is partly diverted by ridge (R) where stream crosses the San Andreas fault (F–F′). Gully (G) heads southwest of fault, flowing toward observer. *B*, Displacements (D), caused by fault slip, offset stream and lengthen its channel; gully erodes headward across fault. *C*, Low gradient of stream channel causes alluviation upstream from fault, facilitating capture of its headwaters by gully and abandonment of streamcourse S–S′. Date of alluviation, 1,130±160 yr B.P., from detrital charcoal dated by ^{14}C methods. *D*, Renewed fault displacements (D′) offset captured stream (S–S″) by 13.5 m, an amount that includes 2.7 m of slip in 1906.

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OTHER FAULTS

The rate of Quaternary strike slip along the northern section of the San Andreas fault south of San Francisco, about 1.5 cm/yr, is less than either the 5.1 cm/yr attributed to the plate boundary or the 2.5 to 3.5 cm/yr observed along more southerly segments of the fault. Much of this slip deficit can be accounted for by distributed slip on several other northern California faults that nearly parallel the main trace of the San Andreas.

One of these faults, the San Gregorio, is the northernmost of a 400-km-long set of coastal faults lying southwest of the main trace of the San Andreas. The San Gregorio fault extends northward from Monterey Bay, joining the San Andreas about 20 km northwest of San Francisco, near Bolinas Bay. Where it cuts the coastline near Point Año Nuevo, the San Gregorio is a complex, 3- to 5-km-wide zone of near-vertical strike-slip and northeast-dipping reverse faults. Faults in this zone offset stream channels incised into marine and nonmarine strata that were deposited on a 105-ka-old wave-cut platform; the faults also offset the shoreline angle of this and at least one older wave-cut platform (fig. 4.7). Evidence from offset shoreline angles and faulted strata indicates a late Pleistocene, right-lateral slip rate of 0.6 to 1.1 cm/yr across the fault zone (Weber and Cotton, 1981, p. 16, 72–75); Hamilton and others (1979), however, argued for rates of only 0.1 cm/yr in the same area.

If the higher slip rate on the San Gregorio fault and the rates estimated for the San Andreas fault south of San Francisco are correct, Quaternary slip on the San Andreas north of its junction with the San Gregorio must be about 2.6 cm/yr—the sum of the rates on the two separate faults. This rate agrees closely with that previously cited for the San Andreas near Point Arena (Prentice, 1989).

Additional slip occurs along faults northeast of the San Andreas, as shown by geomorphic evidence, alignment of earthquake epicenters, and, on some faults, gradual fault creep amounting to as much as 1 cm/yr. Direct geologic evidence of Quaternary slip on such faults as the Hayward, Calaveras, and Green Valley is abundant, but the age and crossfault correlation of displaced stratigraphic markers are uncertain, and Quaternary slip rates are only weakly constrained. These rates, however, can be estimated from such other criteria as modern creep rates, geologic slip rates for displaced pre-Quaternary markers, and geomorphic expression relative to that along the San Andreas fault.

On such evidence, the most active fault trend, with Quaternary slip rates estimated to range from 0.5 to 1.0 cm/yr, is that defined by the southern section of the Calaveras fault and by the Hayward, Rodgers Creek-Healdsburg, and Maacama faults (fig. 4.3). Together, these faults extend for 375 km as a series of chiefly right-stepping breaks that exhibit abundant geomorphic evidence of recent movement. The seismically active Green Valley fault, locally as well defined as the Rodgers Creek and 27 km farther east, offsets cultural features that record right-lateral creep of 0.5 cm/yr between 1922 and 1974 (Frizzell and Brown, 1976).

The east boundary of the northern section of the San Andreas fault system follows a series of faults that trend north-northwest, exhibit recognizable components of right-lateral strike slip, and approximately separate the Coast Ranges from the Great Valley. This discontinuous

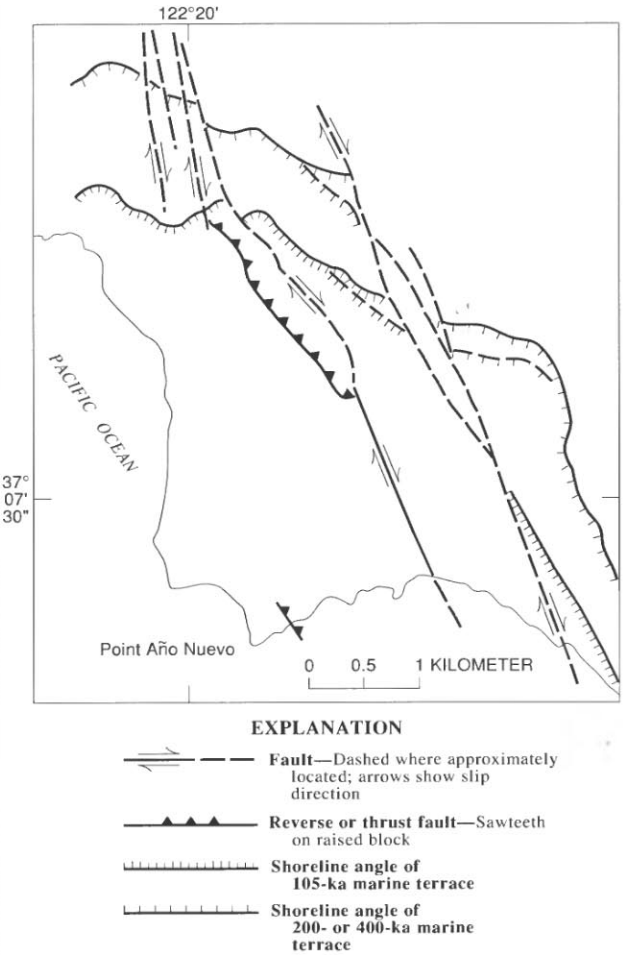

FIGURE 4.7.—Sketch map of Point Año Nuevo area, northern California, showing fault-displaced shoreline angles in the San Gregorio fault zone. Broken segments of shoreline angles indicate possible alternative locations. This figure, simplified from Weber and Cotton (1981), shows the difficulty of accurately measuring displacement where faults intersect a relict shoreline at acute angles (see fig. 4.8*A*).

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and somewhat diffuse belt of faulting includes, from north to south, the Stony Creek, Greenville, and Ortigalita faults. No obvious surface faulting bridges the 100-km interval between the Stony Creek and Greenville faults, but major earthquakes in 1892 at Vacaville (lat 38°12.5′ N., long 121°35′ W) and Winters (lat 38° 18.5′ N., long 121°34′ W.) may signify fault continuity at depth on this trend.

The historically aseismic Stony Creek fault follows and locally truncates a major detachment surface (the Coast Range thrust) that has been rotated to vertical or overturned. It now exhibits a steep east-facing scarp along the front of the Coast Ranges and separates a mountainous Franciscan terrane on the west from less deformed rocks on the east. Stream-terrace and fan deposits of Quaternary age east of the fault terminate at its scarp and are gently tilted and dissected by erosion. Sparse geologic evidence of renewed Quaternary faulting favors dominantly vertical slip, up to the west, but a right-lateral strike-slip component is indicated by asymmetric cusps and bays in the mapped trace of the fault and by nearby southeasterly-plunging folds that deform rocks at least as young as late Pliocene (Fox, 1983, p. 22).

System-boundary faults to the south exhibit both local seismic activity and evidence of Quaternary slip. The Greenville fault, here (fig. 4.3) combined with the Marsh Creek and Clayton faults, displaces Quaternary stream-terrace deposits and soils, as well as fold axes in middle to upper Tertiary marine deposits. Right-lateral slip rates on these faults range from 0.01 to 0.30 cm/yr, but most Quaternary rates are less than 0.1 cm/yr (Sweeney, 1982; Wright and others, 1982). These relatively low rates are consistent with weak geomorphic expression along this fault trend.

FOLDING, UPLIFT, AND VOLCANISM

Northwest- or east-west-trending folds deform much of the San Andreas fault system except for the relatively undeformed Sebastopol block (Fox, 1983) between the San Andreas fault and the fault trend defined by the Hayward, Rodgers Creek, and Maacama faults. The relative structural simplicity of this block is most evident between San Francisco Bay and about lat 39°30′ N. (fig. 4.3), where flat-lying upper Miocene and Pliocene strata of the Wilson Grove (Fox, 1983) and Ohlson Ranch (Higgins, 1960) Formations extend across much of its surface. The erosional surface of this part of the block, the Mendocino Plateau (Lawson, 1894; Wahrhaftig and Birman, 1965, p. 323; Fox, 1983, p. 22–24), is a planar or gently warped upland with accordant ridge crests at elevations of 300 to 600 m. Fox (1983) contrasted the apparent stability of his Sebastopol block with a more typical, highly deformed region to the east, his Santa Rosa block.

In the Santa Rosa block and in other more easterly parts of the Coast Ranges, Quaternary folding and faulting have left uplifted or anticlinal ridges and downwarped or downfaulted basins. Some of the larger basins, now filled with locally derived sediment of Pliocene and Quaternary age, are the southern arm of the San Francisco Bay, Napa and Livermore Valleys (lat 38°20′ N., long 122°20′ W., and lat 37°40′ N.,long 121°50′ W.), and the topographic basin surrounding Clear Lake (lat 39°01′ N., long 122°30′ W.). Smaller aligned or linear basins that follow northwest-trending faults or synclinal folds (fig. 4.3) clearly are structurally controlled.

Rates of folding and uplift are best known for coastal regions. Marine terraces between San Francisco and Monterey Bay indicate general uplift of 120 to 180 m during the past 0.5 to 1 m.y. (Helley and others, 1979, p. 18)—an uplift rate of about 0.02 cm/yr. Local variation in uplift is shown by the deformed shoreline angle and wave-cut platform of the youngest (82 ka) terrace (fig. 4.8); near Half Moon Bay, the wave-cut platform has been warped by northwest-trending folds into a surface that exhibits 60 m of structural relief over a distance of about 11 km (Lajoie, 1986, fig. 6.21). About 10 km west of Santa Cruz, this terrace is about 14 m above modern sea level (Bradley, 1957; Bradley and Griggs, 1976; Hanks and others, 1984, p. 5776–5777), indicating a local uplift rate of 0.04 cm/yr.

Coastal uplift south of San Francisco contrasts with Quaternary crustal subsidence 25 to 30 km inland and east of the San Andreas fault (figs. 4.3, 4.5). Estuarine, stream-laid, and freshwater-swamp deposits of Quaternary age underlie the northwest-trending structural basin containing the San Francisco Bay and the Santa Clara Valley (lat 37°10′ N., long 121°40′ W.) to depths greater than 200 m below sea level. This prolonged Quaternary downwarping (Wahrhaftig and Birman, 1965) locally attained subsidence rates of 0.02 to 0.04 cm/yr (Atwater and others, 1977) during post-Sangamon time.

Despite such local variations in the amount and orientation of crustal processes, Quaternary uplift (fig. 4.9) prevails throughout the northern Coast Ranges. Regional uplift, at least partly of Quaternary age, is greatest and most evident east of the Hayward-Rodgers Creek-Maacama fault trend. Summit elevations north of Clear Lake exceed 1,500 m (Wahrhaftig and Birman, 1965, fig. 9), and those in the Diablo Range, south of the Livermore Valley, range from 600 to 1,200 m (Christensen, 1965, pl. 1). Both of these colinear uplands exhibit high relief, evidence of rapid downcutting, and cores of the emergent Franciscan complex flanked by outward-dipping strata of Pliocene and Quaternary age.

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Volcanic rocks of late Cenozoic age, widely distributed between the San Pablo Bay and Clear Lake, define a triangular, northwest-trending outcrop area, 120 km long by 35 km wide, with its most acute, north apex at Clear Lake. These rocks are assigned to two geographically separated extrusive sequences: the late Miocene and Pliocene Sonoma Volcanics to the south, and the younger, more areally restricted Clear Lake Volcanics (fig. 4.3) to the north. The Clear Lake Volcanics is almost wholly of Quaternary age. Flow surfaces, volcanoes, cinder cones, obsidian domes, and craters retain their original

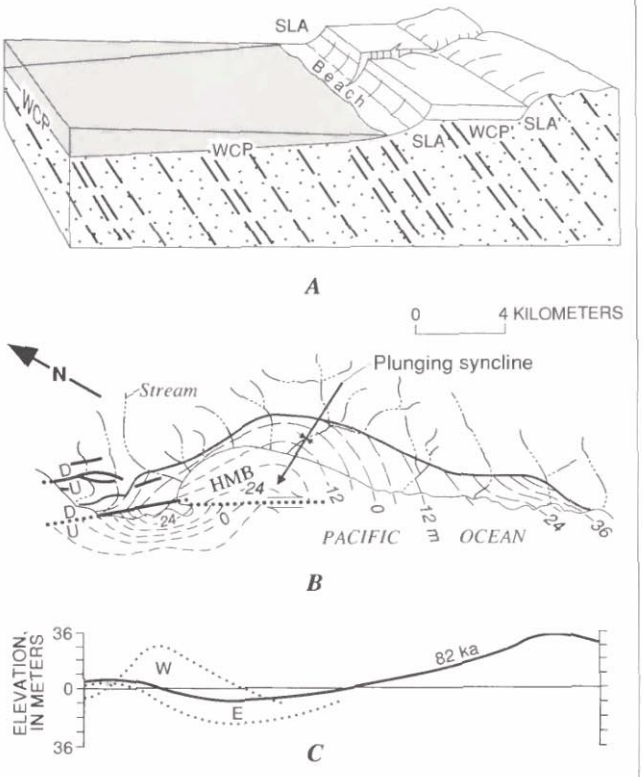

FIGURE 4.8.—Local variability in coastal uplift shown by deformed shoreline angle and wave-cut platform. *A*, Coastal geomorphic features used to measure Quaternary deformation. SLA, shoreline angle carved by marine erosion at present sea level; WCP, wave-cut platform; WCP′ and SLA′, elevated surface and shoreline angle, respectively, of an older wave-cut platform now mantled by marine terrace deposits and terrestrial sediment (light stippling). Normal seaward slope of wave-cut platform, exaggerated in diagram, is about 1°–2°. *B*, Folding and right-lateral faulting along the Seal Cove branch of the San Gregorio fault zone near Half Moon Bay (HMB), as shown by warped surface of an 82-ka wave-cut platform and deformation of its landward edge, the shoreline angle (heavy line). Structure contours (long dash on land, short dash off shore) on platform are derived from shallow boreholes and seismic-refraction data. Arrows on fault (dotted where concealed) indicate direction of relative movement: U, upthrown side; D, downthrown side. Modified from Lajoie (1986). *C*, Platform profiles on fault plane (dotted lines: E, east; W, west), showing vertical separation across fault and deformation relative to shoreline angle (heavy line). Modified from Lajoie (1986).

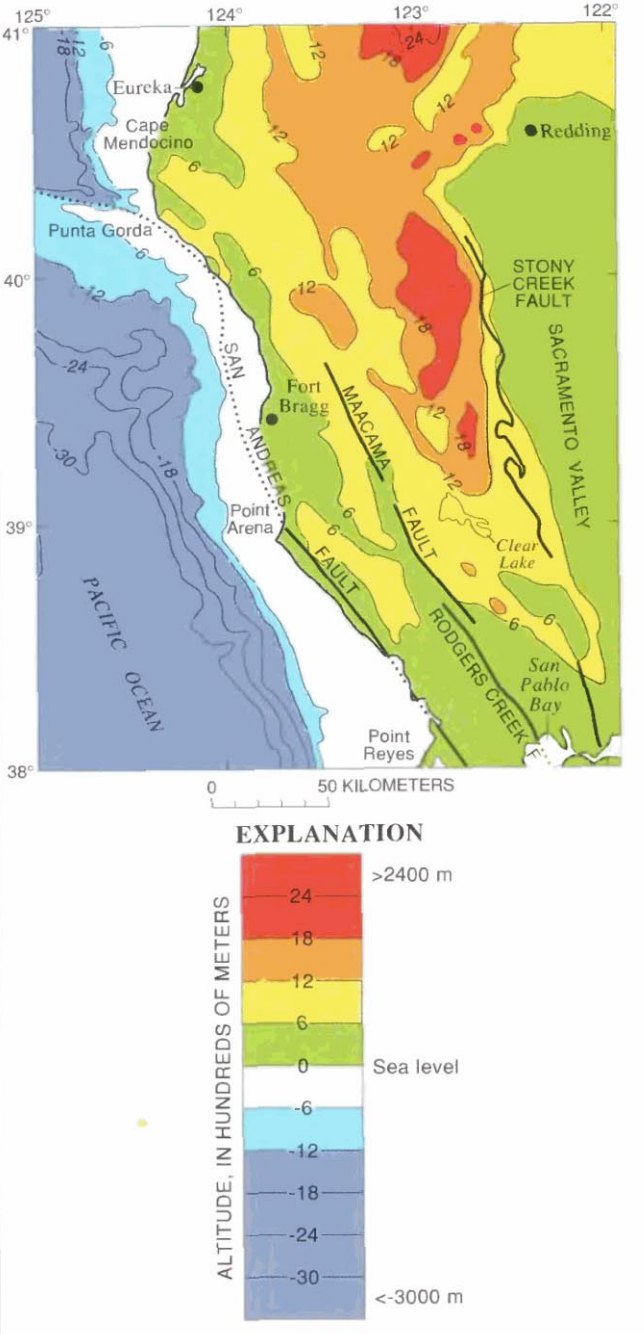

FIGURE 4.9.—Generalized surface on summit altitudes (*Gipfelflur*) in the Coast Ranges north of San Francisco, showing major faults with Quaternary activity in the San Andreas fault system—that part of the map south of Cape Mendocino and west of the Sacramento Valley. *Gipfelflur* approximately defines regions of Quaternary uplift and crustal blocks bounded by strike- and dip-slip faulting (dotted where concealed). Generalized from Wahrhaftig and Birman (1965).

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constructional form, and the Geysers Hot Springs area on the west side of the main volcanic field attests to continuing geothermal activity. Lava flows range in composition from olivine basalt to rhyolitic obsidian, and pyroclastic deposits are nearly as varied. The oldest well-dated rocks in the Clear Lake Volcanics yield K-Ar ages near 2.1 Ma; the youngest—ash beds in lake sediment beneath Clear Lake—yield ^{14}C ages of about 11 ka (Hearn and others, 1976; Sims and Rymer, 1975).

The sustained late Cenozoic volcanic episode recorded by the Sonoma and Clear Lake Volcanics is unique within the San Andreas fault system, although similar but less extensive Quaternary volcanism marks the northern end of the Gulf of California ridge-transform system in the Salton Trough (lat 33°19′ N., long 115°50′ W.).

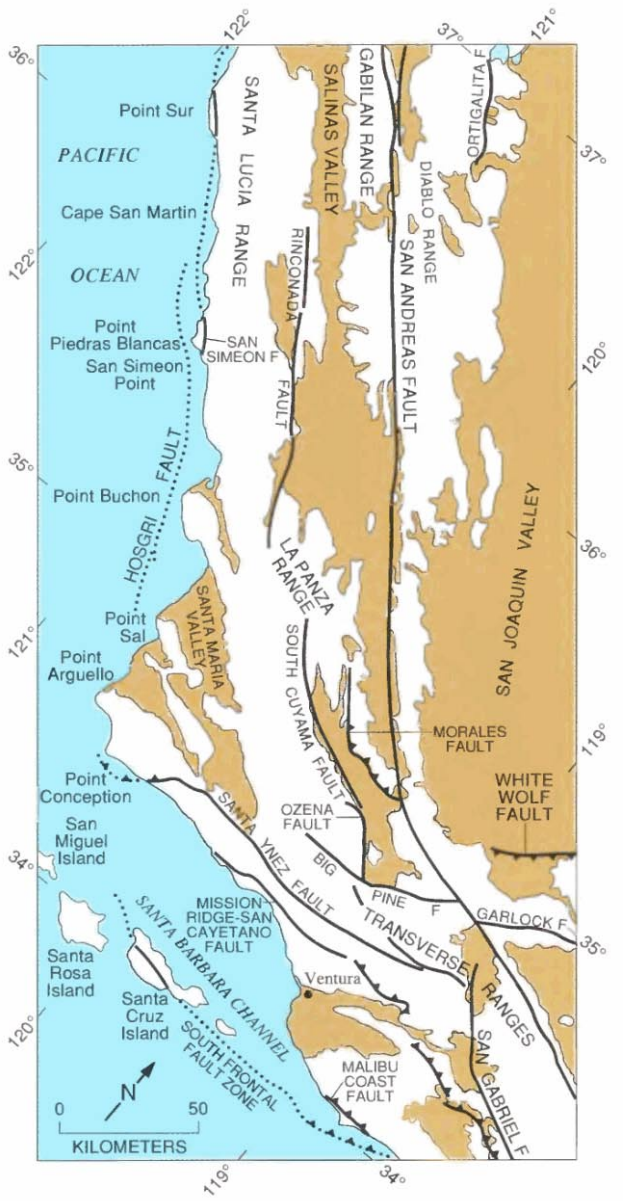
CENTRAL SECTION OF THE SAN ANDREAS FAULT SYSTEM

SAN ANDREAS FAULT

From the Gabilan Range southward to the Transverse Ranges, the San Andreas fault itself dominates the fault system. Except for the San Gregorio-Hosgri set of coastal faults, branch faults are few and short, and exhibit less evidence of Quaternary activity than those farther north. This relatively simple pattern changes at the northern margin of the Transverse Ranges, where major folds and faults trend more east-westerly and incorporate large components of reverse and thrust motion. In this chapter, faults in the western Transverse Ranges and southern Coast Ranges are grouped together as components of the central section of the San Andreas fault system. This combination of two different structural and physiographic provinces stresses that the transition from compressional structures in the Transverse Ranges to strike-slip structures in the Coast Ranges is more gradual and less sharply defined than the physiographic boundary.

This section of the fault system, 340 km long by 140 km wide, extends from the northern Gabilan Range to the southern Transverse Ranges, near lat 34° N. (fig. 4.10). Besides the San Andreas, faults with Quaternary slip include the Hosgri, San Simeon, and Rinconada in the north; the Big Pine, Ozena, South Cuyama, and Morales to the south and in the Coast Ranges; and the east-west-trending reverse and thrust faults in the Transverse Ranges. Several faults in the Transverse Ranges continue offshore into the Santa Barbara Basin.

The San Andreas fault trends S. 40° E. from the northern Gabilan Range to the Carrizo Plain; there, it bends eastward and ultimately attains a S. 75° E. trend in the Transverse Ranges. North of the bend, it follows a series of nearly aligned stream valleys, which separate the Diablo Range and parts of the Temblor Range on the



EXPLANATION

Alluvial and estuarine deposits (Quaternary)—Chiefly basin fill; may also include some deposits of Pliocene age

Bedrock (Tertiary and older)—Varied rock types

Fault exhibiting evidence of Quaternary displacement—Sawteeth on upthrown block of reverse or thrust fault; dotted where concealed by water

FIGURE 4.10.—Sketch map of southern Coast Ranges and western Transverse Ranges, southern California, showing faults with Quaternary activity and basin deposits in the central section of the San Andreas fault system. Fault patterns are generalized, and only major faults are shown.

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northeast from the Gabilan Range, Cholame Hills (lat 35°27′ N., long 120°18′ W.), and Caliente Range (lat 35°02′ N., long 119°46′ W.) on the southwest (Brown, 1970; Vedder and Wallace, 1970). An actively creeping length of the fault, with historical slip rates as high as 3.4 cm/yr, extends 160 km southward from the northern Gabilan Range to the south end of the Diablo Range.

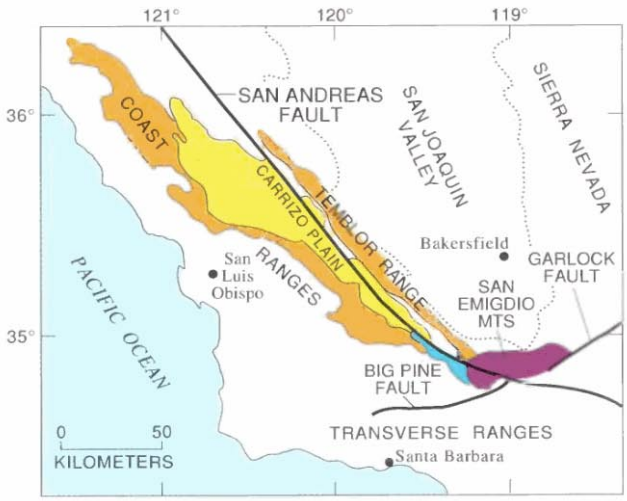
To the south, along the boundary between the Transverse Ranges and the Mojave Desert, the fault continues as a series of closely aligned echelon breaks, in a narrow (0.5 km wide) linear trench. This segment, which also displays abundant geomorphic evidence of Quaternary slip (Ross, 1969), is currently locked and seismically quiet.

Hill and Dibblee (1953, p. 446), in proposing large sustained strike slip on the San Andreas fault, described fault-juxtaposed gravels of similar age but different lithologies in the area between the Temblor Range and the Transverse Ranges (fig. 4.11). Pebble gravel in the Paso Robles Formation, of Pleistocene and Pliocene age, consists chiefly of porcellanite and siliceous shale clasts derived from the Miocene Monterey Formation of the western Coast Ranges and the Temblor Range. These distinctive Paso Robles gravel beds are most extensive southwest of the San Andreas fault, but northeast of the fault they extend as a narrow band to about lat 35° N. For several kilometers near this latitude, they are faulted against Pleistocene gravel containing clasts of plutonic and metamorphic rock and indurated sandstone, derived from the San Emigdio Mountains to the south. According to Hill and Dibblee (1953, fig. 2), the depositional contact between the two gravel lithologies is displaced about 16 km from its prefaulting location.

Farther north, between lat 35°30′ and 35°45′ N., Galehouse (1967, p. 974–976) described different clast compositions and heavy-mineral assemblages in Paso Robles strata on opposite sides of the fault. These differences are reasonably and consistently resolved if 40 km of right-lateral fault slip is removed, restoring the offset facies to their original positions.

These displaced stratigraphic relations imply Quaternary slip of 16 to 40 km, but the uncertain age of the faulted strata makes estimates of the slip rate unreliable. More accurate measurements of fault slip have been obtained at three localities north of the Transverse Ranges: two in the creeping segment and one in the more southerly, currently locked segment that produced the 1857 earthquake.

At the northernmost locality (lat 36°34.9′ N., long 121°10.4′ W.), along the San Benito River near the east boundary of the Gabilan Range, the fault displaces the risers of river terraces (fig. 4.12), exhibiting 64 m of right slip. Trenches on the terrace near the fault disclosed a fluvial scarp and a distinctive sand bed, both offset about 17.7 m by faulting during the past 790±144 ^{14}C yr



EXPLANATION

[Distribution of rock units shown only for region adjacent to San Andreas fault]

Coast Ranges

Paso Robles Formation (Pleistocene and Pliocene)—Chiefly gravel, sand, and clay; gravel clasts, derived from sources in the Coast Ranges and Temblor Range, consist chiefly of porcellanite and siliceous shale from the Monterey Formation

Monterey Formation (Miocene)—Well-bedded siliceous shale, porcellanite, and sandstone. Source unit for the type Paso Robles Formation of the southern Coast Ranges

San Emigdio Mountains

Deformed alluvial deposits of Vedder (1970) (Pleistocene)—Chiefly gravel and sand; gravel clasts, derived from sources in the San Emigdio Mountains, consist chiefly of plutonic and metamorphic rocks and indurated sandstone. Mapped by some authors as Paso Robles Formation

Plutonic, metamorphic, and sedimentary rocks (Paleogene and pre-Tertiary)—Source rocks for conglomerate near the San Emigdio Mountains

FIGURE 4.11.—Midway between Bakersfield and Santa Barbara, Calif., the San Andreas fault locally juxtaposes conglomerates of similar age but different lithologies. Porcellanite and siliceous shale clasts immediately northeast of the fault were derived chiefly from the folded and uplifted Monterey Formation in the southern Coast Ranges; plutonic, metamorphic, and sedimentary clasts across the fault to the southwest were derived from the San Emigdio Mountains of the northern Transverse Ranges. Total displacement and precise age of conglomerate units are unknown, but mapped offset of at least 16 km requires sustained Quaternary strike slip, as recognized by Hill and Dibblee (1953).

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(Perkins and others, 1989). The slip rate calculated from these data, about 2.2 cm/yr, agrees closely with creep rates currently observed along this section of the fault.

In Bitterwater Valley (lat 36°23.9′ N., long 120°58.9′ W.), 27 km southeast of the San Benito River locality, fault-displaced buried channels in an alluvial fan of Quaternary age record a slip rate over the past 1 ka of about 2.8 cm/yr (Cotton and others, 1986), but the slip rate, as well as its distribution within the fault zone, has varied over time. The historical slip rate, 3.4 cm/yr, represents chiefly gradual fault creep and is based on offsets observed in fences built in 1908 and in channels that presumably date from about 1885. According to Cotton and others (1986), at least one episode of slower movement is evident, and, during the past 1 ka, slip across the 20-m-wide fault zone has followed different breaks.

Sieh and Jahns (1984) measured and dated late Quaternary displacement on the San Andreas fault at Wallace Creek (lat 35°16.3′ N., long 119°49.7′ W.), near the southwestern margin of the Temblor Range. "Wallace Creek," an informal name (Sieh and Jahns, 1984, p. 896) for a previously unnamed drainage, does not appear on published U.S. Geological Survey topographic maps. At this locality, dated fan and channel deposits, stratigraphic and geomorphic relations, and fault offsets of both abandoned and existing stream channels document 128±1 m of strike-slip displacement (fig. 4.13). This record of cumulative fault slip began with incision of the existing channel of Wallace Creek sometime after 3,680±155 yr ago and ended with the nearly 10 m of fault slip that accompanied the 1857 earthquake. Because the 3,680-yr ^{14}C age is measured relative to A.D. 1950, the appropriate timespan for the measured slip is 3,680−(1,950−1,857), or 3,587 yr. The minimum rate is thus 128 m/3,587 yr, or 3.57±0.2 cm/yr; the maximum rate, based on the stratigraphy and geometry of the abandoned channel, is 3.53±0.2 cm/yr. When these maximum and minimum values are combined and adjusted to incorporate uncertainty in the state of strain at the beginning of the time interval, a preferred slip rate (Sieh and Jahns, 1984, p. 891) of 3.39 ± 0.3 cm/yr is obtained. A similar but more complex analysis of 13,250-yr-old fan deposits displaced 475 m from their source gullies yields a slip rate of 3.58±0.5 cm/yr (Sieh and Jahns, 1984, p. 891–892) for the past 13,250 yr. The close agreement of these rates suggests that the average rate of late

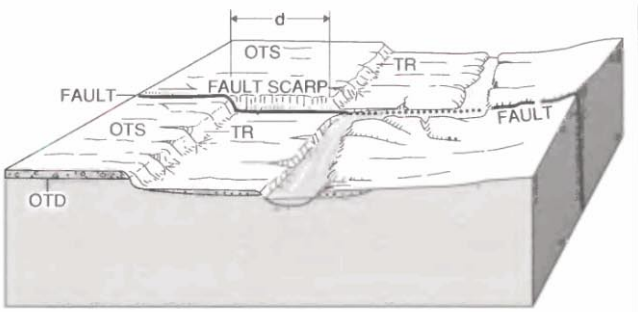

FIGURE 4.12.—Fault displacement (d) of stream-terrace risers (TR) postdates old terrace deposits (OTD), which underlie old terrace surface (OTS). Dating of terrace deposits gives a maximum age for displacement and thus a minimum slip rate for the fault (arrows indicate direction of relative movement; fault dotted where concealed by stream). The unrealistically simple relations shown in this sketch eliminate the effects of multiple terraces, changing rates of lateral erosion by the stream, and other processes that, under normal field exposures, make analysis much more difficult.

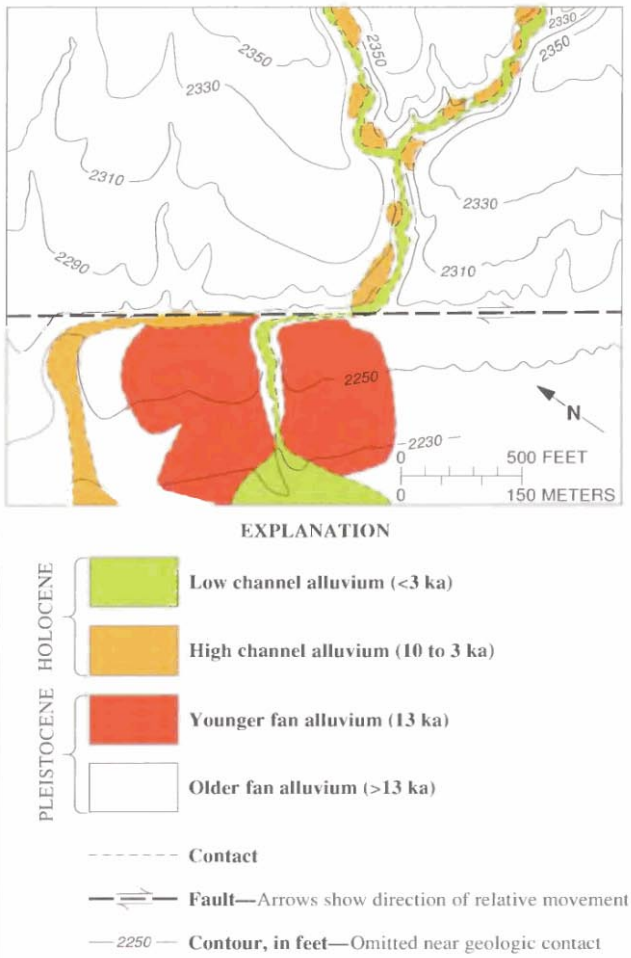

FIGURE 4.13.—Slip on the San Andreas fault at Wallace Creek (lat 35°16.3′ N., long 119°49.7′ W.) has displaced dated alluvial deposits, as well as stream channels and other geomorphic features. Trenches excavated across and parallel to fault at this locality disclose details of stratigraphy, origin of stratigraphic units, and their age as determined from detrital charcoal. Displacements of different ages yield similar average slip rates of about 3.4 cm/yr. Original source drainages for older fan alluvium are near or southeast of right margin of figure. Simplified from Sieh and Jahns (1984, fig. 2).

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Quaternary fault slip has been relative uniform at this locality.

Horizontal slip rates on the San Andreas fault are less well constrained in the western Transverse Ranges. Davis (1983, p. 368) and Rust (1982) independently estimated slip rates in the range 2–5 cm/yr for areas 70 km apart and on opposite sides of the junction of the Garlock fault with the San Andreas. These estimates involve substantial uncertainty in the amount and (or) timing of slip; they also apply to different parts of the Quaternary—no more than the past 400 ka for displaced gravel deposits in the San Emigdio Mountains (Davis, 1983), and no more than the past 2 ka for offset landslide deposits 32 km southeast of the Garlock-San Andreas fault junction (Rust, 1982). These rates, however, are broadly consistent with those measured to the north. Moreover, they indicate that much Quaternary strike slip in the western Transverse Ranges has followed the main trace of the San Andreas—a departure from pre-Quaternary history, when the San Gabriel fault to the southwest accommodated much of the fault slip (Crowell, 1975).

OTHER FAULTS

Other faults with known or probable Quaternary slip in the central Coast Ranges include the Rinconada, Big Pine, Ozena, South Cuyama, Morales, and a coastal fault defined by its aligned but separately named segments: Hosgri, San Simeon, Sur (lat 36°10.8′ N., long 121°32′ W.), Monterey Bay (lat 36°40′ N., long 122°06′ W.), and San Gregorio. For most of these faults, the evidence of Quaternary activity is sparse, discontinuous along strike, and in places arguable. It includes weakly expressed scarps and drainage offsets, displaced deposits of late Pliocene and Quaternary age, and historical seismicity along some fault trends. The geologic and geophysical evidence for Quaternary activity is somewhat more convincing for the Hosgri fault and its northern, colinear counterparts than for faults farther inland.

The Hosgri and similarly aligned coastal faults trend north-northwesterly from near Point Conception (Steritz and others, 1986) to the latitude of Monterey Bay (Silver and Normark, 1978), where they continue northward as the San Gregorio fault. For most of its length, this coastal fault zone is a complex, multistrand break a few kilometers off shore; it is recognized and mapped from juxtaposed stratal units interpreted from seismic-reflection profiles and truncated magnetic anomalies. Locally, seafloor scarps and displaced Holocene deposits, interpreted from the seismic-reflection profiles, confirm its Quaternary activity (Wagner, 1974; Leslie, 1981).

The San Simeon fault (fig. 4.14), which may be an onshore segment of the Hosgri (Leslie, 1981), is also a multistrand break; it cuts and displaces late Pleistocene marine terraces and Holocene dune sands near San Simeon Point (Weber, 1983). Although faulted shoreline-angle geometry and the correlation of wave-cut platforms across this fault are subject to some uncertainty, Weber (1983, p. 56–59) and Hanson and others (1987) suggested a horizontal right-slip component of about 0.5 cm/yr. Earthquake focal mechanisms along the San Simeon fault indicate a dip of 55° E. and nearly equal components of reverse and strike slip (Eaton, 1984). Right-oblique slip at a rate of about 0.5 cm/yr on the Hosgri fault is indicated by earthquake focal mechanisms, sea-floor scarps, the distribution of late Quaternary wave-cut platforms, and faulted seismic-reflection horizons of late Cenozoic age. Much of this evidence is documented from investigations near the Diablo Canyon Powerplant (Pacific Gas and Electric Co., 1988), where it has been interpreted as pure strike slip.

In the western Transverse Ranges, faults with Quaternary displacement include some, like the San Andreas and San Gabriel, that exhibit chiefly strike slip and others, trending east-west or southwest, that exhibit reverse or oblique slip. The left-lateral Santa Ynez fault is an exception to the more general pattern of reverse and thrust faults. The reverse- and oblique-slip faults in the Transverse Ranges are complicated by splays, offsets, and changes in strike, but from north to south they define at least four major continuous, or nearly continuous, fault zones of different lengths: the Santa Ynez (130 km); the More Ranch-Mission Ridge-San Cayetano (110 km), from the coast near Santa Barbara, eastward; the Mission Hills-San Fernando-Sierra Madre (56 km), along the southwest side of the San Gabriel Mountains; and the South Frontal (250 km). Many of these faults exhibit evidence of Holocene movement, and the San Fernando fault produced the surface rupture and destructive $M=6.6$ earthquake of February 1971. Some of these faults, and others with east-westward trends, extend offshore into the Santa Barbara Channel (lat 34°09′ N., long 119°33′ W.), where they also cut Pleistocene or Holocene deposits (Clarke and others, 1985). Ziony and Yerkes (1985, p. 43–60) provided more detailed descriptions and maps of the late Quaternary faults in this and nearby areas; they also noted (p. 44) a profound increase in deformation rates in and near the Transverse Ranges during the past 750 ka. This pulse of orogenic activity—manifested by the growth of folds, uplift, and accelerated slip on reverse and thrust faults—coincides with middle Pleistocene and younger deformation observed to the south (Woodford and others, 1954, p. 77–78) in the Los Angeles Basin.

Maximum and minimum slip rates for many of the faults in the Transverse Ranges are deduced from offsets observed in drainages, fan surfaces, river terraces, and wave-cut platforms. Reported by numerous investiga-

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tors (Clark and others, 1984), these rates of chiefly oblique slip cluster around a few tenths of a centimeter per year, but dip-slip components as great as 0.9 cm/yr are reported (Rockwell, 1988) for the San Cayetano fault. Observed slip rates may represent only a fraction of the total structural growth of the ranges because much of the late Quaternary deformation is by folding and uplift.

Although most Quaternary faulting south of the Gabilan Range is confined to structural blocks west and south of the San Andreas, two major faults, the Garlock and White Wolf, diverge northeastward from the San Andreas near the north boundary of the Transverse Ranges (fig. 4.10). Neither of these faults exhibits a clearly defined junction with the San Andreas, but together they

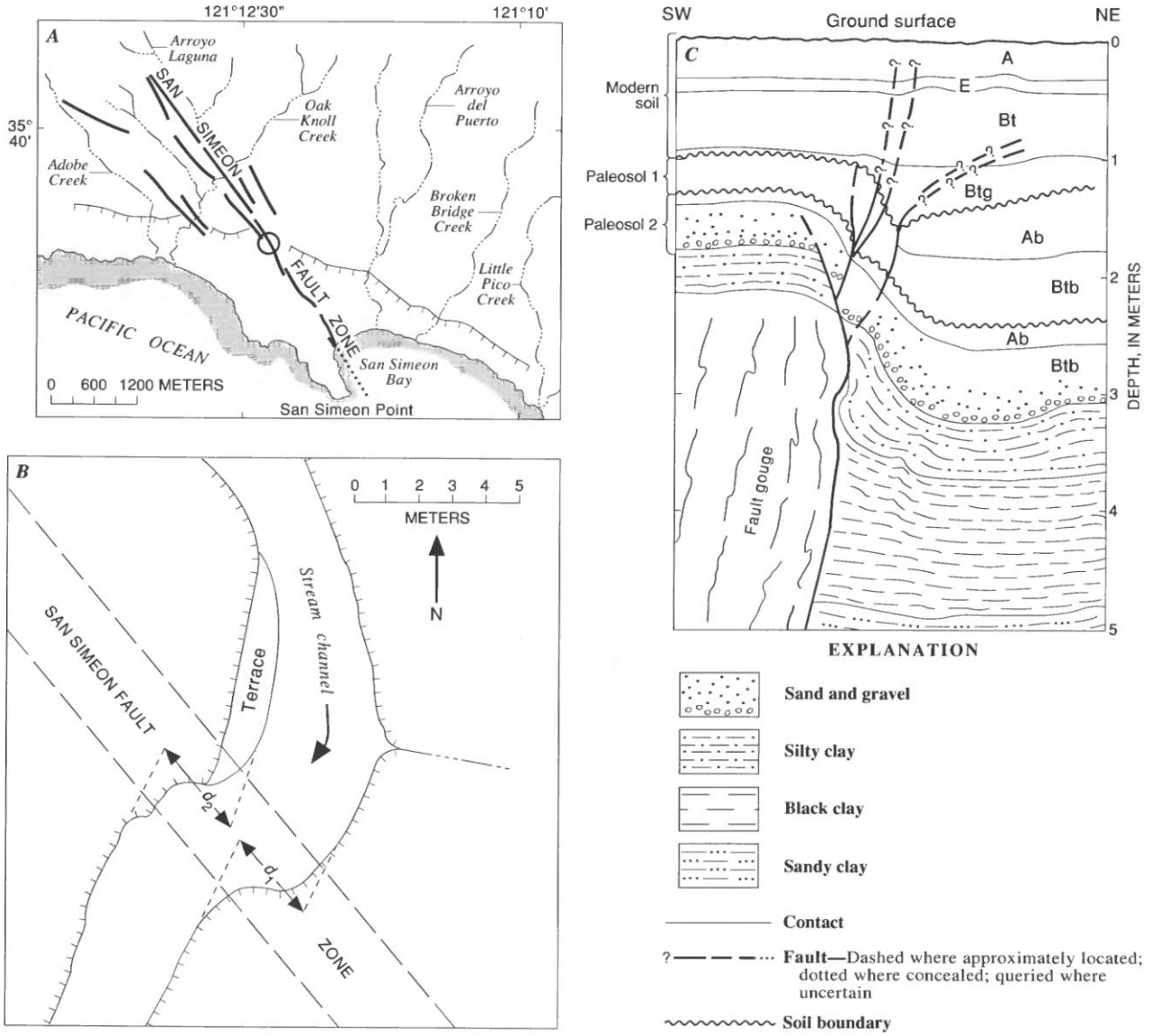

FIGURE 4.14.—Sketch maps and columnar section of San Simeon area, central California, showing selected examples of Quaternary faulting on the San Simeon fault zone. *A*, Displacement of shoreline angle (hachured line) of 124-ka wave-cut platform; other younger and older marine terraces, mapped by Weber (1983), are not shown. *B*, 3-m offset (d_1 and d_2) of stream channel near circled locality in figure 4.14*A*. *C*, Faulted paleosols and possibly faulted modern soil in trench exposure near circled locality in figure 4.14*A*; letters on right designate soil classifications. Quaternary strike-slip rate for this fault at the surface is about 0.5 cm/yr, but earthquake focal mechanisms (Eaton, 1984) indicate right-reverse slip at 6.6-km depth. From Pacific Gas and Electric Co. (unpub. data, 1986; see Pacific Gas and Electric Co., 1988).

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bound the horstlike block of Sierran basement that makes up the Tehachapi Mountains. The White Wolf, a southeast-dipping reverse fault that was the source of the Kern County $M=7.7$ earthquake of July 1952, exhibits geomorphic evidence of recent slip at the range front but is concealed to the west beneath the southern San Joaquin Valley. The Garlock, devoid of major historical seismicity, exhibits clear evidence of left-lateral Quaternary slip (Clark, 1973) that increases eastward from 0.2 cm/yr at a point 55 km east of the San Andreas to 1.1 cm/yr at a point 75 km to the east (Clark and others, 1984).

FOLDING AND UPLIFT

Typically, Quaternary folds are more intense and better defined in thick Tertiary marine sequences than near or above such basement blocks as the granitic and metamorphic complexes of the Santa Lucia, La Panza, and Gabilan Ranges or the Franciscan core of the Diablo Range. Thus, some of the best expressed Quaternary folds are in the western Transverse Ranges (Bailey and Jahns, 1954, p. 95–98), the west side of the San Joaquin Valley (Harding, 1976), the Santa Maria Basin (Woodring and Bramlette, 1950, p. 109–116), and the southeast flank of the Santa Lucia Range (Compton, 1966). Harding (1976) used subsurface geologic data from oil fields northeast of the San Andreas fault to demonstrate that folding has moved outward from the San Andreas over time—the more northeasterly folds along the west side of the San Joaquin Valley being the youngest.

Rates of Quaternary folding in the westernmost Transverse Ranges exceed those elsewhere in the fault system. On the coast near Ventura (lat 34°07′ N., long 119°18′ W.), Pleistocene basin deposits more than 4 km thick have been intensely folded and faulted during the past 200 ka, attaining dips of 32°–45° in the southern limb of the Ventura Avenue anticline (fig. 4.15); uplift rates of about 1 cm/yr (Yeats, 1977; Lajoie and others, 1982) characterize the axis and southern limb of this fold. Uplift and folding elsewhere in the western Transverse Ranges may be slower but probably still exceeds deformation rates elsewhere in the fault system.

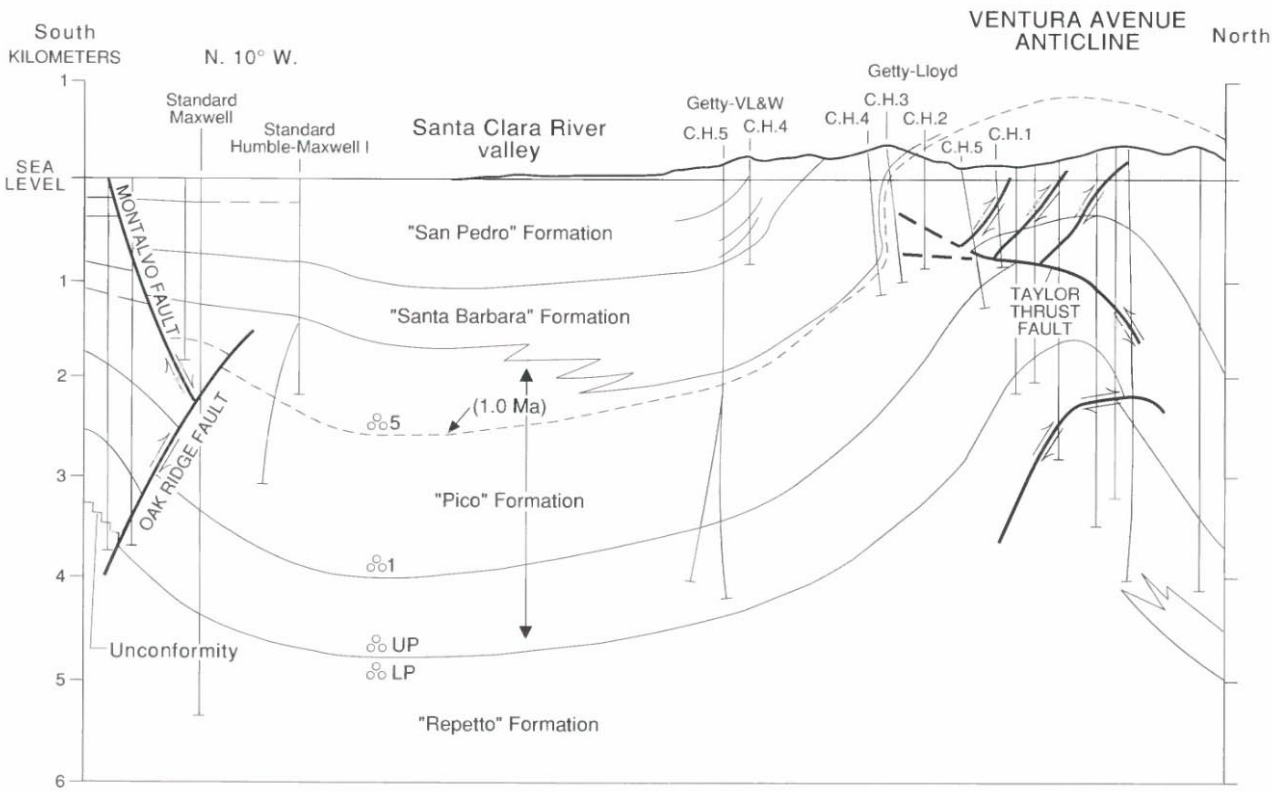

FIGURE 4.15.—Many drill holes penetrate well-dated Quaternary strata near the Ventura Avenue anticline. Besides the provincial microfaunal control shown here (3 small circles), Lajoie and others (1982b) employed a marine terrace (0.1–0.08 Ma) and 3 ash beds (0.6, 0.7, and 1.2 Ma) in the "San Pedro," "Santa Barbara," and "Pico" Formations of Yeats (1982) to estimate an average uplift rate of 1.25 cm/yr at the fold crest during the past 200 ka. Nearly all of this uplift is Quaternary in age; most is late Quaternary, as this highly generalized figure shows. Modified from Yeats (1982, fig. 7). Contacts and faults dashed where approximately located; arrows on faults indicate direction of relative movement. C.H., corehole; LP, lower Pliocene; UP, upper Pliocene; 1 and 5, provincial microfaunal markers.

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Evidence for Quaternary uplift in this part of the San Andreas fault system is abundant and varied. High-standing ranges (Diablo, Santa Lucia, La Panza, and Transverse) emerge from a cover of their own eroded debris, represented by the Paso Robles Formation of the Coast Ranges, the Tulare Formation of the San Joaquin Valley and northern San Emigdio Mountains, and the Saugus Formation (and equivalent marine deposits) of the western Transverse Ranges. These upper Tertiary and Quaternary strata consist chiefly of alluvial debris, which has been deposited in fans, channels, and flood basins. Although the stratified deposits have been tilted, uplifted, and eroded (Bailey and Jahns, 1954; Christensen, 1965; Compton, 1966; Yeats, 1977; Davis, 1983), the map pattern of their remnants documents regional patterns of uplift.

Christensen (1965) employed such evidence (fig. 4.16) to document uplift of 600 m in the Diablo, Santa Lucia, and La Panza Ranges and to establish general system-wide uplift, north of the Transverse Ranges, of about 300 m. This broad pattern of late Pliocene and Quaternary uplift is reversed chiefly in the Salinas and Santa Maria Valleys (lat 36°09′ N., long 121°09′ W., and lat 34°34′ N., long 120°15′ W.), Kettleman Plain (lat 35°55′ N., long 120°05′ W.), and southern San Joaquin Valley, where elongate deep (100–900 m) but local basins have formed at the edge of basement blocks.

Late Pliocene and Quaternary uplift of the northern San Emigdio Mountains totals about 1,800 m (Davis, 1983, p. 299–300), the present average height of a Pliocene erosion surface preserved on accordant ridge crests near the summit of the mountains. Relatively rapid uplift of the western Transverse Ranges was also accompanied by local downwarping of narrow basins—for example, the offshore Santa Barbara Basin and the Santa Clara River valley (fig. 4.15) east of Ventura.

Evidence that uplift is still continuing is found in raised, paired stream terraces and youthful drainage patterns in the Santa Lucia, Diablo, and western Transverse Ranges, in elevated Holocene marine terraces near Ventura (Lajoie and others, 1982), and in the radially segmented slopes of Holocene alluvial fans that record progressive episodes of deformation along the east front of the Diablo Range (Bull, 1964).

SOUTHERN SECTION OF THE SAN ANDREAS FAULT SYSTEM

SAN ANDREAS FAULT

South of the Transverse Ranges, the San Andreas fault system (fig. 4.17) extends to the latitude of the Salton Sea as a broad belt of northwest-trending strike-slip faults bounded on the northeast by the San Andreas and on the southwest by the offshore Santa Cruz-Catalina Ridge fault zone. Between the Salton Sea and the Gulf of California, the San Andreas fault system merges with a complex pattern of active ridge segments and transform faults that continues beneath the gulf for more than 1,200 km (see chap. 3). Alluvium of the Colorado River, lake deposits, and the waters of the gulf obscure the transition

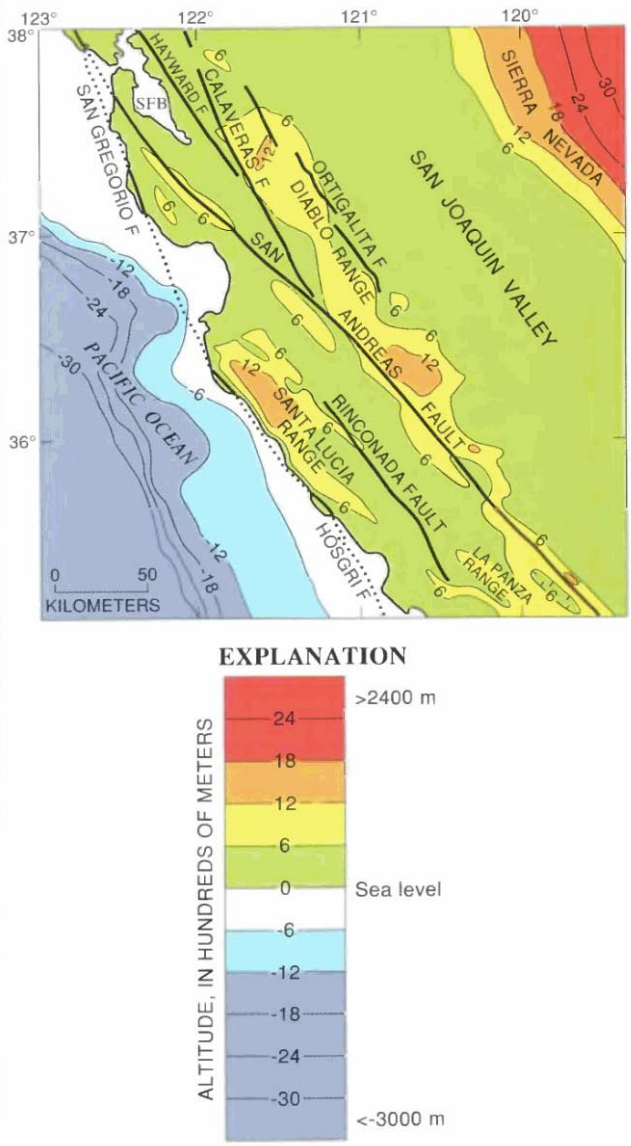

FIGURE 4.16.—Generalized topographic map of central California between the San Francisco Bay (SFB) and the La Panza Range, showing major faults with Quaternary activity in the San Andreas fault system. Modified from Christensen (1965, pl. 1). Faults dotted where concealed by water; hachures on contours indicate area of closed low. Compare with figure 4.9.

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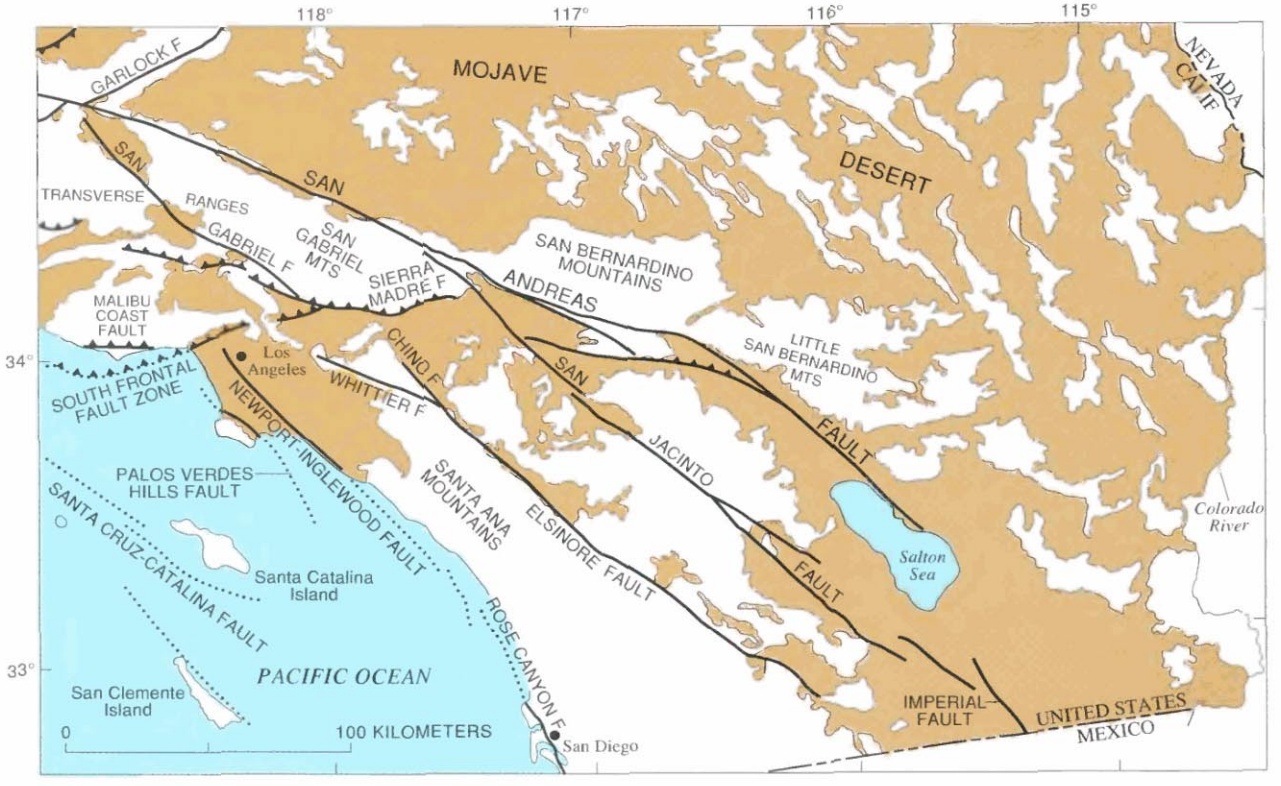
from the San Andreas pattern of deformation, dominated by northwest-trending strike-slip faults, to the ridge-transform pattern of the gulf, but current practice (see chap. 3; Crowell, 1981, p. 596–597) places the south boundary of the fault system near the latitude of the Salton Sea. Thus defined, the southern section of the San Andreas fault system is about 200 km long by 150 to 175 km wide.

Late Quaternary faulting in this region follows several major breaks, of which the San Andreas is the most easterly and most active. The dominant role of the San Andreas fades south of Cajon Canyon (lat 34°18′ N., long 117°28′ W.), where the San Jacinto fault diverges from it, and farther south along the south front of the San Bernardino Mountains, where it merges into the Banning and Mission Creek reverse faults (lat 33°56′ N., long 116°47′ W., and lat 34°00′ N., long 116°33′ W.). Despite such complexities, continuity of Quaternary faulting on the main San Andreas can be traced at least as far south as the Salton Sea.

Large increments of Quaternary strike slip on the segment of the San Andreas fault along the San Gabriel Range front near Palmdale (lat 34°34′ N., long 118°07′ W.) were first recognized by systematic right-lateral stream offsets and by Pleistocene fan and terrace deposits displaced 2 to 8 km from their source regions across the fault (Wallace, 1949, p. 799–802; Noble, 1954, p. 46). Underlain by distinctive bodies of plutonic and metamorphic rocks, the ranges have contributed eroded debris to fans that spread across the range-front faults. Subse-



EXPLANATION

Alluvial and estuarine deposits (Quaternary)—Chiefly basin fill; may also include some deposits of Pliocene age

Bedrock (Tertiary and older)—Varied rock types

Fault, exhibiting evidence of Quaternary displacement—Sawteeth on upthrown block of reverse or thrust fault; dotted where concealed by water

FIGURE 4.17.—Sketch map of the eastern Transverse Ranges, Mojave Desert, and Salton Trough area, southern California, showing faults with Quaternary activity and basin deposits in the southern section of the San Andreas fault system. Fault patterns are generalized, and only major faults are shown.

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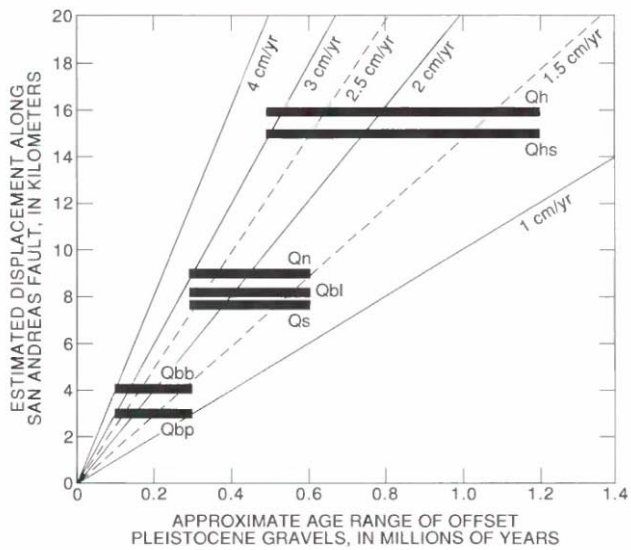
quent strike slip along these faults has displaced the distal parts of the fans laterally, separating them from their source rocks and opposing them against unlike rock types in nearby parts of the range front. Recent mapping (Barrows and others, 1985, p. 195–197) along the fault segment first described by Wallace (1949) and Noble (1954) constrains the slip rate there to values of 1.5 to 3.0 cm/yr (fig. 4.18).

Most historical slip on the San Andreas fault has accompanied earthquakes of $M \geq 6$. A remarkable record of earlier earthquake-related faulting has been interpreted (Sieh, 1978, 1984; Sieh and others, 1989) from natural and manmade exposures across the fault at Pallett Creek, about 55 km northeast of Los Angeles, within the eastern part of the segment mapped by Barrows and others (1985). At Pallett Creek, Sieh described sandblows and other liquefaction structures, buried scarps, and truncated fault strands in dated peat and alluvium that record (fig. 4.19) a history of 12 earthquakes during the past 1,700 yr. The latest 10 episodes of faulting establish an average recurrence interval of about 132 yr (Sieh, 1989) but show an irregular, clustered distribution over time for large earthquakes on this section of the fault.



EXPLANATION

Qh	**Harold Formation (undifferentiated)**
Qhs	**Harold Formation (schist and sandstone clast member)**
Qn	**Nadeau Gravel**
Qbl	**Boulder gravel (Little Rock Creek)**
Qs	**Shoemaker Gravel**
Qbb	**Boulder gravel (Big Rock Creek)**
Qbp	**Boulder gravel (Pallet Creek)**

FIGURE 4.18.—Estimated ranges in strike-slip rate on a 90-km segment of the main San Andreas fault north of Los Angeles. Stratigraphic nomenclature (from Barrows and others, 1985, fig. 4) identifies lithologically distinctive Quaternary deposits that have been horizontally displaced by fault slip on the San Andreas fault system.

Slip rates along the San Andreas south of Pallett Creek are lower than those in the central section of the fault system; in part, this difference is accounted for by slip on the San Jacinto and other, more westerly faults.

A site on the San Andreas fault in Cajon Canyon (lat 34°16.4′ N., long 117°27.9′ W.) about 100 km east of Los Angeles, establishes a consistent slip rate (Weldon and Sieh, 1985) for the late Pleistocene and Holocene time. Along Cajon and Lone Pine Creeks, the fault displaces terrace risers, buried and active stream channels, and landslides. The alluvial and swamp deposits have yielded 14 ^{14}C ages. These dated fault displacements, in combination with a reconstructed fluvial history of the site, provide four independent measurements of fault slip that document an average slip rate for the past 14.4 ka of 2.5±0.4 cm/yr (fig. 4.20; Weldon and Sieh, 1985).

Harden and Matti (1989) reported slip rates that are less well constrained and possibly more variable for the San Andreas fault near Yucaipa, 45 km southeast of Cajon Canyon. There, displaced alluvial fans yielded average slip rates of 1.4 to 2.5 cm/yr for the past 14 ka, 2.2 to 3.4 cm/yr for the past 30 ka, and 1.2 to 1.6 cm/yr for the past 65 or 90 ka. These rates imply an accelerating rate of latest Quaternary slip, but uncertainties in measurements of displacement and age permit rates that are constant or even diminishing over time.

Paired stream offsets along the southern branch of the San Andreas fault (lat 34°07.5′ N., long 117°10.0′ W.), between Yucaipa and Cajon Canyon and in San Bernardino (lat 34°06′ N., long 117°17′ W.), indicate a maximum slip rate of 2.5 cm/yr (Rasmussen, 1982, p. 112) based on estimated ages of 30 and 50 ka for faulted alluvial units. If, as Rasmussen suggested, these are minimum ages, the actual slip rate may be somewhat lower.

On the San Andreas fault and about 30 km north of the Salton Sea (lat 33°46.9′ N., long 116°14.4′ W.), Keller and others (1982) mapped a total offset of 700 m where two strands of the fault cut an alluvial fan. Soils developed on the fan surface indicate an age of 30 to 20 ka, bracketing the slip rate between 2.3 and 3.5 cm/yr. At a nearby locality, a rate of only a few tenths of a centimeter per year can be derived from displaced (1 m) sedimentary deposits associated with the latest highstands of former Lake Cahuilla, 700–300 yr B.P. (Sieh, 1981). These deposits, however, may be too young to record slip accompanying large earthquakes with recurrence times longer than 700 yr.

The San Andreas follows the east side of the Salton Sea southward for about 30 km; its trace is marked by offset

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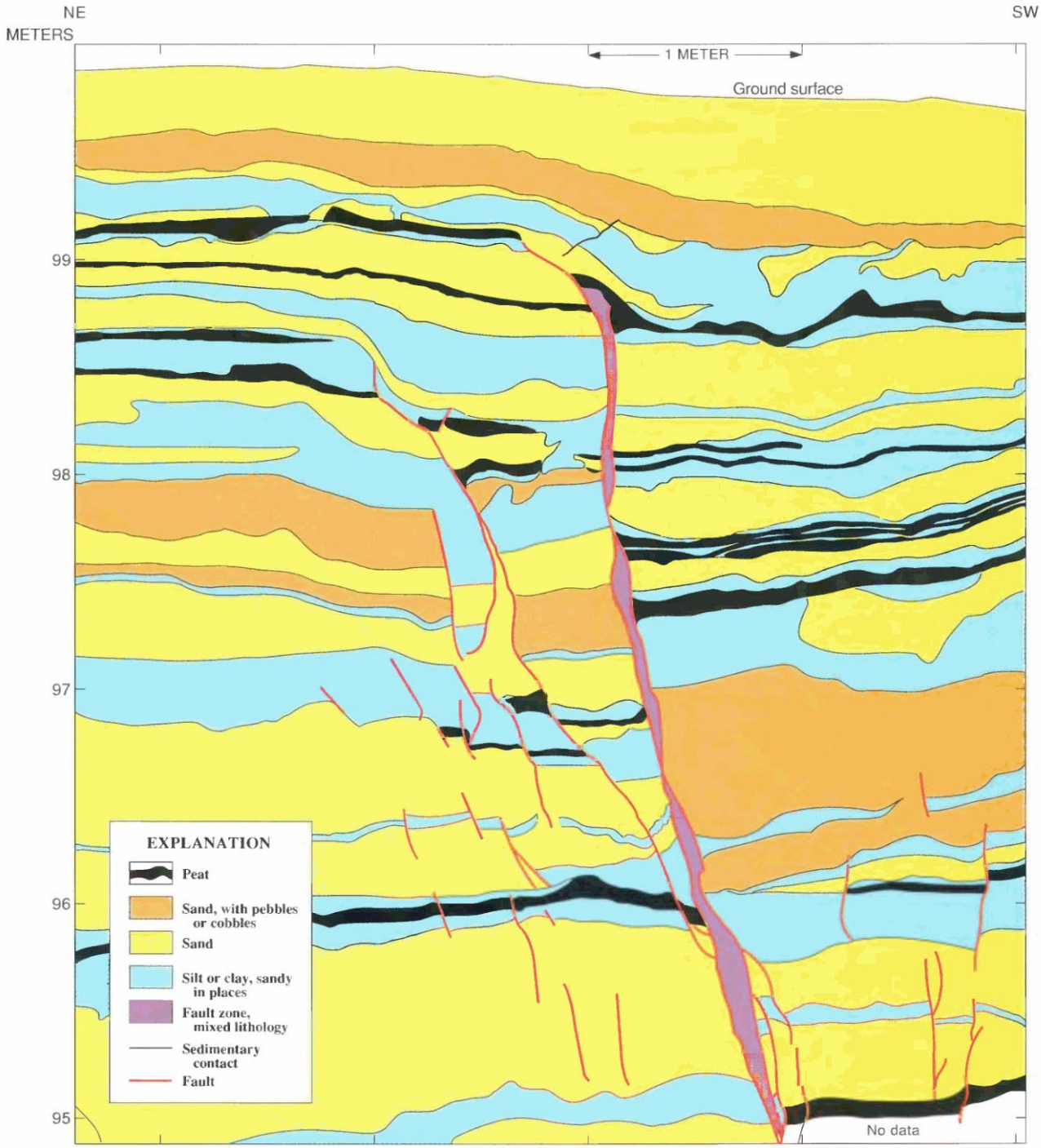

FIGURE 4.19.—San Andreas fault exposed in southeast wall of a trench at Pallett Creek, Calif., 55 km northeast of Los Angeles. Black strata are peat layers, datable by ^{14}C methods, that show increasing amounts of vertical displacement with depth, owing to cumulative slip from repeated earthquakes. Vertical component of displacement visible here is a few percent of net displacement, which is chiefly strike slip, approximately normal to trench wall, with block on right moving toward observer. Uppermost, unfaulted deposits postdate 1857 earthquake; lowermost peat bed on southwest side of fault was deposited about A.D. 800. Modified from Sieh (1978).

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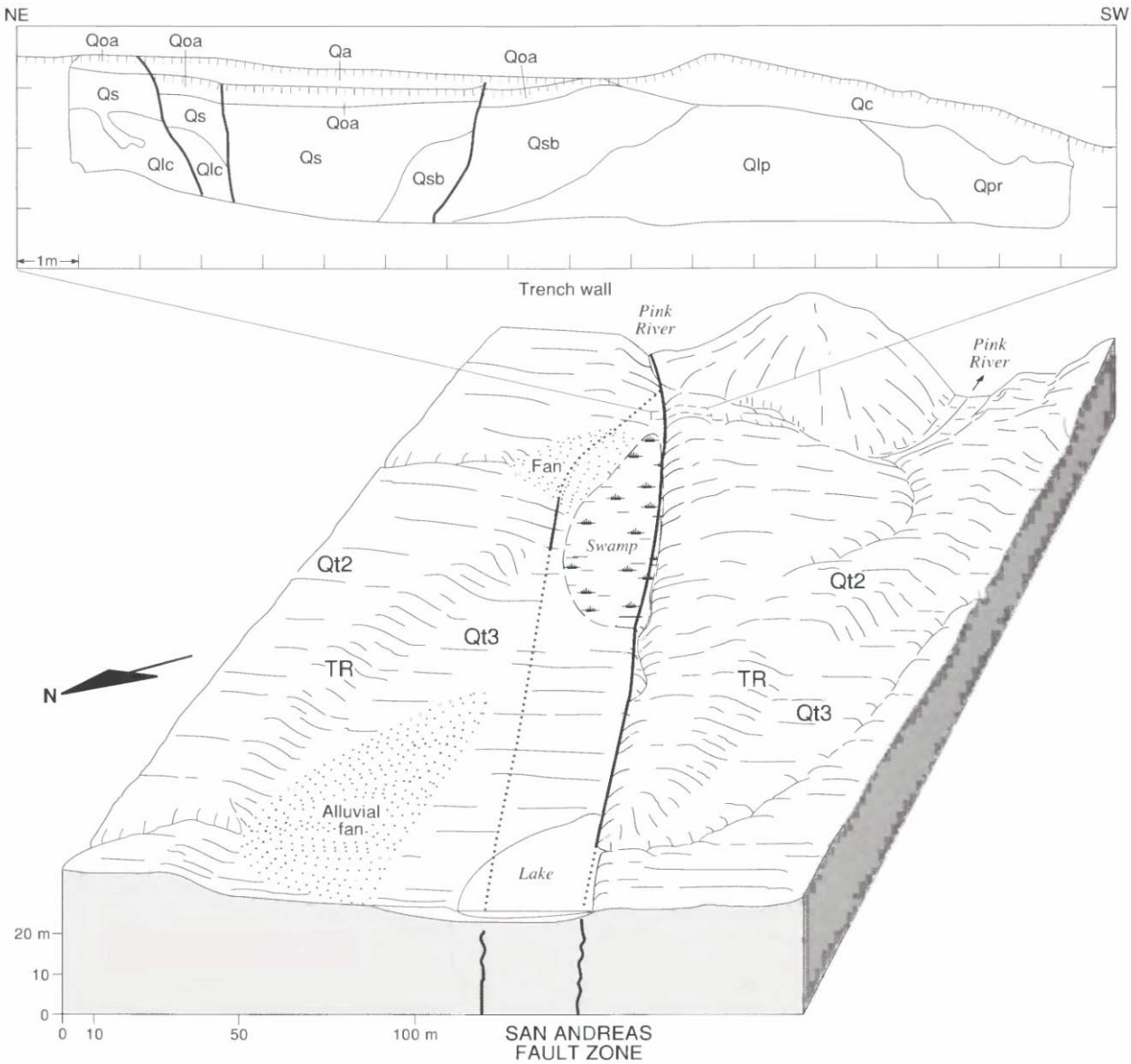

EXPLANATION

[Units exposed in trench wall]

Qc	**Colluvium (Holocene)**
Qa	**Alluvium (Holocene)**—A.D. 1725-1805 near base
Qoa	**Older alluvium (Holocene)**
Qsb	**Fault-scarp breccia (Holocene)**
Qs	**Organic-rich sandy clay; swamp deposits (Holocene)**—~ 2,510-500 yr B.P., in part contemporaneous with unit Qsb
Qlc	**Lake clay (Holocene)**—~ 8,350-2,500 yr B.P.
Qpr	**Channel fill of Pink River (Holocene)**
Qlp	**River gravels of Lone Pine Creek (Pleistocene)**—~ 13,000 yr B.P.

Contact—Hachures indicate ground surface or buried ground surface

Fault—Dotted where concealed

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Holocene features and at least two historical slip events (Sharp, 1982, p. 9). Farther south, in the Imperial Valley, evidence of surface faulting disappears, and a 40-km gap separates the south end of the San Andreas from the north end of the Imperial fault. This gap, nearby geothermal and volcanic activity, and the broad structural trough occupied by the Salton Sea and the Imperial Valley indicate a major change in deformation processes and a transition from the San Andreas fault system to the ridge-transform system of the Gulf of California.

OTHER FAULTS

The seismically active San Jacinto fault diverges from the San Andreas northwest of Cajon Canyon and follows a nearly straight course for 215 km, ending along the southwest side of the Salton Trough. On small-scale maps, it appears as a linear southward extension of the San Andreas segment bounding the San Gabriel Mountains—a simpler, more direct break than the arcuate, branching pattern of the nearly parallel San Andreas, 45 km to the northeast. Geomorphic and geologic evidence of Quaternary strike slip (Sharp, 1967, 1972, 1981) resembles that for the main San Andreas, but locally vertical motion, southwest side up, may account for as much as 10 percent of the net slip.

Sharp (1981) determined minimum slip rates for two active segments of the San Jacinto fault zone: the Clark fault near Anza Valley and the Coyote Creek fault, 80 km farther south. At the Anza Valley locality (lat 33°34′ N., long 116°39′ W.), the base of a distinctive gravel marker bed, displaced at least 5.7 km from its source terrane of schist, gneiss, and amphibolite, overlies 30 m of sediment which, in turn, overlie a rhyolite ash layer dated at 730 ka and correlated with the air-fall ash at the base of the Bishop Tuff. Geologic data require a slip rate of at least 0.8 cm/yr (Sharp, 1981, p. 1755–1757), and a higher rate, as high as 2.5 cm/yr, is possible (R.V. Sharp, in Clark and others, 1984). North of Anza, geologic relations during the past 30 ka yield evidence of average slip rates of 1.2 to 1.7 cm/yr (Merifield and others, 1987) for this fault. The minimum Holocene slip rate for the past 6 ka on the Coyote Creek fault—derived from a 14C-dated, displaced channel margin (lat 33°05.4′ N., long 116°02.7′ W.)—is 0.3 cm/yr, but a much higher rate is possible (R.V. Sharp, oral commun., 1986). Upper limits for the slip rate on the San Jacinto fault (Prentice and others, 1986; Rockwell and others, 1986; Merifield and others, 1987) thus range from 1.0 to 1.7 cm/yr, in close agreement with Sharp's (1981) estimate of 0.8 to 1.2 cm/yr for the late Quaternary.

The Elsinore fault and its northern branches, the Whittier and Chino faults, lie about 35 km to the southwest of the San Jacinto fault. Seismic activity, occurring chiefly as small earthquakes, increases southward, but the strongest evidence for Quaternary faulting is along the north half of the fault, where Kennedy (1977) and Ziony and Yerkes (1985, table 5) reported examples of offset stratigraphy and landforms. South of lat 33°30′ N., evidence of recent movement on the fault is sparse and widely spaced (Clark, 1975), although faulted Holocene fan deposits within 25 km of the United States-Mexican border indicate a strike-slip rate of about 0.4±0.1 cm/yr (Pinault and Rockwell, 1984).

South of its junction with the northeast-dipping Whittier reverse fault, the northern section of the Elsinore fault displays consistent evidence of oblique, dominantly horizontal slip. The vertical component is up to the southwest (Jahns, 1954, p. 45–46; Kennedy, 1977; Heath and others, 1982), as it is along the San Jacinto fault. For 100 km, the northern section of the Elsinore fault follows the northeast front of the Santa Ana and Elsinore Mountains, juxtaposing a thick Quaternary sedimentary fill on the northeast against pre-Tertiary crystalline and sedimentary rocks in the mountain blocks. South of Lake Elsinore (lat 33°39′ N., long 117°21′ W.), a facies boundary between sandstone and conglomerate, dated at about 700 ka by a layer of the Bishop Tuff, is offset 5 km (Kennedy, 1977, p. 5, 9), indicating a strike-slip rate of 0.7 cm/yr. North of Lake Elsinore, Millman and Rockwell (1985) reported at least 1.6 km of strike-slip offset since the middle Quaternary, equivalent to a minimum slip rate of about 0.2 cm/yr. These observations and other geologic and geomorphic evidence along the fault suggest that the component of horizontal slip on the northern section of the Elsinore fault during the late Quaternary has been somewhat less than on the San Jacinto and probably does not exceed 0.7 cm/yr.

The Newport-Inglewood zone of deformation (Hill, 1971, p. 2958), 40 km southwest of the Elsinore fault, is a narrow (1–3 km wide) belt of echelon folds and

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FIGURE 4.20.—Near Cajon Canyon, 75 km east-northeast of Los Angeles, a displaced terrace riser (TR) between two Quaternary terrace levels (Qt2 and Qt3 of Lone Pine Creek, out of view in foreground) records slip on the San Andreas fault. Sketch, based on a planetable map (Weldon and Sieh, 1985, fig. 5), exaggerates relief by about 1.4×; terrace risers actually slope no more than 25°. Relations used to establish Holocene history of faulting and a slip rate of about 2.5 cm/yr are derived from trench-wall exposures, here generalized from Weldon and Sieh (1985, fig. 12), and from geomorphic and stratigraphic evidence of stream piracy and other fluvial processes.

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left-stepping fault segments, characterized by oblique right slip, chiefly down to the west (Harding, 1973, fig. 5). This zone contains six major oil fields, within which subsurface structural relations in upper Cenozoic strata are well defined by drilling. Quaternary folding and faulting is expressed as an aligned series of anticlinal hills and by deformed and faulted upper Pliocene and Pleistocene deposits (Poland and others, 1959; Barrows, 1974). The overall structural trend is commonly mapped as the Newport-Inglewood fault (fig. 4.17), but individual segments are less continuous and less closely aligned than along other major strike-slip faults in the San Andreas system. Moreover, many anticlines along the zone retain their original ellipsoidal form even where they are cut by strike-slip faults (Harding, 1973, figs. 2, 4, 7, 9–15).

The onshore, northern part of the Newport-Inglewood fault zone extends 65 km from the Santa Monica Mountains (lat 34°03′ N., long 118°24′ W.) at the southern margin of the Transverse Ranges southeastward to Newport Beach. Farther southeast, the offshore part of the zone continues for about 70 km, defined by folding and faulting in Tertiary and Quaternary deposits (Clarke and others, 1985, p. 359) beneath the sea floor. Whether this zone of deformation is continuous with aligned but more distant offshore faults, such as the Rose Canyon fault near San Diego, is unresolved; if the zone is continuous, its overall length is at least 240 km.

Aligned swales and discontinuous eroded scarps, a few meters to as much as 80 m high, delineate individual fault segments; many of these scarps cut folded Pleistocene deposits. At the Inglewood and Long Beach oil fields on the northern, onshore part of the fault, folding and faulting are nearly as great in upper Pliocene strata as in older rocks (California Division of Oil and Gas, 1961, p. 577, 595), indicating that most of the deformation is Quaternary in age. Historical faulting is evident from the 1933 Long Beach earthquake (M=6.3) on an offshore segment of the zone, and from faulted artificial fill near Newport Beach (lat 33°22′ N., long 117°33′ W.) (Guptill and Heath, 1981). The horizontal slip in upper Pliocene strata, estimated from offset fold axes and from structure-contour maps of producing zones in faulted anticlines (Poland and others, 1959, p. 75; California Division of Oil and Gas, 1961), is about 1.5 km, equivalent to a slip rate of less than 0.1 cm/yr. Vertical components of slip are about a fifth as large, and vertical separation of faulted basal Pleistocene deposits rarely exceeds 60 m (Yerkes and others, 1965, p. A48).

West of the Newport-Inglewood fault zone, northwest-trending faults that exhibit evidence of Quaternary slip (Clarke and others, 1985, fig. 185) include the Palos Verdes Hills fault, and the offshore San Pedro Basin and Santa Cruz-Catalina Ridge faults. The direction and amount of Quaternary displacement on these faults are ill defined, but they probably have strike-slip components smaller than those on the San Jacinto and San Andreas faults.

Many northwest-trending faults end near the 34th parallel against a major structural boundary that extends westward 250 km from the San Jacinto fault to Santa Cruz Island. This boundary separates the east-west-trending structures of the Transverse Ranges, Santa Barbara Basin, and northern Channel Islands (lat 34° N., long 120° W.) from northwest-trending structures to the south; it also separates higher land and sea floor to the north from lower to the south. A north-dipping zone of aligned or echelon faults (Yerkes and Lee, 1987; Ziony and Jones, 1988), here named the "South Frontal fault zone" (of the Transverse Ranges block), follows the structural boundary and includes, from west to east, the Santa Cruz Island, Anacapa, Santa Monica, Hollywood, Raymond, Sierra Madre, and Cucamonga faults. All of these faults are down to the south, all exhibit evidence of Quaternary activity, and many have been active during the Holocene. The San Fernando fault, an element of the Sierra Madre trend, was the source of the damaging M=6.6 San Fernando earthquake in 1971.

Slip rates on the South Frontal fault zone are probably lower than 0.5 cm/yr but are difficult to measure because most of the best exposed range-front faults consist of several branches. Typically, the youngest branches are farthest from the range front (Bull and others, 1979; McFadden and others, 1982) and cut tectonically derived fan deposits.

The vertical component of slip on the Cucamonga fault, about 0.3 cm/yr (Matti and others, 1982), is derived from a progressive increase in scarp heights—all close multiples of 2 m—in successively older alluvial-fan deposits. These deposits range in age from middle Pleistocene (approx. 700 ka) to late Holocene. The ages are based on stratigraphic relations, the maturity of soils developed on the fan surface (McFadden and others, 1982), and correlation of these soils with others (Bull and others, 1979) on ancient stream terraces in the San Gabriel Mountains.

FOLDING AND UPLIFT

The southern section of the San Andreas fault system resembles an inclined block (fig. 4.21), with its raised northeast edge along the San Andreas fault and its downtilted southwest half submerged beneath the Pacific Ocean. Near Los Angeles, topographic relief across this block exceeds 4,300 m: from Mount San Antonio (3,067 m) in the San Gabriel Mountains to the floor of the Catalina Basin (−1,300 m). This sloping and apparently tilted surface actually incorporates the results of strike-slip and reverse or thrust faulting, and regional uplift.

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Marine Quaternary deposits of the Los Angeles Basin, Ventura Basin, and adjoining offshore areas are locally as thick as 1,200 m (Yerkes, 1972), and lower Pleistocene beds, folded along northwestward trends, exhibit structural relief of more than 1 km in some parts of the Los Angeles Basin. Upper Pleistocene strata are deformed nearly as much, and evidence from drill holes and surface geologic mapping (Durham and Yerkes, 1964; Yerkes and others, 1965; Yerkes, 1972; Shoellhamer and others, 1981) show that much of the folding is of late Quaternary age. Offshore Pliocene and Quaternary basins and folds also trend northwest. These basins, which border the coast as far south as San Diego (Howell and others, 1978), contain a thinner section of Upper Cenozoic strata than the Los Angeles Basin.

Some of the Quaternary folding, like that along the Newport-Inglewood fault zone, is probably directly related to strike slip on deeper wrench faults (Wilcox and others, 1973). Other, more westerly striking folds may reflect a compressional component of deformation similar

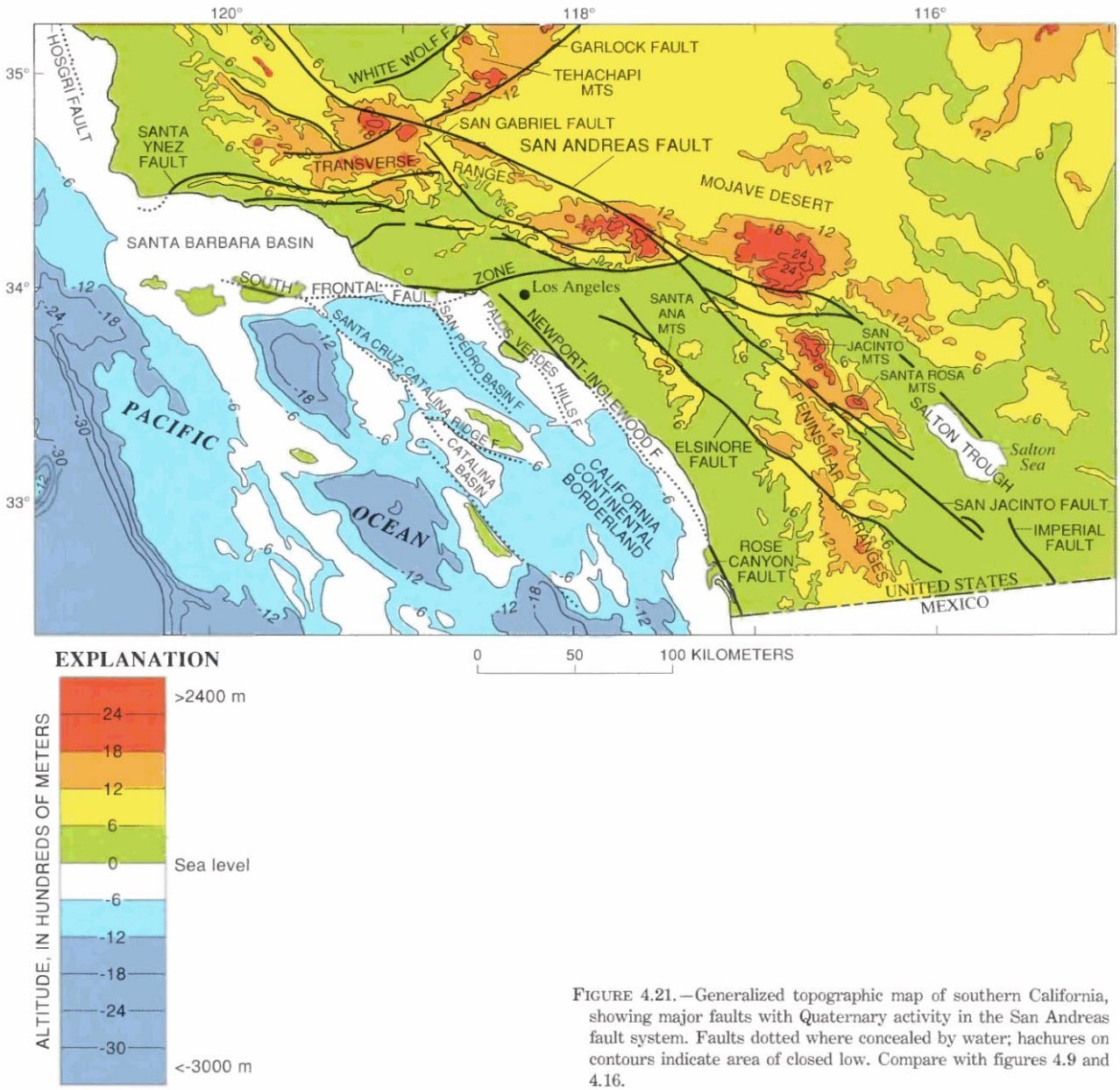

FIGURE 4.21.—Generalized topographic map of southern California, showing major faults with Quaternary activity in the San Andreas fault system. Faults dotted where concealed by water; hachures on contours indicate area of closed low. Compare with figures 4.9 and 4.16.

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to that shown by folds in the central and southern Coast Ranges. Fold patterns in the Los Angeles Basin are complicated by unknown amounts of differential compaction over a faulted and folded basement surface. This surface, nearly 10,000 m deep at the center of the basin (Yerkes and others, 1965, fig. 2), underlies a nearly complete section of marine Neogene strata, of which the near-surface Quaternary deposits make up a small part. The basin fill thus records almost continuous subsidence and marine deposition from Miocene time to the present.

Northeast of these late Cenozoic coastal basins, crystalline basement rocks either crop out or lie within a few hundred meters of the surface. Neogene subsidence of the coastal marine basins contrasts sharply with sustained and evidently rapid uplift, accompanied by thrust faulting, of the mountainous region to the east and northeast. The north-dipping San Fernando fault provided an example of such range-front tectonics in February 1971. Failure on this fault caused an M=6.6 earthquake, opened a 15-km-long zone of surface thrusting, and elevated the land north of the fault by as much as 2 m. Similarly, major Quaternary upwarping and faulting have helped shape the San Gabriel and San Jacinto Mountains; the San Bernardino Mountains (just beyond the boundary of the fault system as defined here) also display evidence of Quaternary uplift and thrust faulting and have apparently deformed with the other ranges.

Geologically recent uplift and tilting of the mountain ranges is indicated by extensive summit areas above 2,000 m, steep southwesterly-flowing streams in narrow V-shaped canyons, extensive alluvial fans and fan complexes at the northeast and southwest range fronts, and incompletely dissected Quaternary surfaces at elevations near 2,000 m. The dissected upland surfaces, most evident in the San Bernardino (Dibblee, 1975) and San Gabriel Mountains, appear as accordant ridge crests and as remnants of originally extensive uplands, some of which are underlain by Quaternary fan deposits and alluvium.

Other geologic evidence also implies rapid late Pleistocene and Holocene uplift. The Blackhawk and Silver Reef debris-avalanche deposits at the north edge of the San Bernardino Mountains record high-velocity (31 m/s), voluminous (0.28×10^9 m^3) debris flows (Woodford and Harriss, 1928; Shreve, 1968), which surged northward from the range front as recently as 17.4 ka (Stout, 1975, 1977), leaving relict lobes of slide debris on the desert floor 10 km from the slide source. Smaller and slower debris flows and rock slides still occur from time to time in both the San Gabriel and San Bernardino Mountains.

Rates of late Quaternary uplift can be estimated for parts of the southern and central San Gabriel Mountains: near the mouth of Little Tujunga Canyon (lat 34°17′ N., long 118°22′ W.) (Menges and others, 1979), on the North Fork of the San Gabriel River (lat 34°09′ N., long 117°31′ W.) (McFadden and others, 1982), and across the Cucamonga fault (lat 34°10′ N., long 117°31′ W.) (Matti and others, 1982). Strath and fill terraces at the first two localities have been dated by physiographic position, ^{14}C methods, and soil maturity; they range in age from middle Pleistocene to late Holocene (approx 1,000–700 ka). Terrace elevations above modern stream channels reflect both climatic and tectonic influences, but Bull and others (1979) and Menges and others (1979) separated these effects to obtain uplift rates of about 0.3 cm/yr for the Holocene and about 0.03 cm/yr for the late Pleistocene. Interpretation (Matti and others, 1982) of the displacement history across strands of the Cucamonga fault, as discussed above, also results in an uplift rate of about 0.3 cm/yr for the latest Pleistocene and Holocene at the south front of the range. Together, these consistent estimates of uplift rate sample a 78-km segment of the San Gabriel front. Regional uplift rates to the north and northwest and within the main body of the Transverse Ranges are probably somewhat higher; rates for the western Transverse Ranges, as discussed in the section above entitled "Central Section of the San Andreas Fault System," are locally as high as 1 cm/yr near Ventura.

Elevated wave-cut platforms and marine-terrace deposits document Quaternary uplift of the southern California coast from the Transverse Ranges southward to San Diego. Mappable, well-dated (450–85 ka) marine terraces, which correlate with major worldwide highstands of the sea, show nearly uniform coastal uplift at rates that range from about 0.01 to 0.05 cm/yr (Lajoie and others, 1979).

Similar uplift rates (approx 0.02 cm/yr) can be interpreted from the elevations and estimated ages of Quaternary erosional surfaces on the Perris structural block, which lies between the Elsinore and San Jacinto faults. Late Quaternary drainage systems on the Paloma erosional surface are presumed to be superimposed from the Gavilan-Lakeview surface (Woodford and others, 1971), which is nearly 200 m higher and an estimated 1 Ma older than the Paloma surface. Persistent uplift of the Perris block must be geologically recent because a late Miocene erosional surface, overlain by basalt dated at 8.3±0.5 Ma (J.W. Hawkins, in Woodford and others, 1971), is at an altitude intermediate between the two younger surfaces. The nearly horizontal remnants of the late Miocene erosional surface and the relatively undeformed detrital and eruptive strata of Neogene age attest to long-term vertical stability of the Perris structural block.

Together, the Quaternary geomorphic and geologic evidence south of the Transverse Ranges implies system-wide Pleistocene and Holocene uplift, but at higher rates toward the northeast than on the Perris and coastal blocks.

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SUMMARY

Right-lateral strike slip on fewer than 10 major faults dominates the Quaternary record of deformation within the San Andreas fault system. Of these faults, the San Andreas is the longest and most active, but the fault system includes other structural elements, such as shorter or discontinuous strike-slip faults, reverse and thrust faults, regional fold systems, minor folds genetically related to strike slip along wrench faults, and tilted, uplifted, or depressed crustal blocks. All of these structures result from relative, predominantly horizontal motion at the boundary separating the Pacific and North American plates.

Though chiefly strike slip, the detailed pattern of Quaternary deformation differs from place to place within the fault system. Although the ultimate causes of these different structural patterns are ill defined and the subjects of continuing research, some geologic controls are evident: (1) the lithology and structure of basement rocks (see chap. 3), (2) the thickness of upper Mesozoic and Cenozoic strata overlying geologic basement, (3) the geometric orientation of major strike-slip faults, especially the San Andreas, and (4) the slip rates along structures controlling deformation.

Plutonic basement includes the granitic and associated metamorphic rocks of the Salinian block west of the San Andreas fault in the central Coast Ranges, similar rocks of the southern California batholith in the Peninsular Ranges, and a more complex suite of metamorphic and crystalline rocks in the central and eastern Transverse Ranges. Elsewhere in the fault system, the dominant basement-rock unit is the intensely sheared and broken Franciscan complex, which locally contains ophiolite bodies and remobilized, cold intrusive masses of serpentinite. The simplest patterns of Quaternary deformation are within regions of exposed or near-surface plutonic basement, where block-bounding strike-slip faults and block uplift or tilting prevail. Deformation is greater and more complex in regions of exposed or near-surface Franciscan basement, where broad anticlinoria, local basins, and distributed shearing are more evident. It is most intense and complex where basement rocks are covered by a kilometer or more of stratified upper Mesozoic or Cenozoic rocks.

Control of Quaternary deformation processes by fault geometry, or the interdependence of process and geometry, is best shown at the Big Bend in the San Andreas fault near the north boundary of the Transverse Ranges. There, west-northwest-trending folds and northwest-trending strike-slip faults of the northern and central sections of the fault system abut against a compressional domain characterized by east-west-trending folds, active thrust and reverse faults, and accelerated rates of vertical uplift. On much smaller scales, similar changes in structural trend and pattern appear at other changes in strike of the San Andreas or major branch faults.

The effect of different slip rates is demonstrated by the contrast in structural style along the San Andreas fault in central California and along the Newport-Inglewood fault zone in southern California. At a slip rate of 3.5 cm/yr, the San Andreas has displaced middle Pleistocene (1 Ma) outcrop belts and major structures by about 35 km, effectively creating—on opposite sides of the fault—two independent structural domains, each of which responds differently to its new structural setting. In the same period of time, the much lower slip rates on the Newport-Inglewood fault zone have separated Quaternary structures by less than 500 m, leaving the initial structural patterns at least partly intact and connected.

Our current knowledge of Quaternary deformation within the San Andreas fault system can be expressed in terms of estimated rates for deformation processes (fig. 4.22), even though reliable quantitative measurements of slip, folding, and uplift are few. Other lines of evidence from geologic mapping and geophysical investigations permit reasonable inferences regarding regional rates of deformation and the history of the fault system. Although some of these interpretations may change as new data are acquired, several major characteristics of the fault system and its Quaternary history are documented by the available evidence:

1. Quaternary tectonism within the San Andreas fault system has deformed an area of 160,000 km^2, extending from Punta Gorda to the Salton Sea, a system length of about 1,100 km, and from the Great Valley and the Mojave Desert to fault zones off shore in the Pacific Ocean, an average system width of about 145 km.
2. Throughout the fault system, the rate of right-lateral strike slip on northwesterly-trending faults typically exceeds the geologically determined rates for other deformation processes by an order of magnitude. Despite some important exceptions, horizontal slip approximately parallel to the plate boundary dominates the Quaternary history of the fault system.
3. In the central section of the fault system, between lat 35°45′ and 36°30′ N., most of this slip has followed the main San Andreas fault; slip rates on this section of the fault are the highest observed to date within the system, averaging about 3.5 cm/yr.
4. Strike slip is distributed more broadly in both the northern and southern sections of the fault system, where the main San Andreas splits into several active branches; slip rates on some of these branches may equal or exceed the rate on nearby parts of the main fault.

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5. Observed rates of Quaternary faulting, summed across the fault system, are insufficient to account for all of the relative movement (5.1 cm/yr) attributed to the Pacific-North American plate boundary, but neither the magnitude of the difference nor its cause is well constrained.
6. East-westerly- to northwesterly-trending reverse and thrust faults occur near many strike-slip faults and elsewhere in the system; they are longer, more active, and best defined in and near the Transverse Ranges (between lat 33°45′ and 35°00′ N.), where they accompany rapid Quaternary uplift and intense folding on east-west-trending axes.
7. Major west-northwest-trending fold belts deform Quaternary and older strata overlying deeply buried (1–5 km deep) basement rocks; most regional fold belts strike obliquely to strike-slip faults and are consistent with wrench-fault structural patterns, but the age and intensity of folding differ from place to place.
8. Several fault-bounded basement blocks are internally little deformed: the Sebastopol block in northern California (Franciscan basement between the San Andreas and Rodgers Creek faults), the Salinian block in central California (granitic basement between the Rinconada and San Andreas faults), and the Perris block in southern California (granitic basement between the Elsinore and San Jacinto faults).
9. Throughout the Quaternary, widespread uplift has characterized most of the fault system; locally downwarped, fault-controlled basins that reverse this general pattern are the San Francisco Bay and Santa Clara Valley (northern California), the Santa Clara River valley-Ventura Basin (southern California), the Los Angeles Basin, and basins near the southern and southwestern margin of the San Joaquin Valley.
10. Maximum observed uplift rates (0.5–1.0 cm/yr) for the late Quaternary occur near Punta Gorda and in the Transverse Ranges; elsewhere, measured uplift rates average about 0.05 cm/yr, but in large areas of the fault system no reliable measurements of uplift rates are available.
11. Major strike-slip faults bound the west edge of several uplifted blocks in northern California: the Santa Rosa block, bounded by the Rodgers Creek and Maacama faults; the Diablo Range and Temblor Range blocks, bounded by the Calaveras and San Andreas faults; and the Santa Cruz Mountains and Santa Lucia Range blocks, bounded by the San Gregorio, San Simeon, and Hosgri faults.
12. In the Transverse and Peninsular Ranges of south-

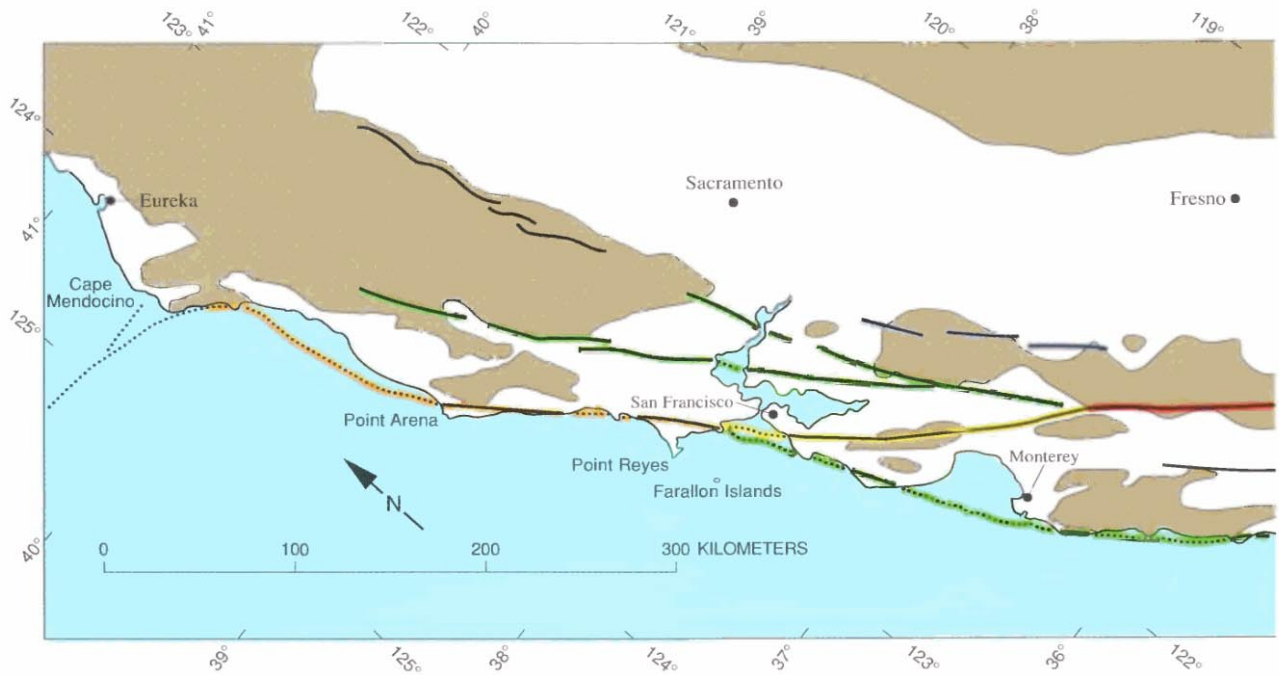

FIGURE 4.22.—Sketch map of western and southwestern California, showing selected major faults exhibiting evidence of Quaternary activity in the San Andreas fault system. Average Quaternary slip rates are based on measured values from published sources and, where measurements are incomplete or unavailable, on interpreted geologic and geomorphic evidence. Slip components on northwest-trending faults are predominantly horizontal, right lateral, and consistent with North American-Pacific plate motion. Group of east-west-trending faults between

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ern California, Quaternary uplift near strike-slip faults has produced two nearly orthogonal mountain chains: (1) the west-northwesterly-trending ranges that separate the Mojave Desert from coastal lowlands and that lie along the trend of Transverse Ranges thrust faults and the southern branch of the San Andreas fault, and (2) the north-south-trending mountain system composed of discrete, northwest-trending ranges that are separated and possibly offset by the Elsinore and San Jacinto faults west of the Salton Sea.

13. Rates of Quaternary faulting, folding, and uplift resemble those for the pre-Quaternary fault system; significantly higher rates, evident near Punta Gorda and in the Transverse Ranges, signify late pulses of accelerated tectonic activity that are still underway.

Despite many still-unsolved problems and unanswered questions, the San Andreas fault system has proved a productive laboratory in which to pursue three tasks: to quantitatively evaluate earthquake hazards in the densely populated, high-risk regions of California; to develop new investigative and analytical methods that can be applied in other regions of high earthquake risk; and to better understand how geologic processes deform the Earth's crust at plate margins. None of these tasks is finished, but the progress so far has improved our knowledge of crustal-deformation processes and aided our efforts to reduce the hazards from damaging earthquakes.

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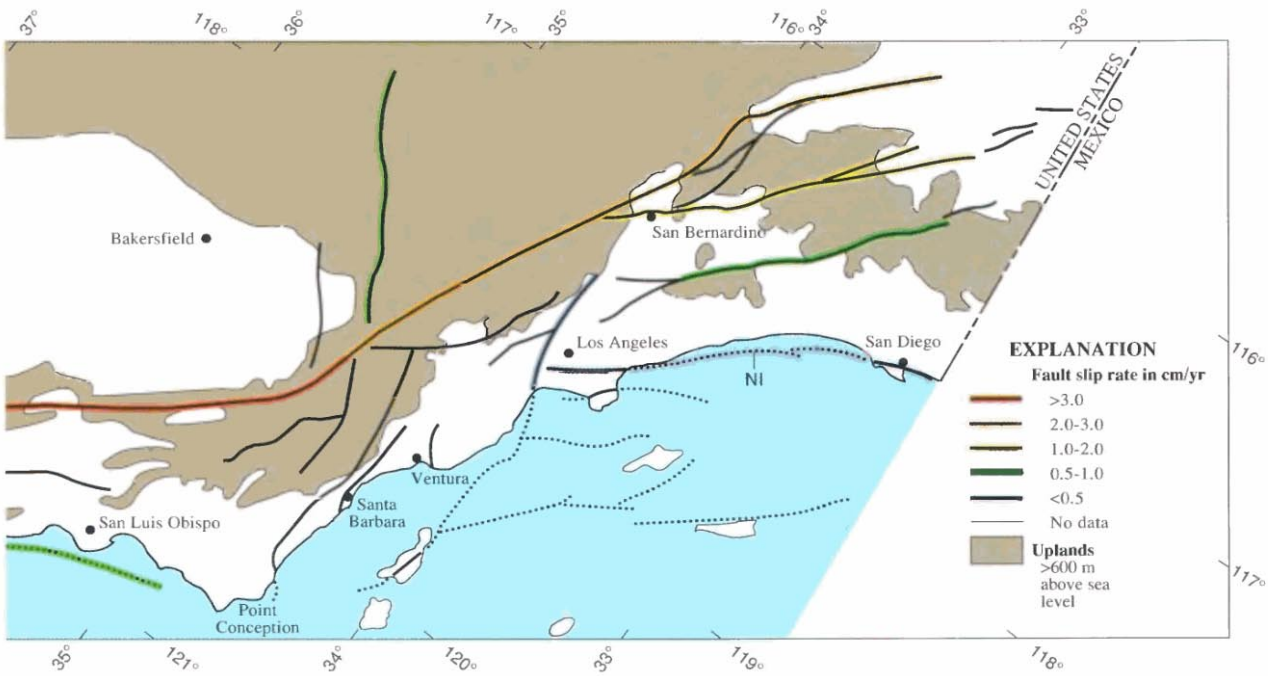

lat 34°00′ and 35°30′ N. exhibit a more complex slip pattern, including chiefly reverse faulting but also some strike slip. Areas above 600-m elevation (colored) exhibit evidence of late Cenozoic uplift and enclose most areas of Quaternary uplift, but elevation pattern reveals no such major local uplifts as those near Ventura (approx 1 cm/yr) and along the Newport-Inglewood fault zone (NI). Faults dotted where concealed by water.

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Tens of thousands of small earthquakes occur in California each year, reflecting brittle deformation of the margins of the Pacific and North American plates as they grind inexorably past one another along the San Andreas fault system. The deformational patterns revealed by this ongoing earthquake activity provide a wealth of information on the tectonic processes along this major transform boundary that, every few hundred years, culminate in rupture of the San Andreas fault in a great (M≈8) earthquake.

5. SEISMICITY, 1980–86

By DAVID P. HILL, JERRY P. EATON, and LUCILE M. JONES

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INTRODUCTION

Earthquake activity along the San Andreas fault system (fig. 5.1) reflects brittle accommodation of the crust to the relative motion along the dextral transform boundary between the Pacific and North American plates (see chap. 3). Great ($M \approx 8$) earthquakes along the main branch of the San Andreas fault accommodate most of this relative plate motion. These plate-boundary earthquakes rupture the entire 15- to 20-km thickness of the brittle crust with right-lateral offsets of as much as 10 m extending for several hundred kilometers along the fault trace, and they recur along a given section of the San Andreas fault at intervals of several hundred years (Sieh, 1981; Sieh and Jahns, 1984). The 1857 Fort Tejon

◀ FIGURE 5.1.—Seismicity from 1969 to 1980 superimposed on color Landsat image for the central Coast Ranges between the San Francisco Bay and Monterey Bay. Size of earthquake epicenters (yellow circles) increases with earthquake magnitude from 1.5 to 6.0. Compiled by Jean Olsen.

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earthquake in southern California and the 1906 San Francisco earthquake in northern California are only the two most recent such great events along the San Andreas fault (see chap. 6).

In this chapter, we focus on the smaller, more frequent earthquakes that dominate the seismicity within the San Andreas fault system between recurrences of great, plate-boundary events. Although this interevent seismicity contributes only marginally to relative plate motion, it is symptomatic of processes underlying the earthquake cycle. In particular, the wealth of data generated by frequent smaller events provides important clues to the seismotectonic fabric, kinematics, and state of stress within the brittle crust and, ultimately, to the seismogenic processes common to earthquakes of all sizes within the San Andreas fault system. This persistent, interevent seismicity also captures widespread popular interest because it includes most of the felt earthquakes in California (earthquakes of $M \geq 3$ can be locally felt), and the larger of these interevent earthquakes ($M = 6$–7) can cause extensive damage and loss of life when they strike near major population centers.

We examine here the detailed patterns of earthquake occurrence along the San Andreas fault system recorded by the combined northern and southern California seismograph networks for the 7-yr interval 1980–86. These networks, which had evolved to much their present configuration (fig. 5.2) by mid-1979, enable uniform detection and location of all earthquakes of $M \geq 1.5$ throughout the San Andreas fault system and of $M \geq 2$ throughout most of California. The telemetered seismic stations in the combined networks approach 550 in number. Signals from the 300 central and northern California stations are recorded and processed at the U.S. Geological Survey's (USGS) offices in Menlo Park; signals from the 250 southern California stations are recorded and processed under a joint USGS-California Institute of Technology (Caltech) effort on the Caltech campus in Pasadena. These dense telemetered networks overlie regional seismic networks operated by the University of California, Berkeley, and Caltech that provide records of $M \geq 3$ earthquakes in northern and southern California, respectively, from the early 1930's onward (table 5.1; Hileman and others, 1973; Bolt and Miller, 1975).

After a brief overview of the San Andreas fault system in the context of a broad transform boundary, we focus on the three-dimensional distribution of earthquakes along the San Andreas fault system itself on the basis of a series of detailed seismicity maps and cross sections for the years 1980–86. We then review selected focal mechanisms for the larger of these earthquakes as a guide to the kinematics of seismogenic deformation along the fault system. Finally, we discuss the implications of these seismicity patterns in terms of current tectonic processes along the transform boundary.

The seismicity maps and cross sections in this chapter, which form the core of our presentation, are largely self-explanatory. The following points, however, deserve special emphasis:

1. The reliability of hypocentral locations correlates closely with the local density of the seismograph network (fig. 5.2). Relative epicentral locations are better than ±0.5 km for earthquakes within the densest sections of the network (corresponding focal depths are better than ±1.0 km). Relative locations may be uncertain by several kilometers or more, however, for earthquakes occurring beyond the margins of the network.
2. All cross sections have a 2× vertical exaggeration as a means of illustrating patterns in the depth distribution of earthquakes beneath profiles that are many times longer than the limited range of focal depths (less than 15 km along most of the fault system).
3. Hypocentral locations are plotted using small circles that scale only weakly with magnitude, to better emphasize detailed spatial structures within the seismicity patterns.
4. The locations of the most commonly used place names and faults in this chapter are shown in figure 5.3 (see front of book for a more complete map).

REGIONAL SEISMICITY AND THE SAN ANDREAS TRANSFORM BOUNDARY

Dickinson (1981), among others, emphasized that the San Andreas fault system and the San Andreas transform boundary are not strictly equivalent structures. The latter is more general, incorporating, for example, the concept of temporal evolution of Pacific-North American plate interaction and the recognition that the faults accommodating most of the plate motion have changed over time. In this section, we emphasize that, although great earthquakes along the San Andreas fault system currently accommodate most of the relative plate motion, plate interactions along the transform boundary influence deformation of the brittle crust over a much broader region.

The breadth of the seismicity pattern in California and western Nevada (fig. 5.4) suggests the lateral extent of deformation associated with the San Andreas transform boundary. Indeed, it corresponds closely to the zone of distributed shear between those plates as interpreted by Ward (1988) from more than 5 years of very long baseline interferometry (VLBI) observations at 20 Western United States stations from 1982 through 1987. Figure 5.4 includes all $M \geq 1.5$ events recorded by the telemetered

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seismic networks in figure 5.2 during the 7-yr interval 1980–86, as well as events recorded by adjacent telemetered networks in Nevada (see Rogers and others, in press). Although details within this seismicity pattern fluctuate from year to year, the broad aspects of the pattern have remained stable for the entire historical

TABLE 5.1.—*Number of short-period seismic stations in California*

Year	1940	1965	1971	1975	1981
Northern California	<10	<20	≈100	≈200	≈300
Southern California	<10	<20	≈30	≈100	≈200

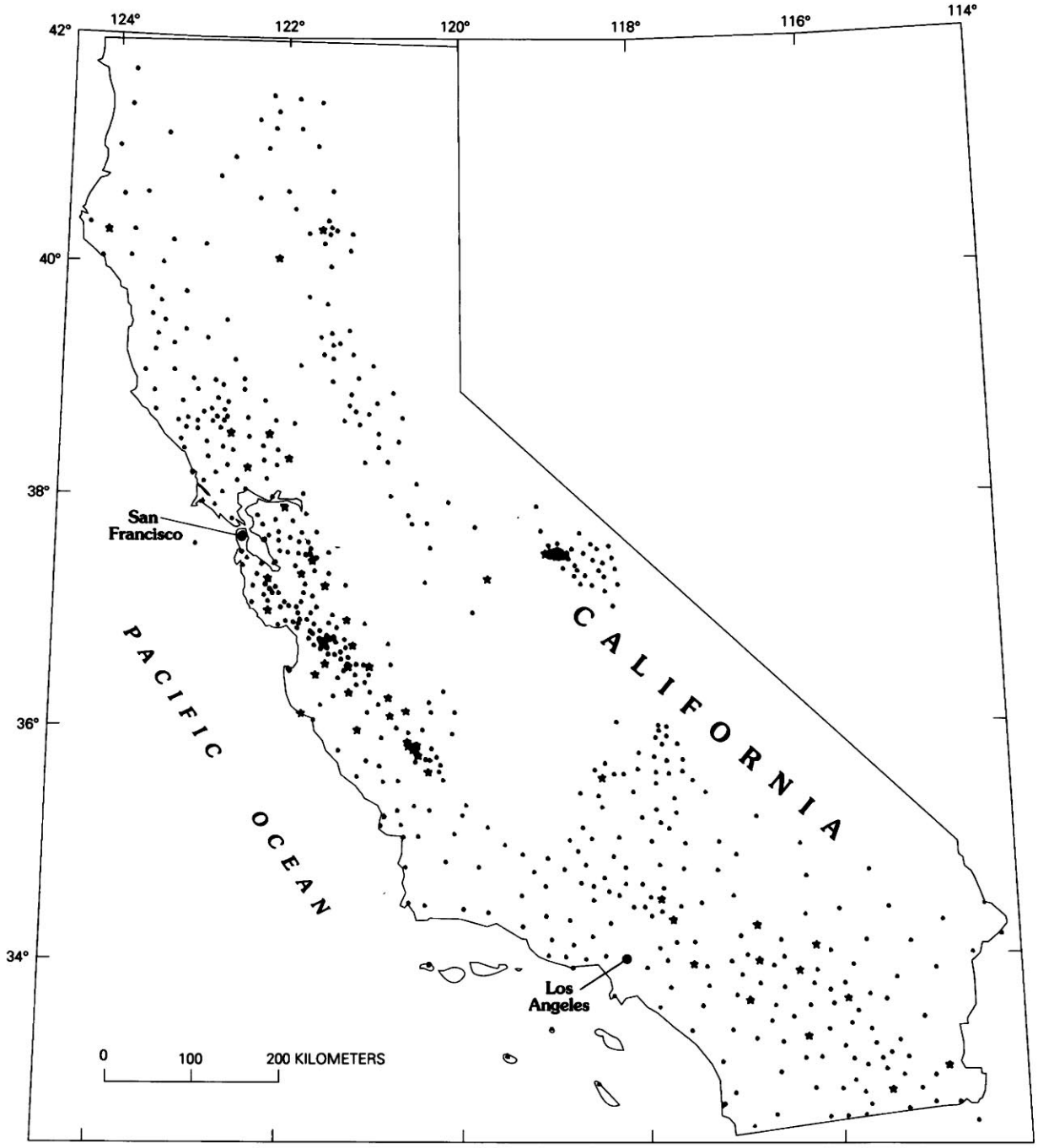

FIGURE 5.2.—Stations in telemetered seismic networks in California operating during 1986. Dot, single (vertical)-component station; star, multicomponent station.

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record of earthquake occurrence in California (see chap. 6; Ellsworth and others, 1981; Hill and others, in press; Hutton and others, in press).

In outline, the seismicity pattern for California and western Nevada forms a hollow ellipse with its long axis nearly coincident with the transform boundary. This

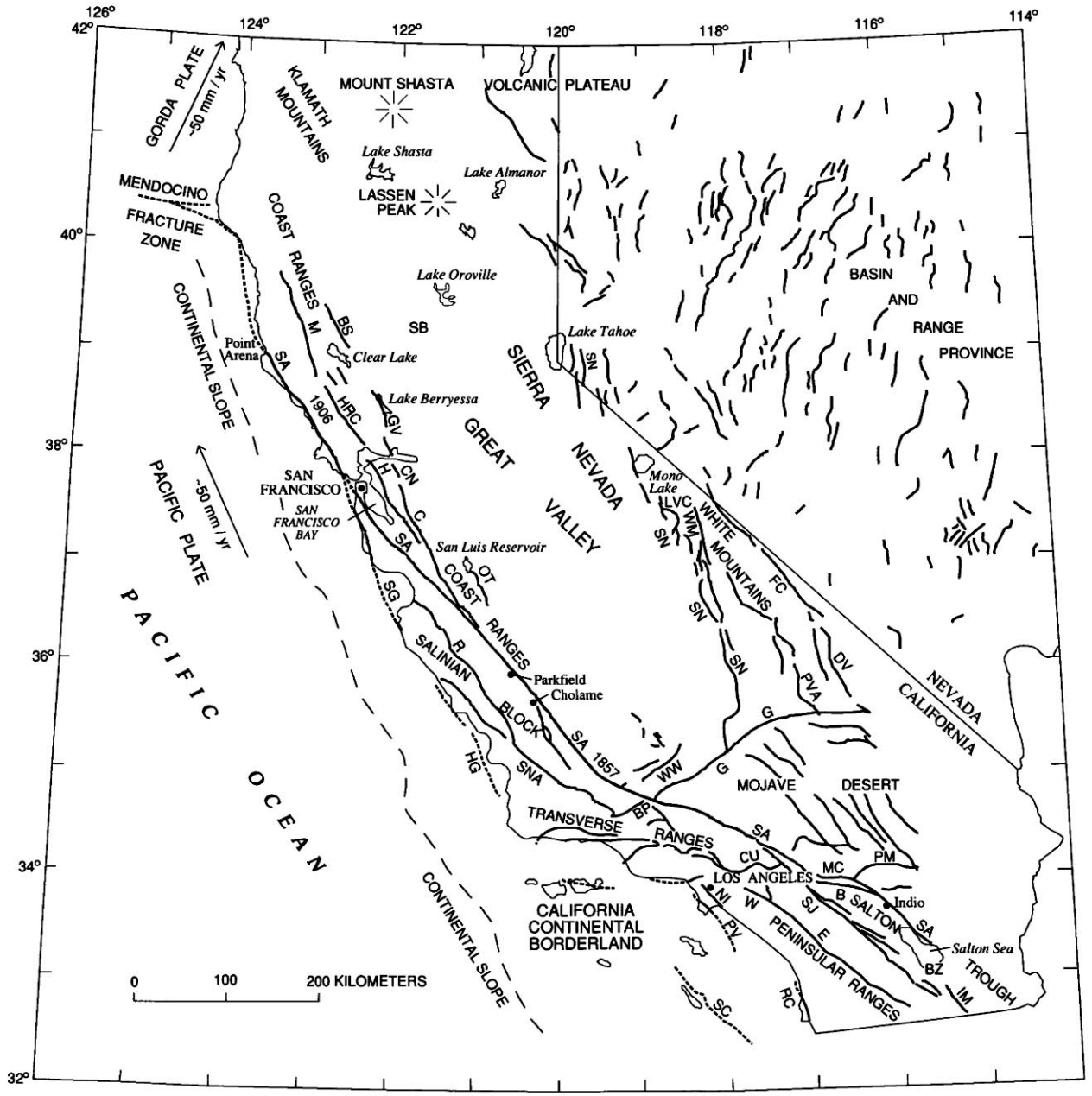

FIGURE 5.3.—Place names and faults most commonly used in text (see front of book for more complete maps of place names and faults). Faults (dotted where concealed): B, Banning; BP, Big Pine; BS, Bartlett Springs; BZ, Brawley seismic zone; C, Calaveras; CN, Concord; CU, Cucamonga; DV, Death Valley; E, Elsinore; FC, Furnace Creek; G, Garlock; GV, Green Valley; H, Hayward; HG, Hosgri; HRC, Healdsburg-Rodgers Creek; IM, Imperial; LVC, Long Valley caldera; M, Maacama; MC, Mission Creek; NI, Newport-Inglewood; OT, Ortigalita; PM, Pinto Mountain; PV, Palos Verdes; PVA, Panamint Valley; R, Rinconada; RC, Rose Canyon; SA, San Andreas; SC, San Clemente Island; SG, San Gregorio; SJ, San Jacinto; SN, Sierra Nevada; SNA, Sur-Nacimiento; W, Whittier; WM, White Mountains; WW, White Wolf. Arrows and numbers indicate direction and amount of motion, respectively, of Pacific and Gorda plates with respect to North American plate to the east; red lines indicate 1857 and 1906 ruptures of San Andreas fault.

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pattern is widest across central California, where it approaches nearly a third of the 1,100-km length of the transform boundary, from the Mendocino triple junction in the north to the head of the Gulf of California at the south. Extended alignments of epicenters within this pattern suggest a coarse structural fabric linking the broad distribution of earthquakes to the transform boundary. Seismicity along the San Andreas fault system itself stands out as a series of subparallel, northwest-trending lineations extending the length of coastal California. The alignment of epicenter clusters along the east side of the Sierra Nevada in eastern California branches northward from the south end of the San Andreas fault system in the Salton Trough only to bend back toward the north terminus of the San Andreas fault system at the Mendocino triple junction in northern California. The

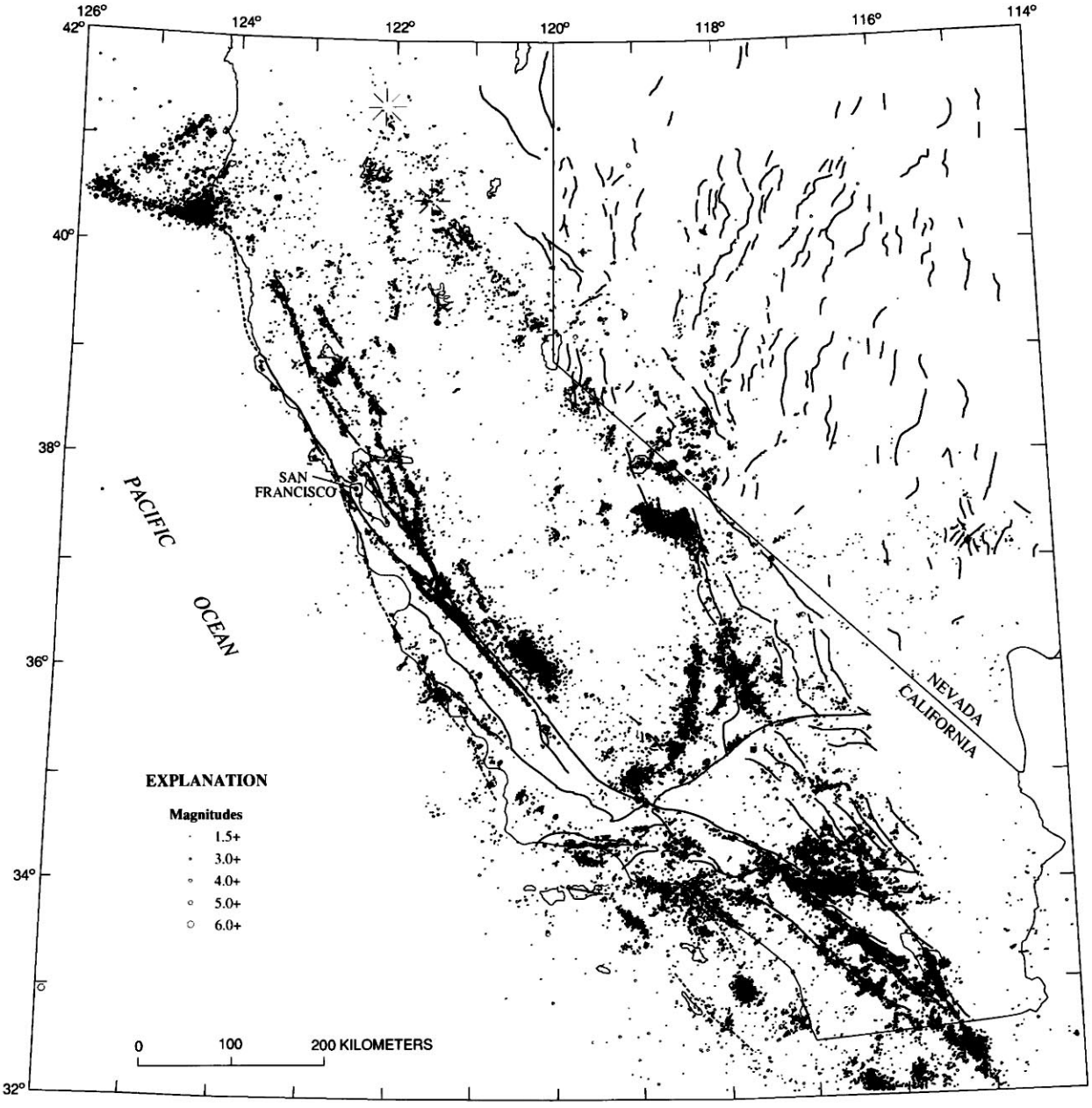

FIGURE 5.4.—Locations of 64,000 $M \geq 1.5$ earthquakes in California and western Nevada during 1980–86 and mapped Holocene faults (dotted where concealed; major branches of the San Andreas fault system marked in red).

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Sierra Nevada-Great Valley and western Mojave Desert blocks form a broad quiescent region between the San Andreas and eastern California seismicity bands. In southern California, pronounced transverse seismicity belts coincident with the southern margin of the Sierra Nevada and Transverse Ranges, respectively, span this otherwise-quiescent region. A weaker, more diffuse seismicity belt near lat 37° N. spans the Sierra Nevada-Great Valley block in central California, forming a visual, if not structural, link between the San Andreas fault system and the dense cluster of epicenters in eastern California. This major cluster in the eastern Sierra Nevada represents an episode of intense earthquake activity in Long Valley caldera and vicinity that began in 1978 and has persisted to the present (Van Wormer and Ryall, 1980; Hill and others, 1985b).

The displacement pattern associated with earthquakes throughout California and western Nevada is broadly consistent with deformation under a coherent, regional stress field dominated by plate-boundary interaction along a northwest-striking, dextral transform boundary (Hill, 1982). Strike-slip focal mechanisms with right-lateral slip on northwest- to north-northwest-striking planes, for example, are common through most of the region. Regional variations within this pattern include a tendency toward normal slip on northerly-striking planes along the western margin of the extensional Basin and Range province in eastern California, and toward reverse slip on easterly-striking planes in the Transverse Ranges of southern California. Compressional deformation perpendicular to the San Andreas fault within the Coast Ranges, however, represents an important deviation from this regional pattern.

SEISMICITY ALONG THE SAN ANDREAS FAULT SYSTEM

Sections of the San Andreas fault system stand out on seismicity maps as a network of northward-branching alignments of epicenters through the central and northern Coast Ranges and as subparallel lineations of clusters of epicenters that branch northward from the south end of the Imperial fault toward the Transverse Ranges in southern California (fig. 5.4). One of the most remarkable aspects of the seismicity pattern associated with the fault system, however, is the nearly complete absence of earthquake activity down to even the smallest magnitudes ($M \approx 1.5$) along those sections of the fault that have ruptured with the largest historical earthquakes, the great ($M \approx 8$) 1857 and 1906 earthquakes (see figs. 5.3, 5.4). The southernmost section of the San Andreas fault, from Indio to the Salton Sea, also lacks microseismicity, although no large earthquake has ruptured this section in the past 200 yr. These quiescent ("locked") segments of the fault stand in sharp contrast to the segments marked by persistent linear concentrations of small to moderate earthquakes.

This dual expression of the fault system evident on current seismicity maps apparently reflects fundamental differences in the long-term behavior of the respective segments. In particular, seismic activity along the "locked" segments of the main trace of the San Andreas fault may be limited to the recurrence of major earthquakes at intervals of 100 to 300 yr accompanied by immediate foreshock and aftershock sequences, and these segments may remain quiescent for most of the interevent time associated with the cycle between great earthquakes (Ellsworth and others, 1981). In contrast, those segments with persistent microearthquake activity probably seldom, if ever, rupture with great earthquakes, although they may be capable of generating earthquakes as large as $M \approx 6$.

Aseismic creep also characterizes and is largely confined to those fault segments along the San Andreas fault system that show persistent microearthquake activity (Wesson and others, 1973; Schulz and others, 1982). Creep is most pronounced along the central California segments of the fault system, where average creep rates match the long-term displacement rates of 32 to 34 mm/yr. Louie and others (1985) documented creep along sections of the seismically active fault segments in the Salton Trough, and Astiz and Allen (1983) documented creep along a section of the Garlock fault that is marked by microearthquake activity. The creep rates in these two areas, however, are more than an order of magnitude less than the long-term deformation rates.

In the following subsections, we consider the 1980–86 seismicity along and adjacent to the major sections of the San Andreas fault system in more detail. We begin with the Mendocino triple junction in the north and move southward, generalizing slightly Allen's (1968) subdivision of the fault system into four major sections of contrasting seismic behavior: (1) the quiescent 1906 break and subparallel branches, (2) branches forming the central California active (creeping) section, (3) the quiescent 1857 break, and (4) branches forming the southern California active section south of the Transverse Ranges.

MENDOCINO TRIPLE JUNCTION

The three lithospheric plates that dominate the modern tectonics of coastal California meet at the Mendocino triple junction, which is marked by a dense cluster of epicenters just off Cape Mendocino (fig. 5.5*A*; see chap. 3). North of this triple junction, oblique subduction dominates, with the eastern margin of the Gorda plate

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(the southernmost section of the Juan de Fuca plate) slipping beneath the North American plate north-northeastward at a rate of 30 to 50 mm/yr (Wilson, 1986). South of the triple junction, the Pacific plate is moving past the North American plate along the San Andreas transform boundary on a heading of 35°–38° W. of N. at a rate of approximately 50 mm/yr (DeMets and others, 1987).

The dense lineation of epicenters that trends west-northwest from Cape Mendocino corresponds closely to the Mendocino Fracture Zone (MFZ) and the Pacific-Gorda plate boundary but follows a slightly more northerly trend. Details of how the San Andreas fault ties into the triple junction, however, are unclear. The trace of the San Andreas fault lies off shore north of Point Arena, and the broad area of seismic quiescence south of the triple junction offers few clues to the kinematics of this northernmost segment of the fault.

The conspicuous linear zone of epicenters marking a northeast-trending slice across the southwest corner of the Gorda plate is the aftershock zone of the M=7.2 Eureka earthquake of November 8, 1980. This was the largest earthquake to occur in California during the interval 1980–86. The N. 53° E. trend of its aftershock zone agrees closely with the strike of the left-lateral slip plane inferred from the focal mechanism of the main shock, which was located about a fourth of the way downstrike from the northeastern end of the aftershock zone (Eaton, 1989). The aftershocks from this earthquake

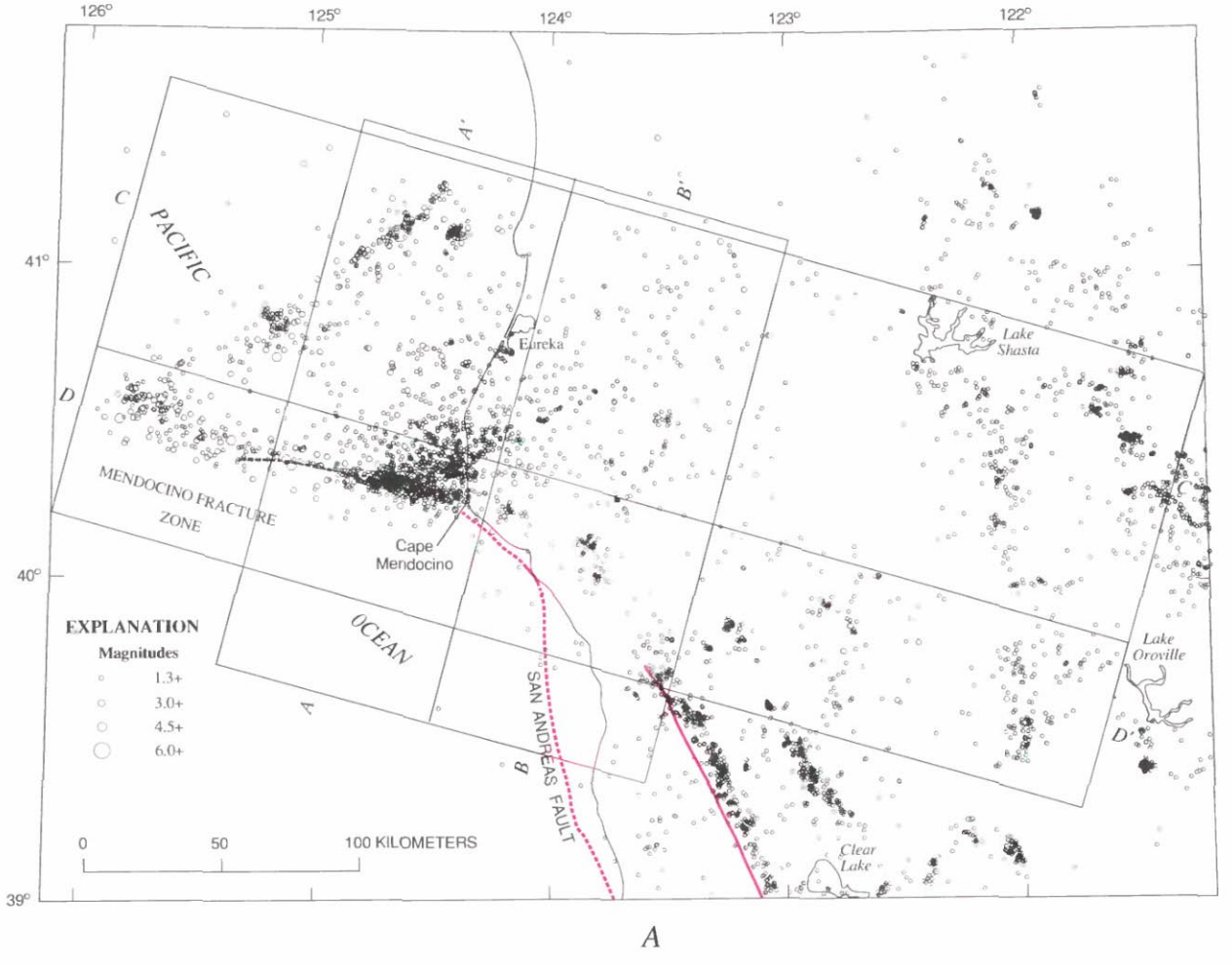

FIGURE 5.5.—Seismicity in the Mendocino triple junction area, northern California. *A*, Earthquake locations, showing major branches of the San Andreas fault system in red; faults dotted where concealed. Magnitude symbols shown in explanation are scaled with enlargement of cross section. *B*, Depth sections perpendicular to N. 75° W. trend of the Mendocino Fracture Zone (*A*–*A*′ and *B*–*B*′ outlined in fig. 5.5*A*). *C*, Depth sections parallel to N. 75° W. trend of the Mendocino Fracture Zone (*C*–*C*′ and *D*–*D*′ outlined in fig. 5.5*A*).

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died off within a few months after the main shock—a notably short aftershock sequence for an earthquake of this size.

A third, more diffuse group of earthquakes in the vicinity of the triple junction shows little tendency to concentrate in linear zones. These epicenters form an irregular zone with the greatest concentration in the vicinity of Cape Mendocino, gradually dying off with distance to the north, east, and west. To the south, the seismicity dies off abruptly across the MFZ and its landward extension.

The three-dimensional aspects of this triple junction seismicity are illustrated by four cross sections (figs. 5.5*B*, 5.5*C*). The two cross sections perpendicular to the N. 75° W. trend of the MFZ (fig. 5.5*B*) compare the distribution of focal depths within the submarine section of the Gorda plate adjacent to the triple junction (*A*–*A*′) with that within the adjacent, subducted section of the Gorda plate and the overlying North American plate (*B*–*B*′). Earthquake hypocenters along the southern margin of the submarine Gorda plate define a dense, vertically elongate zone beneath the MFZ that dips 70°–75° N. and extends to depths of nearly 35 km. Earthquakes north of this zone cluster in a somewhat less dense, wedge-shaped core outlined by a northward shallowing of maximum focal depths accompanied by a northward deepening of minimum focal depths that converge at a depth of about 20 km (Eaton, 1989). Overlying this relatively dense wedge is a more diffuse distribution of hypocenters, the northernmost of which represent the 1980 M=7.2 event and adjacent aftershocks. The absence of seismicity south of the MFZ indicates that the northeast corner of the Pacific plate behaves as a rigid block in its interaction with the younger, thinner, and internally deforming Gorda plate (Wilson, 1986; Eaton, 1989).

In the onshore cross section (*B*–*B*′, fig. 5.5*B*), the intense seismicity associated with the MFZ loses most of

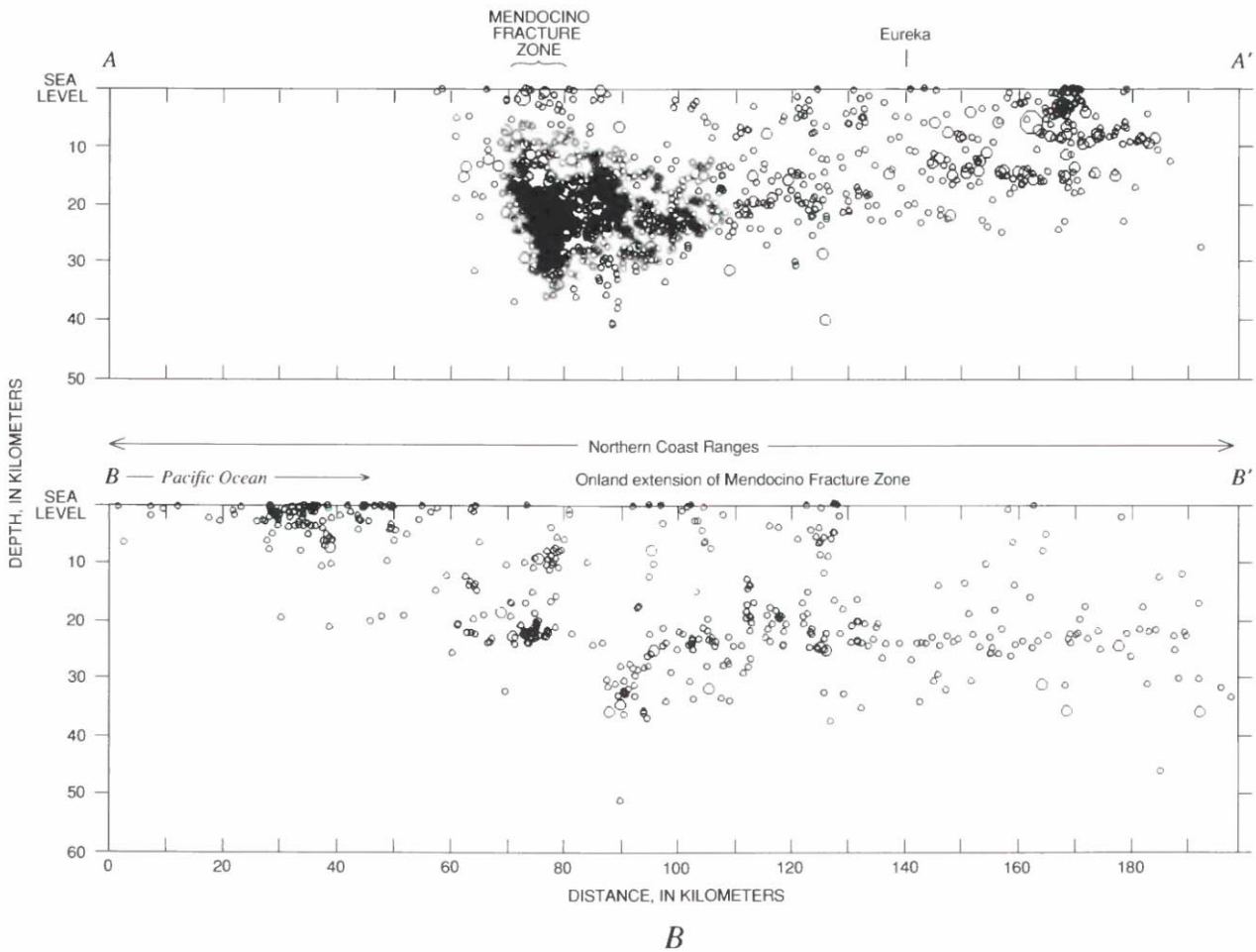

FIGURE 5.5.—Continued.

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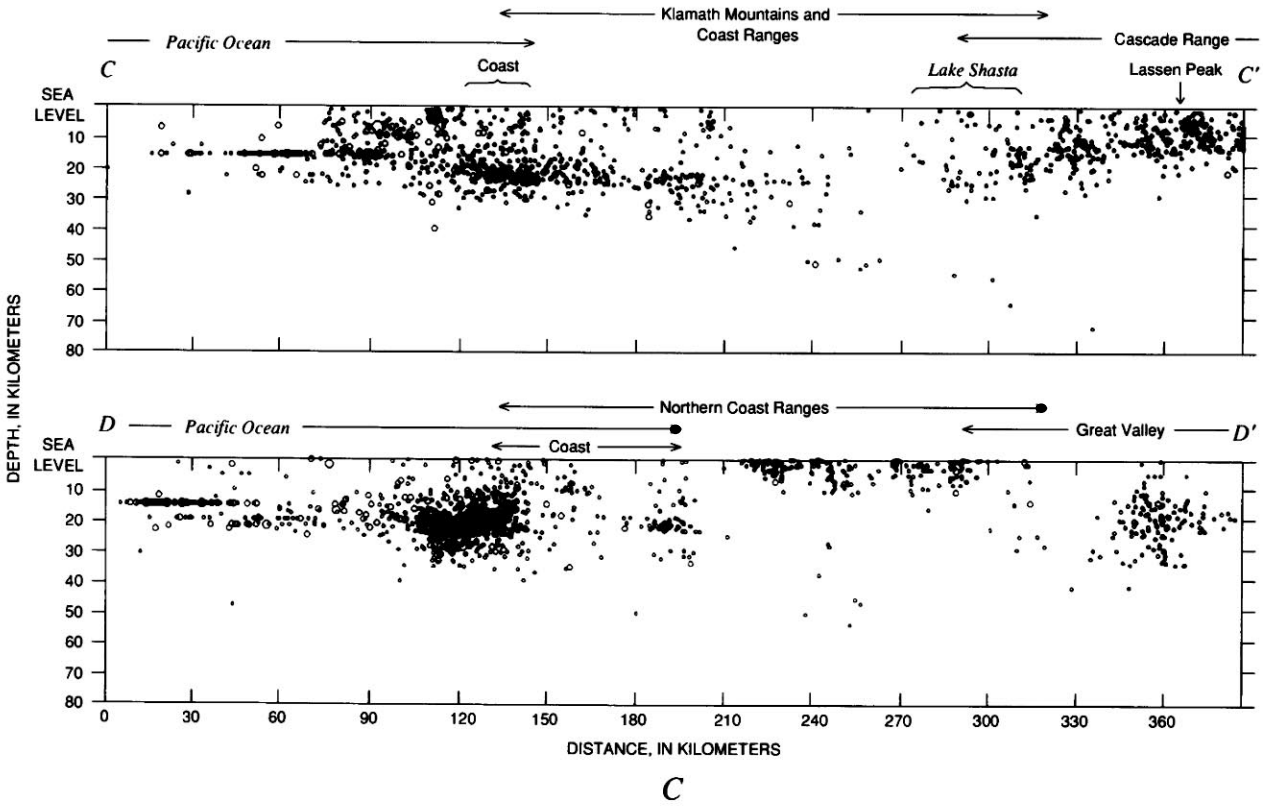
its expression. Here, the southern margin of the subducted Gorda plate is marked only by isolated clusters of hypocenters at depths of 10 and 25 km. To the north, however, a band of hypocenters concentrated at about a depth of 20 km corresponds closely to the base of the wedge-shaped distribution beneath the submarine section of the Gorda plate, including the downward flexing of this band as it approaches the southern margin of the Gorda plate. South of the landward extension of the MFZ, the seismicity shallows rather abruptly, reflecting the edge of the subducted Gorda plate beneath the North American plate and the rather thin seismogenic crust associated with the San Andreas fault system to the south.

The cross section parallel to and including the MFZ and its landward extension (*D–D′*, fig. 5.5*C*) reveals that the dense seismicity cluster along the MFZ near the triple junction tapers westward along the MFZ with a wedge-like geometry to a 20-km-deep band of hypocenters, much the same as it does to the north (cross sec. *A–A′*, fig. 5.5*B*). (The pronounced linear concentration of hypocenters at 15-km-depth beneath the submarine Gorda plate in cross sections *A–A′* and *D–D′* represents the default focal depth for the more poorly located earthquakes beyond the perimeter of the onshore seismic network.) The landward extension of the MFZ shows up only weakly as a diffuse scattering of hypocenters extending to a small, isolated cluster of 25-km-deep hypocenters some 50 km east of the triple junction (Δ=190 km, cross sec. *D–D′*) and, possibly, as far as a handful of 30- to 50-km-deep hypocenters 100 km east of the triple junction (Δ=260 km, cross sec. *D–D′*). Focal depths of the shallow seismicity in the northern Coast Ranges are confined to the upper 10 km of the crust. Farther east, however, focal depths increase again to depths of 35 to 40 km beneath the north end of the Great Valley. An east-dipping quiescent band, about 10 km thick, appears to separate the seismicity associated with the MFZ from that beneath the northern Coast Ranges and the Great Valley to the east. The geometry of this band suggests that it may somehow be related to the geometry of the subducted Gorda plate beneath the western margin of the North American plate.

The parallel cross section immediately to the north (*C–C′*, fig. 5.5*C*) reinforces the impression that the distribution of hypocenters carries an image of subduct-



C

FIGURE 5.5.—Continued.

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ed-Gorda-plate geometry. Maximum focal depths increase systematically from 25 to 30 km beneath the submarine Gorda plate to nearly 80 km beneath the southern Cascade volcanoes. Although the easternmost of these deep earthquakes are small and few, their locations are well constrained (Cockerham, 1984; Walter, 1986). As in the section of the fault to the south, a seismically quiescent, east-dipping band appears to separate earthquakes within the Gorda plate from those in the overlying North American plate.

THE 1906 BREAK AND THE NORTHERN COAST RANGES

Aside from a light scattering of epicenters about the trace of the San Andreas fault through the San Francisco peninsula and the Santa Cruz Mountains to the south, the rupture zone of the 1906 earthquake is nearly aseismic. This pattern has persisted not only through the period 1980–86 shown in figure 5.6 but also at least since the mid-1930's, when instrumental data became available for reliable earthquake locations in the area (see Bolt and Miller, 1975; Hill and others, in press). It was interrupted, however, by the M=7.1 Loma Prieta earthquake on October 17, 1989, which ruptured the southernmost 45 km of the 1906 break (cross sec. L–L', fig. 5.7; see chap. 6). The cluster of epicenters along the fault just west of San Francisco coincides closely with Boore's (1977) estimate of the epicentral location for the 1906 main shock. We note that the greatest offsets along the 1906 rupture occurred north of the epicenter along the stretch of the fault that now shows the lowest seismicity (see Thatcher and Lisowski, 1987).

The pair of subparallel epicenter lineations through the northern Coast Ranges east of the 1906 break closely follow the Rodgers Creek-Healdsburg-Maacama fault zone (west) and the Green Valley-Bartlett Springs fault zone (east). In both lineations, the epicenters tend to cluster along the eastern margins of these 2- to 3-km-wide fault zones, which are characterized by multiple strands of subparallel, curvilinear fault traces (see maps at front of book; Dehlinger and Bolt, 1984). These fault zones are essentially colinear with the Hayward and Calaveras faults to the south, although an aseismic interval coincident with the eastern arm of the San Francisco Bay (San Pablo and Suisun Bays) obscures the connection between these branches of the fault system. Most of the earthquakes defining the pair of subparallel lineations through the northern Coast Ranges are small ($M \leq 3$), and, indeed, these fault zones were not recognized as seismically active branches of the San Andreas system until after the northern Coast Ranges section of the telemetered network (fig. 5.2) became operational in late 1979.

Dense clusters of epicenters just south of Clear Lake define a northeast trending pattern transverse to and midway along these northern two branches of the San Andreas fault system. The southwesternmost of these clusters represents microearthquake activity associated with the Geysers geothermal field (Eberhart-Phillips and Oppenheimer, 1984; Oppenheimer, 1986). The cluster just to the northeast underlies the Clear Lake volcanic field, which last erupted about 10 ka (Donnelly-Nolan and others, 1981). Scattered clusters farther to the northeast suggest a tenuous link between this Geysers-Clear Lake trend and the north-south-trending lineation of epicenters along the axis of the north end of the Great Valley.

In longitudinal cross section (H–H', fig. 5.6), earthquakes occurring along the two northern branches of the San Andreas fault system are moderate in number and rather evenly distributed except for the dense, shallow cluster beneath the Geysers-Clear Lake area. The depth to the base of the continuously seismogenic crust shows considerable relief, deepening to between 12 and 13 km south of the Geysers-Clear Lake area and shallowing to only 5 km beneath and just north of the geothermal field. Farther north, the base of the seismogenic crust deepens gradually to a maximum of about 10 km. Note the isolated cluster of small but well-located events at depths of 13 to 18 km beneath Clear Lake, just north of the shallowest depths to the base of the continuously seismogenic crust. Another isolated cluster of deep earthquakes located beneath Suisun Bay have focal depths as great as 15 to 25 km. The more numerous earthquakes along branches of the fault system south of Suisun Bay paint in a dense distribution of hypocenters throughout the upper 10 to 15 km of the crust.

Although the two transverse cross sections across the northern Coast Ranges (E–E', F–F', fig. 5.8A) show the concentration of hypocenters around the Rodgers Creek and Green Valley branches of the San Andreas fault, they provide no hint of the location of the main branch of the San Andreas fault that ruptured in 1906. The southern of these two cross sections (F–F') includes the dense, shallow cluster of events associated with the Geysers-Clear Lake activity, as well as the cluster of deeper events beneath the eastern margin of the Coast Ranges. Focal depths in the latter cluster, which falls at the northeast end of the Geysers-Clear Lake lineation and at the south end of the north-south-trending lineation beneath the Great Valley, range from 10 to 25 km, a depth range common to earthquakes near the north end of this Great Valley seismicity lineation (cross sec. D–D', fig. 5.5C). Maximum focal depths increase by several kilometers from west to east in both cross sections. Farther east, they increase abruptly to depths of 25 km or so along the Great Valley lineation.

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CENTRAL CREEPING SECTION

Densely aligned epicenters mark the nearly straight, creeping section of the San Andreas fault that separates the south end of the 1906 break near San Juan Bautista from the north end of the 1857 break near Cholame (fig. 5.6*B*). Densely aligned epicenters follow the Calaveras fault northward to a point just east of the south tip of the San Francisco Bay, where the Hayward fault branches to the west and the Greenville fault zone branches to the east. Few epicenters fall along the northward extension of the Calaveras fault beyond this branching point, although a diffuse cluster of epicenters coincides with the right-stepping offset between the north end of the Calaveras fault and the Concord fault (fig. 5.6*A*). This dilatational offset was the site of pronounced earthquake swarms in June 1970 and August 1976 (Lee and others, 1971; Weaver and Hill, 1978/79).

Although these dense alignments of epicenters coincide closely with the mapped surface trace of the San Andreas fault system as first documented by Eaton and others (1970a), the coincidence is not everywhere perfect (fig. 5.6*B*). In the region where the Calaveras fault branches from the main trace of the San Andreas fault, for example, the densely aligned epicenters appear to be systematically displaced 3 to 4 km westward of the surface trace of the San Andreas fault and a somewhat smaller distance eastward of the surface trace of the Calaveras fault. Much of this apparent offset results from a strong contrast in rock type and *P*-wave velocity across the faults that is not adequately accounted for in routine hypocenter locations (Mayer-Rosa, 1973; Pavoni, 1973; Spieth, 1981). When the hypocenter locations are recalculated using a more appropriate, two-dimensional structural model, these offsets are much reduced but not completely eliminated. The remaining offsets reflect deviation of the faults from the vertical, with the San Andreas fault dipping 70° W. (Pavoni,1973; Spieth, 1981) and the Calaveras fault dipping 80° E. (Reasenberg and Ellsworth, 1982).

Wesson and others (1973) recognized the close correlation between active creep and persistent microseismic activity along the 200-km-long section of the San Andreas fault north of Parkfield and proposed that this correlation may hold for other branches of the fault in central California as well. Allen (1981) and Schultz and others (1982) pointed out that this correlation holds for the Calaveras-Hayward fault system, but creep measurements have yet to be made on the subparallel Rodgers Creek-Healdsburg-Maacama and Green Valley-Bartlett Springs faults. Creep is the dominant process for shallow slip along the central section of the San Andreas fault, and geodetic measurements spanning this section of the fault indicate that the long-term slip rate of 32 mm/yr along the fault accommodates nearly all of the local plate motion. Because it appears that little, if any, shear strain is accumulating in the blocks on either side of the fault, most seismologists believe that this section of the fault is unlikely to rupture in a great earthquake (see chap. 7).

The creeping section of the fault system, however, has produced several moderate earthquakes during historical time (see chap. 6). The most recent of these events, which occurred along the right-branching segments northeast of the San Andreas fault, where creep rates average several millimeters per year, include (1) the M=5.9 Coyote Lake earthquake of August 6, 1979, and the M=6.2 Morgan Hill earthquake of April 24, 1984, which ruptured adjacent 20-km-long segments of the Calaveras fault south of its junction with the Hayward fault (Reasenberg and Ellsworth, 1982; Bakun and others, 1984); and (2) the M=5.5 and 5.8 Livermore events of January 24 and 27, 1980, which ruptured a 20-km-long stretch of the Greenville fault north of Livermore (Bolt and others, 1981).

The most noteworthy sequence of moderate earthquakes along the central section of the San Andreas fault involve the five virtually identical M=6 events that have ruptured the same 30-km-long stretch near Parkfield at nearly 22-year intervals since 1881 (Bakun and McEvilly, 1984). This stretch of the fault is defined by a 1-km right-stepping offset on the south and a 5° W. bend on the north; it coincides with the transition between the south end of the creeping section of the fault and the north end of the 1857 break (see Bakun and Lindh, 1985, fig. 1). The most recent of these characteristic Parkfield earthquakes occurred in 1966, and an intensive monitoring experiment is underway to capture a detailed instrumental record of the next Parkfield earthquake, which is predicted to occur sometime within a 10-year window centered on 1987–88 (Bakun and Lindh, 1985).

The scattered seismicity within the Coast Ranges surrounding the San Andreas fault system is distinctly more intense in the Franciscan terrane east of the fault than in the granitic Salinian block to the west. The large, dense cluster of epicenters along the eastern margin of the Coast Ranges adjacent to the south end of the creeping section represents the aftershocks of the M=6.7 Coalinga earthquake of May 2, 1983, and the M=5.7 Kettleman Hills earthquake of August 4, 1985, both of which involved reverse slip on northwest-striking planes subparallel to the adjacent section of the San Andreas fault (Stein and King, 1984; Eaton, 1989). Scattered clusters of epicenters within the Franciscan terrane show a crude northwest-trending alignment with the southwest edge of the Coalinga-Kettleman Hills aftershock zone and the Ortigalita fault, the north end of which passes beneath the San Luis Reservoir (LaForge and Lee, 1982). This weakly defined lineation is essentially

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colinear with the Greenville fault, east of the San Francisco Bay (fig. 5.4).

The Salinian block west of the central section of the San Andreas fault and east of the Sur-Nacimiento fault forms a broad, nearly aseismic swath along the west flank of the Coast Ranges. These two seismically active fault zones separate the granitic Salinian block from the Franciscan terrane on either side (see chap. 3). The Rinconada fault, within the Salinian block, appears to be nearly aseismic except, possibly, toward the south where it approaches the Sur-Nacimiento fault zone. The small cluster of epicenters just east of the midpoint of the Rinconada fault represents a persistent spot of microearthquake activity at depths of 8 to 10 km near the San Ardo oil field (Poley, 1988).

In the cross section along the central section of the San Andreas fault (*L–L′*, fig. 5.7), the actively creeping section of the fault shows up as a densely mottled distribution of hypocenters within the upper 12 to 15 km of the crust. The density of hypocenters within this creeping section tends to decrease with depth, and the denser clusters generally are concentrated at depths of less than 5 to 8 km. The base of the seismogenic zone undulates about an average depth of some 13 km beneath most of the creeping section, but it deepens to 15 km beneath both the northern and southern transitions to the locked sections of the fault. In contrast to the creeping section of the fault, the sparse seismicity associated with the locked segments that ruptured in 1906 (north) and 1857 (south) tends to be concentrated toward the deeper parts of the seismogenic crust. Note that the 1989 Loma Prieta M=7.1 earthquake ruptured the 45-km-long section of the San Andreas fault with a pronounced U-shaped gap in shallow earthquakes immediately north of the creeping section of the fault (cross sec. *L–L′*, fig. 5.7; see chap. 6).

The cross sections transverse to the central San Andreas fault system (*G–G′*, fig. 5.8*A*; *I–I′*, *J–J′*, *K–K′*, fig. 5.8*B*) reveal the seismically active, creeping branches of the fault as narrow, near-vertical hypocenter distributions coincident with the fault plane. The broadened distribution in cross sections *I–I′* and *J–J′* (fig. 5.8*B*) reflects the oblique projection of earthquakes along the Calaveras fault zone and the clustering northeast of the fault in the Bear Valley region (Ellsworth, 1975), respectively. These transverse cross sections also emphasize the quiescence of the Salinian block relative to the Franciscan terrane on either side (note, however, the isolated cluster of deep events beneath San Ardo in the Salinian block in cross sec. *K–K′*), and the fairly uniform depth of 12 to 15 km to the base of the seismogenic zone that persists throughout the central Coast Ranges. As in the area farther north, however, maximum focal depths increase rather abruptly to 25 km beneath the eastern margin of the Coast Ranges and the Great Valley. This increase in focal depth is particularly pronounced beneath the dense cluster of hypocenters associated with the 1983 Coalinga earthquake and its aftershocks (cross sec. *G–G′*, fig. 5.8*B*).

THE 1857 BREAK AND THE TRANSVERSE RANGES

The 1857 rupture of the San Andreas fault began near Parkfield at the south end of the creeping section of the fault and propagated southeastward along the straight segment, through the Carrizo Plain and around the Big Bend near Tejon Pass, and thence along the relatively straight, east-southeastward trend of the Mojave segment to Cajon Pass, where the San Jacinto fault branches to the south (figs. 5.3, 5.9*A*). Right-lateral offsets associated with this great earthquake generally decreased from 9 m along the Carrizo Plain segment, through 6 m around Fort Tejon, to 3–4 m along the Mojave segment (Sieh, 1978).

The pronounced bends in the San Andreas fault at either end of the east-southeast-trending Mojave segment involve strong structural complexities and clusters of persistent seismic activity. Both bends, for example, spawn major left-lateral faults that form conjugate sets to the San Andreas system. Sykes and Seeber (1985) proposed that these two major bends in the San Andreas fault system represent large-scale asperities that exert a strong influence on the rupture patterns of great earthquakes along the San Andreas fault in southern California. The San Andreas fault appears to maintain its integrity as a single, more or less continuous zone through the 30° bend at Fort Tejon. Convergence resulting from the pronounced counterclockwise cant of the Mojave segment of the San Andreas fault (N. 66° W.) with respect to the average N 37° W. orientation of the transform boundary largely accounts for the crustal uplift and shortening expressed in the Transverse Ranges.

The straight Carrizo Plain segment is, except for a small cluster of events near Simmler (lat 35°25′ N., long 120°00′ W.), almost completely aseismic, much like the Point Arena segment of the 1906 break. The straight part of the Mojave segment also is seismically very quiet. The southernmost 80 km of the 1857 rupture zone produces few earthquakes, forming a sinuous lineation around the fault. Again, an analogy can be drawn with the 1906 rupture zone: The southernmost 80 to 100 km of the 1906 rupture, which exhibited less slip than the rupture zone farther north, also has a slightly higher background seismicity rate than that to the north. The Mojave earthquakes are temporally clustered (Sauber and others, 1983) and, because of their reverse focal mechanisms and displacement from the surface trace of the San

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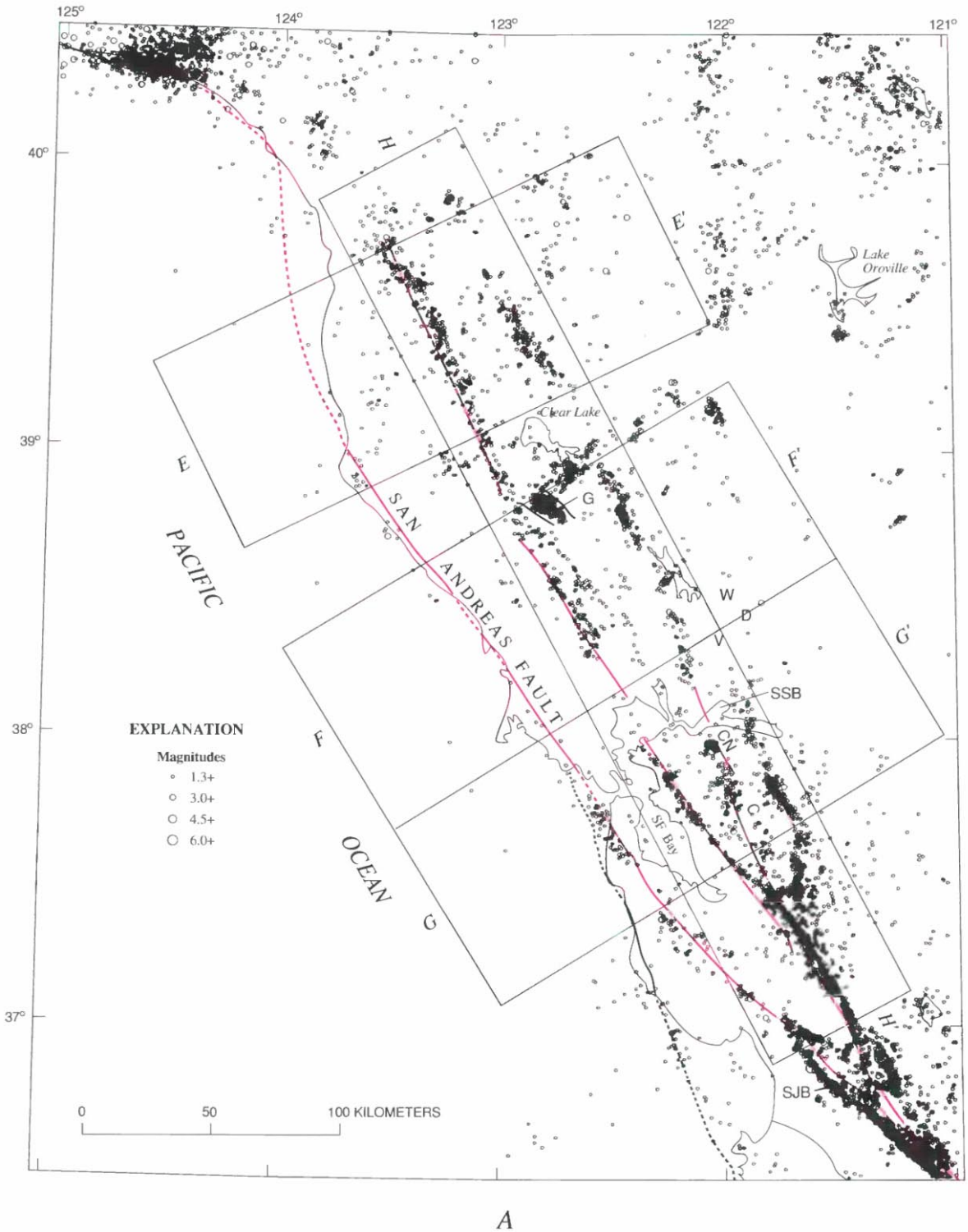

FIGURE 5.6.—Seismicity in the northern (*A*) and central (*B*) Coast Ranges. Major branches of the San Andreas fault marked in red; faults dotted where concealed. Earthquakes within rectangles are plotted in corresponding depth sections in figures 5.7 and 5.8. C, Calaveras fault; CN, Concord fault; G, The Geysers; SF Bay, San Francisco Bay; SJB, San Juan Bautista; SSB, Suisun Bay; D, Dixon; V, Vacaville; W, Winters.

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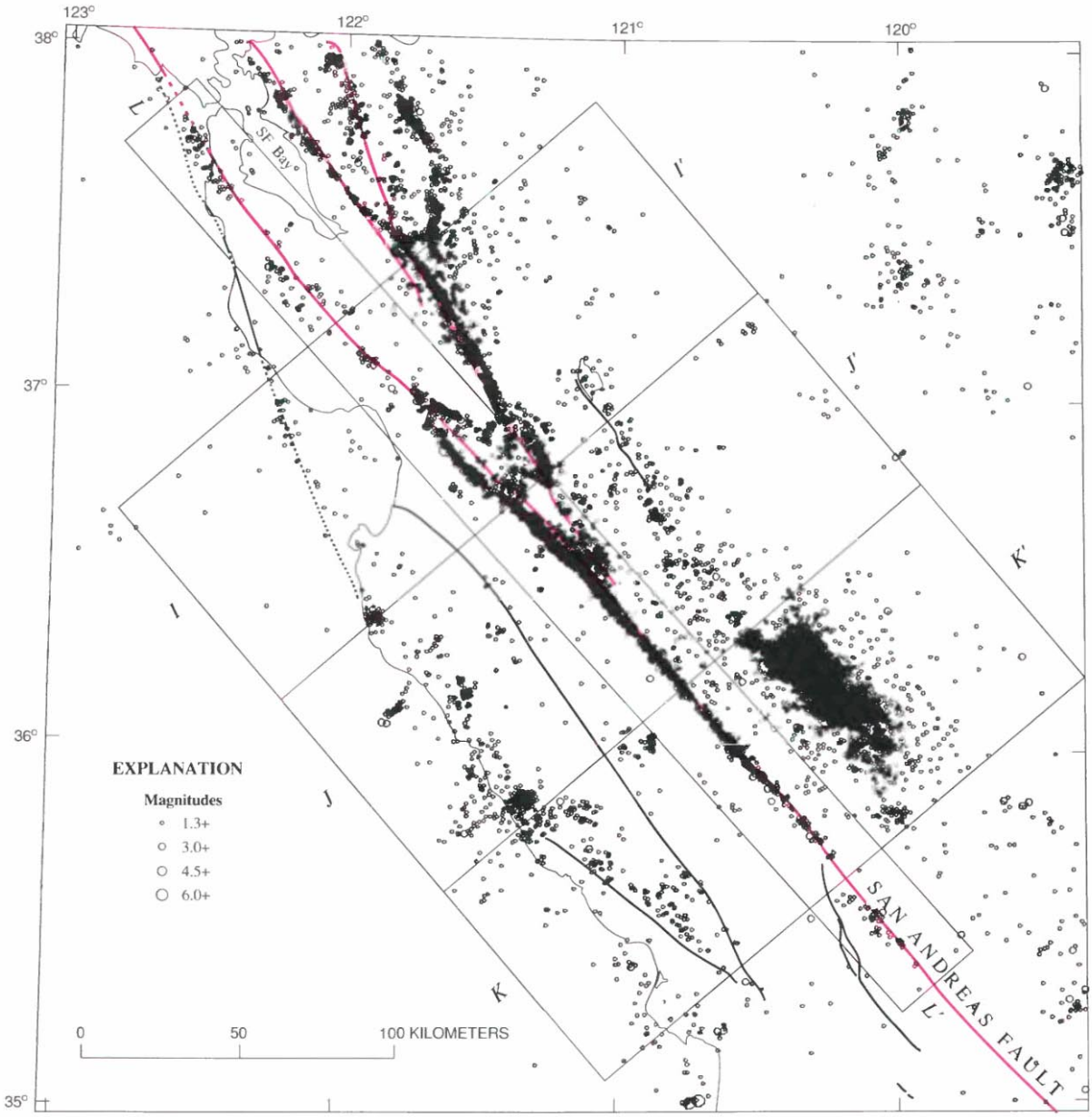
Andreas, are thought to be on secondary fault structures rather than on the San Andreas fault itself.

Within the area of the Big Bend of the San Andreas fault near Tejon Pass, the level of seismicity is much higher than in the adjoining regions. Much of this activity is associated with the Pleito-White Wolf fault system, which abuts the San Andreas fault in the northern bend, some 40 km west of the junction with the Garlock-Big Pine faults (fig. 5.9*A*; cross sec. *N*–*N*′, fig. 5.9*B*; see fig. 5.12). The White Wolf fault ruptured in 1952 with the M=7.7 Kern County earthquake, accompanied by left-oblique reverse slip on a southeast-dipping fault plane (Richter, 1958; Stein and Thatcher, 1981). This is the largest earthquake to occur in California since the M≈8 San Francisco earthquake. In contrast to the quiescent 1906 rupture, however, the White Wolf fault continues to



B

FIGURE 5.6.—Continued.

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be marked by persistent aftershocks of the 1952 Kern County earthquake. The Garlock and Big Pine faults are essentially quiescent within 40 to 50 km of the San Andreas, although two small clusters of epicenters form a nearly symmetrical pattern on either side of the junction of these sinistral faults with the San Andreas.

Seismicity increases markedly near the south end of the 1857 rupture zone, where the San Jacinto fault and the east-west-striking Cucamonga fault, which forms the south front of the central Transverse Ranges, intersect the San Andreas fault. A bulbous lobe of epicenters extends westward along the Cucamonga fault from this junction. Scattered epicenters fill in the wedge of the Transverse Ranges between the Cucamonga and San Jacinto faults. In figure 5.9*A*, note the tight lineation of epicenters that appears to follow the trace of the Cucamonga fault westward to its intersection with the Elsinore fault (Chino branch). The significance of this lineation is unclear because the Cucamonga fault presumably dips north beneath the central Transverse Ranges (Morton, 1987).

The cross section along the Mojave segment of the San Andreas fault (*M–M'*, fig. 5.9*B*) shows a wide variation in focal depths. The few events along the straight section of the Mojave segment are strongly clustered around depths of 10 km, with the maximum focal depth always above 15 km and almost no shallow earthquakes. This pattern is similar to the concentration of hypocenters in the lower half of the seismogenic crust beneath the locked 1906 segment (compare with cross sec. *L–L'*, fig. 5.7). In contrast, the earthquakes at Tejon Pass cover the full depth range from 0 to 25 km. At the southeast end of the 1857 rupture zone at Cajon Pass, maximum focal depths increase with the seismicity level to a maximum of 20 km. In this section, there are no shallow (less than 5 km deep) events.

Note, in particular, that focal depths of more than 20 km are broadly associated with the convergent tectonics of the Transverse Ranges; they are not limited to the seismicity clusters in the vicinity of the bends in the San Andreas fault system as might be inferred from cross section *M–M'* (fig. 5.9*B*). Cross sections *N–N'* and *O–O'* (fig. 5.9*B*), for example, illustrate that the seismogenic crust reaches thicknesses of 20 to 25 km beneath the Santa Barbara Channel and the western Transverse Ranges, as well as beneath the Tehachapi Mountains to the east.

SOUTHERN SECTION OF THE SAN ANDREAS FAULT SYSTEM

Southeast of the 1857 rupture, the San Andreas fault splays into several branches associated with intense

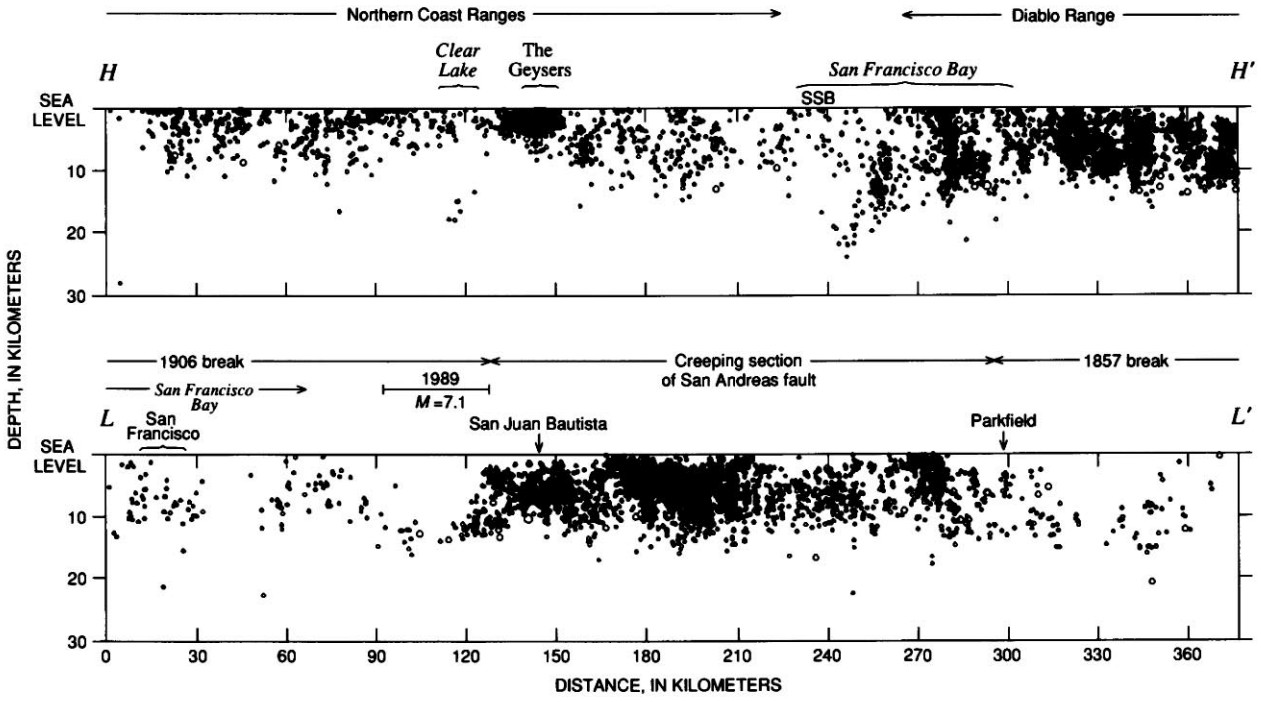

FIGURE 5.7.—Longitudinal depth sections along the San Andreas fault system in the northern and central Coast Ranges. Bar above section *L–L'* indicates rupture extent of the October 17, 1989, Loma Prieta *M*=7.1 earthquake (see chap. 6). SSB, Suisun Bay. See figure 5.6 for locations of sections and explanation of symbols, which are scaled with scale change of cross sections.

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seismicity in the Banning-San Gorgonio area. Like the Tejon Pass bend in the 1857 rupture zone, the San Gorgonio bend spawns a major left-lateral fault (the Pinto Mountain fault) conjugate to the San Andreas system. Unlike the situation at Tejon Pass, however, the San Andreas fault at San Gorgonio splays into a complex pattern of branching and intersecting fault segments. South of San Gorgonio, the San Andreas fault reconverges into a single strand and bends again to the more southeasterly trend that characterizes the southern section of the fault system.

This section of the fault system south of the Transverse Ranges is transitional from oblique spreading along the axis of the Gulf of California to the obliquely convergent strike-slip displacement that dominates deformation along the continental section of the San Andreas transform boundary to the north. Several major strike-slip faults run west of and subparallel to the main strand of the San Andreas fault south of the Transverse Ranges. These faults, which are considered part of the San Andreas system and include the Imperial, San Jacinto, and Elsinore faults, accommodate a significant proportion of the plate-boundary motion. The Imperial and San Jacinto faults, in particular, have produced more moderate earthquakes than any other segment within the fault system (see chap. 6; Hanks and others, 1975).

SOUTHERN BRANCH OF THE SAN ANDREAS FAULT

The most intense seismicity along the main trace of the southern section of the San Andreas fault is associated with the San Gorgonio bend and is concentrated between the two principal branches of the San Andreas fault: (1) the Mission Creek fault, or northern branch of the San Andreas; and (2) the Banning fault, which runs nearly due west from the south end of the Mission Creek fault toward an ambiguous junction with the San Jacinto fault just south of San Bernardino (see fig. 5.3*A* and maps at front of book). Neither strand forms a continuous structure through the bend. This San Gorgonio seismicity cluster produced numerous M=5.0–6.5 earthquakes in the 1930's and 1940's, and in 1986 it produced the M_L=5.6 North Palm Springs earthquake, which involved dextral strike-slip displacement on the north-dipping Banning fault (Jones and others, 1986). The background seismicity in this area is the highest in southern California, but it is distributed throughout a volume and cannot be clearly associated with any fault. To the west, seismicity associated with the Banning cluster abuts the dense lineation of epicenters coincident with the northernmost segment of the San Jacinto fault. Nicholson and others (1986) suggested that much of the seismicity within the upper 10 km of the crust in this cluster involves left-lateral slip on a series of northeast-striking faults; however, Jones (1988) pointed out that the evidence for northeast-trending lineations of epicenters within the Banning cluster is less than clear.

Diffuse seismicity extends northward from the Banning cluster into the San Bernardino Mountains and eastward into the Pinto Mountains, with no clear lineations along the sinistral Pinto Mountain fault. Indeed, a diffuse, north-south-trending lineation of epicenters seems to cut directly across the Pinto Mountain fault from the west-central Pinto Mountains. Two M=5.2 earthquakes (see events 75, 76, fig. 5.11*A*) with right-lateral strike-slip planes parallel to this trend occurred at the north end of this zone in 1975 and 1979. Somewhat farther south, however, a broad, east-west-trending lineation appears to coincide with the Blue Cut fault. Even farther south, a second broad lineation extends eastward from near the junction of the Banning and Mission Creek branches, although this lineation does not coincide with a mapped fault.

The southernmost section of the San Andreas fault, the Indio segment, which extends from the junction of the Banning and Mission Creek branches southward to the end of the San Andreas at the Salton Sea, has been almost completely aseismic in historical time. At the north end of this segment, periodic swarms of small ($M \leq 4$) earthquakes a few kilometers east of the San Andreas appear to occur on small northeast-trending structures (for example, Norris and others, 1986; Jones, 1988). The sparse background seismicity is also offset a few kilometers to the east from the surface trace of the San Andreas. Although the possibility of systematic offsets related to P-wave-velocity contrasts across the fault has not been investigated in detail, the observed offset seems too large to be explained entirely by lateral velocity contrasts.

Although it has not ruptured with a major earthquake in historical time, the aseismic Indio segment of the San Andreas fault seems to have much in common with the 1857 and 1906 rupture zones. Sieh (1986) presented geologic evidence for at least four major ruptures along the Indio segment since A.D. 1000; the last occurred approximately 300 yr ago. Unlike the two major locked sections, however, the south end of the Indio segment adjacent to the Salton Sea shows minor aseismic creep (Louie and others, 1985) and has shown episodes of sympathetic slip accompanying $M \approx 6$ earthquakes on the Imperial fault and the southern section of the San Jacinto fault (Sieh, 1982). Not only is the Indio segment aseismic, but also the entire Coachella block extending from the San Andreas fault on the northeast to the crest of the San Jacinto Mountains on the southwest.

A cross section of hypocenters along the southern branch of the San Andreas fault (M–M', fig. 5.9*B*) shows that the earthquakes associated with the bend at San

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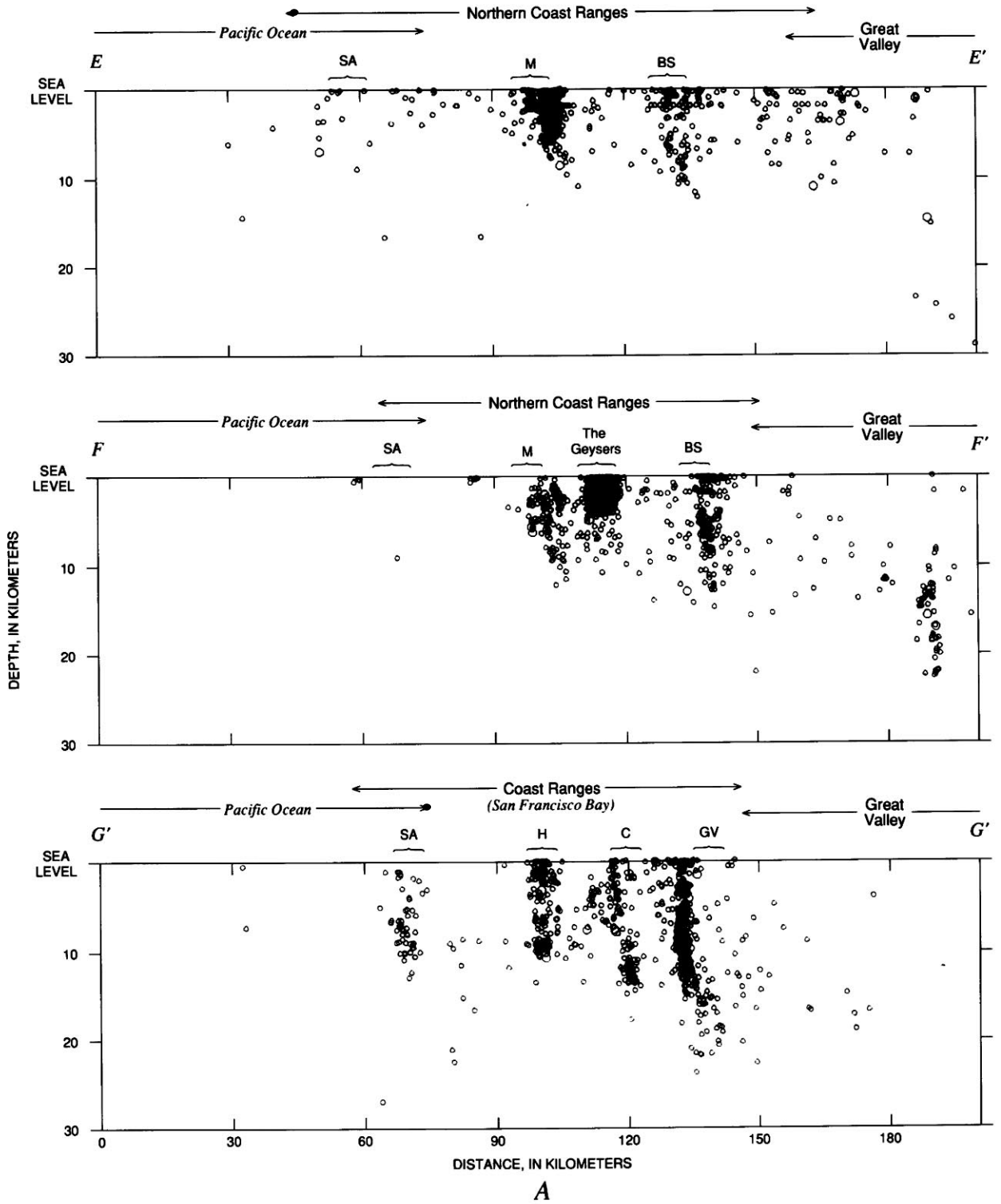

FIGURE 5.8.—Transverse depth sections across the San Andreas fault system in the northern (*A*) and central (*B*) Coast Ranges. See figure 5.6 for locations of sections and explanation of symbols, which are scaled with enlargement of cross sections. Faults: BS, Bartlett Springs; C, Calaveras; GV, Greenville; H, Hayward; M, Maacama; R, Rinconada; SA, San Andreas; SG, San Gregorio; SNA, Sur-Nacimiento. BV, Bear Valley on cross section *J–J'*. FRT, Franciscan terrane.

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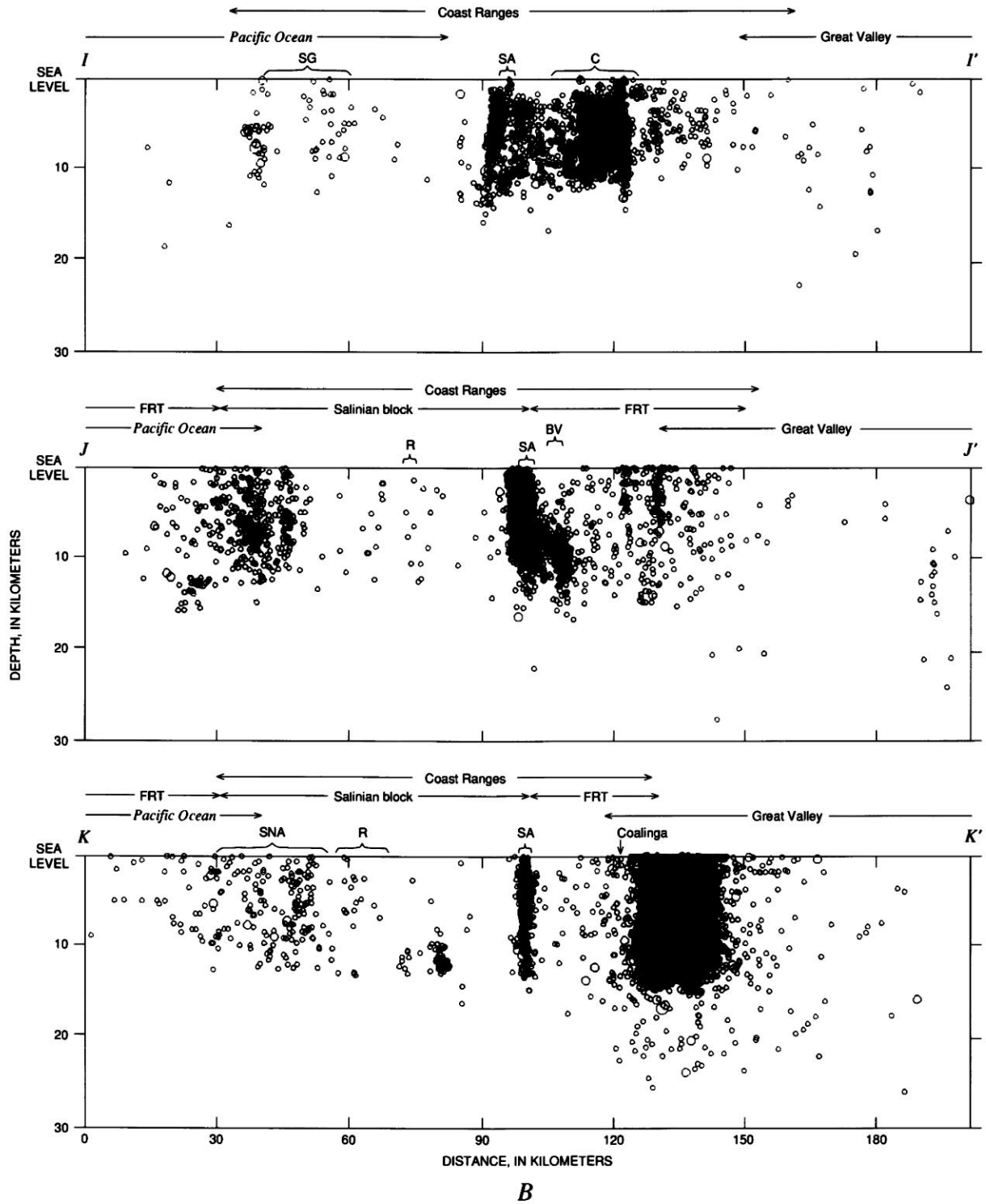

B

FIGURE 5.8.—Continued.

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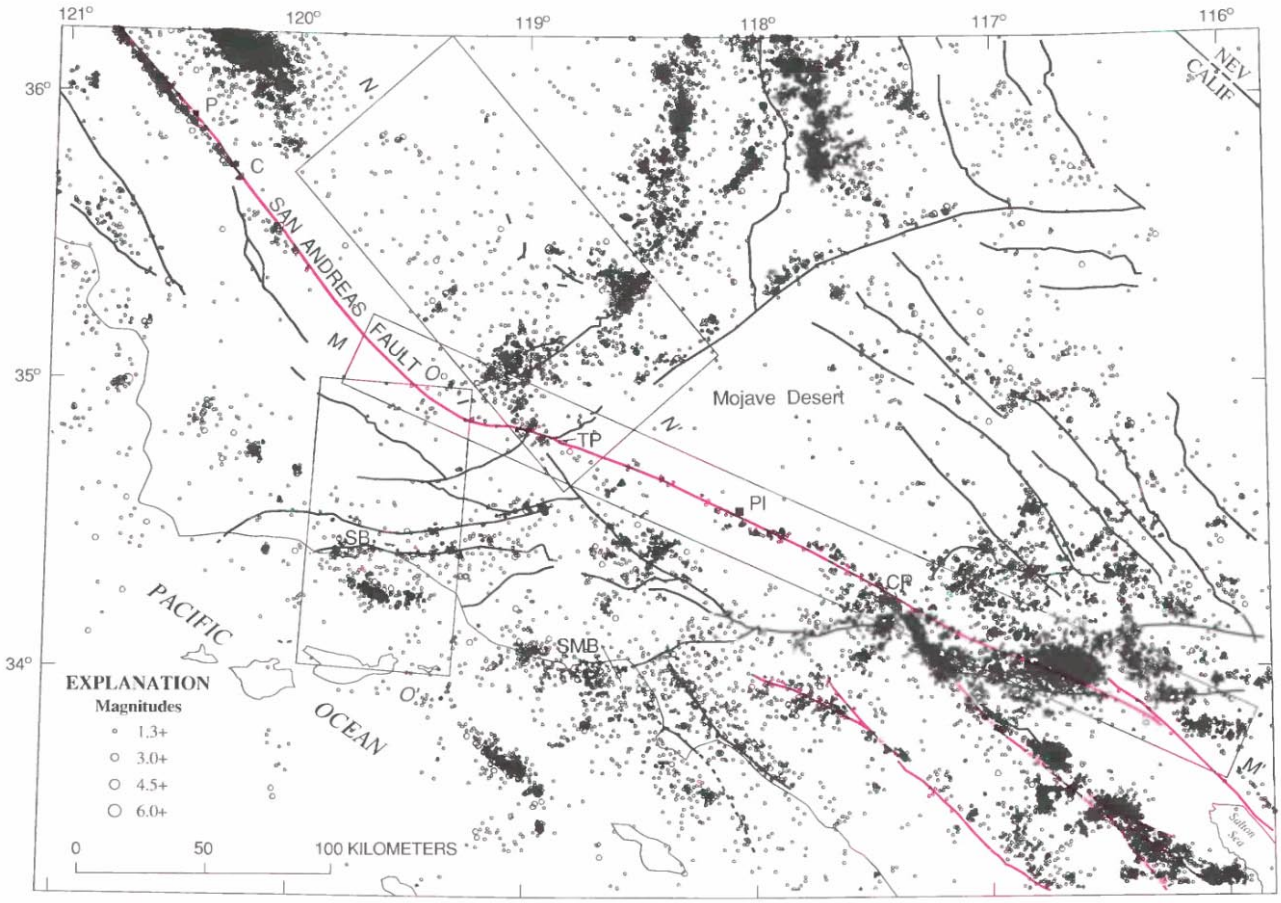
Gorgonio are among the deepest in southern California, with maximum focal depths approaching 25 km. The maximum focal depths deepen southward along the San Andreas fault from about 12 km beneath the Mojave segment to 25 km beneath the San Gorgonio fault. At the south end of the San Gorgonio area, however, maximum focal depths abruptly decrease to 10 km. This shallowing of seismicity is associated with a shift in the most concentrated seismicity from between the two segments (Mission Creek and Banning) of the San Andreas to east of the Mission Creek fault. The sparse seismicity of the Indio segment is limited to depths of 5 km or less.

ASSOCIATED FAULTS

Although the southernmost section of the San Andreas fault is almost completely aseismic, associated subparallel faults are extremely active. These faults are marked by the three bold north-south- to northwest-trending alignments of epicenters that dominate the seismicity pattern within the San Andreas fault system south of the Transverse Ranges (fig. 5.10*A*), from east to west: (1) the Brawley seismic zone (Johnson, 1979), defined by a dense, spindle-shaped cluster of epicenters connecting the north end of the Imperial fault and the south end of the Indio segment of the San Andreas fault; (2) the northwestward alignment of densely clustered epicenters along the San Jacinto fault zone, which appears to branch from the northern section of the Imperial fault; and (3) the northwestward alignment of more diffusely clustered epicenters along the Elsinore fault, which appears to branch from somewhere near the south end of the Imperial fault.



A

FIGURE 5.9.—Seismicity in the southern Coast Ranges and Transverse Ranges. *A*, Earthquake locations, showing major branches of the San Andreas fault system in red; faults dotted where concealed. Magnitude symbols shown in explanation are scaled with enlargement of cross sections. C, Cholame; CP, Cajon Pass; P, Parkfield; Pl, Palmdale; SB, Santa Barbara; SMB, Santa Monica Bay; TP, Tejon Pass. *B*, Depth sections outlined in figure 5.9*A*. Faults: B, Banning; G, Garlock; MC, Mission Creek; N.Br.SA, northern branch of the San Andreas; PM, Pinto Mountain; SA, San Andreas, SJ, San Jacinto; WW, White Wolf.

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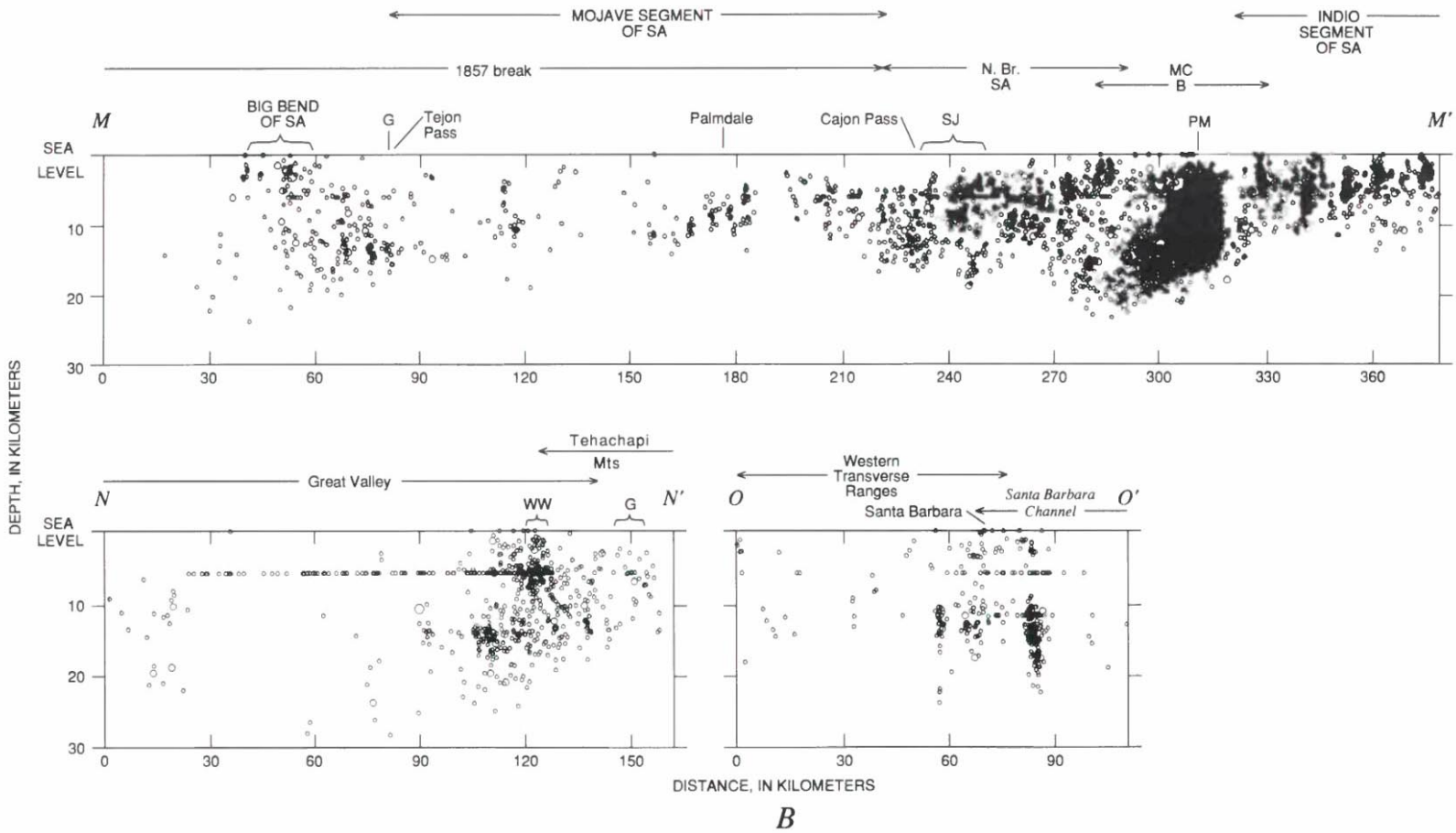

FIGURE 5.9.—Continued.

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The Brawley seismic zone and the cluster of epicenters at the south end of the Imperial fault (coincident with the Cerro Prieto volcanic-geothermal field in Mexico) represent the two northernmost in the series of small spreading centers offset by right-lateral transform faults that characterize oblique spreading in the Gulf of California (Lomnitz and others, 1970; Johnson and Hill, 1982). The Imperial fault itself, which is marked by a scattered alignment of epicenters, serves as the transform fault between these two small spreading centers. The M=7.1 El Centro earthquake ruptured the entire length of the Imperial fault in 1940, and the M=6.6 Imperial Valley earthquake of 1979 ruptured the north two-thirds of the fault; intensity data suggest that moderate earthquakes ($5.5<M<6.3$) in 1906, 1915, 1917, and 1927 may also have been located on the Imperial fault (Johnson and Hill, 1982). Most of the aftershocks associated with the 1979 Imperial Valley earthquake were concentrated in the south half of the Brawley seismic zone, which was first recognized because of the many earthquake swarms it produced from 1973 through mid-1979 (Hill and others, 1975; Johnson 1979; Johnson and Hutton, 1982). Many of the individual swarm sequences, as well as individual clusters of events in the aftershock sequence, defined lineations transverse to the strike of the Imperial fault and the long axis of the Brawley seismic zone. Most earthquakes within the Brawley seismic zone have strike-slip focal mechanisms; thus, kinematically, these transverse lineations represent conjugate structures to the dominant north-northwestward trend of the Imperial-Brawley fault system.

Irregular clusters of epicenters mark the San Jacinto fault zone, which runs along the southwest base of the Santa Rosa and San Jacinto Mountains. These clusters tend to be concentrated near bends and junctions within the complex set of multiple fault strands that form the surface expression of this fault zone. In several places, particularly within the southern and northern sections of the fault zone, epicenters define linear concentrations that tend to be closely aligned with mapped fault traces. The San Jacinto fault zone has produced at least 10 earthquakes of M=6.0–6.6 since 1890, the most recent of which were the M=6.2 earthquake of 1954, the M=6.6 Borrego Mountain earthquake of 1968, and the M=6.6 Superstition Hills earthquake of 1987. Thatcher and others (1975) pointed out that this series of historical $M>6$ earthquakes along the San Jacinto fault zone has left two seismic gaps: one along the northern 40 km of the fault, and the other along a 20-km-long stretch of the central section of the fault zone (the Anza gap). The Anza gap shows up in figure 5.10*A* as a relatively quiescent stretch of the fault zone between two dense clusters, with a third cluster located off the fault zone some 20 km southwest of the gap (see Fletcher and others, 1987; Sanders and Kanamori, 1984).

The Elsinore fault zone is defined not so much by a coincident alignment of epicenters as by the loci of western end points for clusters of epicenters elongate northeastward between the Elsinore and San Jacinto fault zones. This pattern is most pronounced along the southeast half of the fault; the northwest half, which defines the northeast scarp of the Elsinore Mountains, is marked by scattered clusters of epicenters. As the Elsinore fault enters the Los Angeles Basin to the north, it splays into the Whittier and Chino faults. Historical seismicity levels are considerably lower along the Elsinore fault than either the San Jacinto fault zone or the Imperial fault/Brawley seismic zone. The largest historical earthquake on the Elsinore fault was an M=6 event in 1910 in the central section. The Whittier Narrows earthquake (M_L=5.9) of 1987, which caused over $300 million in damage, was located at the north end of the Elsinore-Whittier fault. Because its mechanism was thrust faulting on an east-west-striking plane with a shallow dip, however, it does not appear to be simply related to the Elsinore system.

Seismicity in the relatively quiescent southwestern corner of California between the Elsinore fault and the coast shows up in figure 5.10*A* as small, sparsely scattered clusters of epicenters. Activity picks up again, however, in the vicinity of the major northwest-striking faults along the coast (the Rose Canyon fault through San Diego and the Newport-Inglewood and Palos Verdes faults along the western margin of the Los Angeles Basin). Except for weak alignments along the Newport-Inglewood fault, which ruptured with an M=6.3 earthquake in 1933 (Richter, 1958), the seismicity patterns associated with these faults show little tendency to align along mapped fault traces.

The cross sections in figure 5.10*B* emphasize that, except in the immediate vicinity of the Salton Sea, maximum focal depths associated with earthquakes aligned along the principal branches of the southern section of the San Andreas fault system are systematically deeper than those aligned along its central and northern sections. Maximum focal depths, for example, decrease from 15 to 18 km beneath the central section of the Imperial fault near the United States-Mexican border to less than 10 km beneath the north end of the Brawley seismic zone at the southeast tip of the Salton Sea (cross sec. Q–Q', fig. 5.10*B*). The focal depths associated with earthquakes along the Coyote Creek, Superstition Hills, and Superstition Mountain faults forming the southwestern section of the San Jacinto fault zone adjacent to the Salton Sea are concentrated in the upper 10 km of the crust (cross sec. P–P', fig. 5.10*B*).

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Those segments of the San Andreas fault system in southern California with maximum focal depths shallower than 12 to 15 km are also those that show evidence of aseismic creep (see Louie and others, 1985). Indeed, actively creeping segments of the San Andreas fault system throughout California seem to be confined to those along which microearthquakes are concentrated in the shallow crust (focal depths of less than 12–15 km).

Moving northwestward along the San Jacinto fault zone, the base of the seismogenic crust deepens systematically to a maximum of 20 km beneath the stretch adjacent to San Jacinto Mountain (which at 3,293 m, is the second highest point in southern California) midway along the fault zone (cross sec. *P–P′*, fig. 5.10*B*). The base of the seismogenic crust maintains this 20-km depth farther northwestward along the fault zone to its junction with the Banning fault just south of San Bernardino (fig. 5.10*A*), beyond which it begins to shallow again. Note, in particular, that earthquakes tend to be concentrated between 10- and 20-km depth beneath the San Jacinto fault zone, leaving the upper 10 km of the crust relatively quiescent along the middle stretch of the fault zone. The dense knot of hypocenters in the upper 5 km of the crust midway along cross section *P–P′* corresponds to the cluster of epicenters 15 km southwest of the fault zone near the Anza gap (fig. 5.10*A*). The Anza gap itself shows up between $\Delta = 120$ and 140 km in cross section *P–P′* as a quiescent zone below and southeast of the shallow cluster of hypocenters (Fletcher and others, 1987; Sanders, 1987). The distribution of hypocenters beneath the Elsinore fault zone (cross sec. *R–R′*, fig. 5.10*B*) is in many ways similar to that beneath the San Jacinto fault zone. Maximum focal depths increase northwestward from 12–15 km at the southeast end of the fault near the United States-Mexican border to about 20 km midway along the fault zone (generally coincident with the highest topography in this section of the Peninsular Ranges) and then gradually decrease farther northwestward toward the Los Angeles Basin. Maximum focal depths show evidence of increasing again at the northwest end of the fault as it approaches the Transverse Ranges and branches into the Whittier and Chino faults. The hypocenters along the south half of the Elsinore fault also tend to concentrate in the lower 10 km of the seismogenic crust, although this pattern is not as well defined in the diffuse seismicity of the Elsinore fault zone as in the dense clustering along the San Jacinto fault zone.

FOCAL MECHANISMS AND TRANSFORM-BOUNDARY KINEMATICS

Focal mechanisms of selected earthquakes recorded in California from 1933 through 1988 are shown in figure 5.11*A*, and the corresponding source parameters are listed in tables 5.2 and 5.3. Primary considerations in the selection of these events were (1) size—larger events were chosen where available, because they represent large-scale processes along major boundaries; (2) date of occurrence—the quality of data for focal-mechanism determinations improved significantly during the mid-1970's; and (3) location—some larger events were omitted because they were redundant in terms of mechanism and location, and some smaller events were included because they occurred in regions of significant seismicity where no larger events were available. Most focal mechanisms were determined from first arrivals at stations in the northern and southern California seismic networks. The evolving capability of these networks for such studies is reflected in the number of stations in the networks, summarized in table 5.1. Fault-plane solutions for the few large earthquakes on the list before the mid-1970's were supported by observations from stations outside the California networks.

Since the mid-1970's, focal mechanisms have been determined for only a fraction of the events for which adequate local first-motion data were available. Therefore, in addition to the three considerations listed above, there was a fourth, the interests of the investigators who analyzed the data. These interests included topical studies of large earthquakes and aftershock sequences, analyses of regional traveltimes on the basis of $M \geq 4$ earthquakes, and a special study of the focal mechanisms of earthquakes on or near the San Andreas fault in southern California (Jones, 1988).

Focal mechanisms discussed in the first two subsections below are for earthquakes in the contiguous Coast Ranges-Transverse/Peninsular Ranges-Mojave Desert region associated with the principal seismic expression of the San Andreas fault system, where the seismic networks are best developed. Outside that region, except for the Cape Mendocino area and the vicinity of Long Valley caldera, the few well-determined focal mechanisms that are available provide only limited information on tectonic processes.

STRIKE-SLIP KINEMATICS OF THE SAN ANDREAS FAULT SYSTEM

Most moderate and large ($M \geq 3$) earthquakes along the San Andreas fault and its major branches produce nearly pure right-lateral displacements along near-vertical planes that closely follow the surface traces of the respective fault segments. This relatively simple kinematic pattern holds for the great earthquakes that rupture "locked" sections of the fault every few hundred years (Sieh, 1981), as well as for nearly all the moderate earthquakes that rupture limited patches along persistently active segments of the fault system (Ellsworth and others, 1982; Jones, 1988). Displacements associated with

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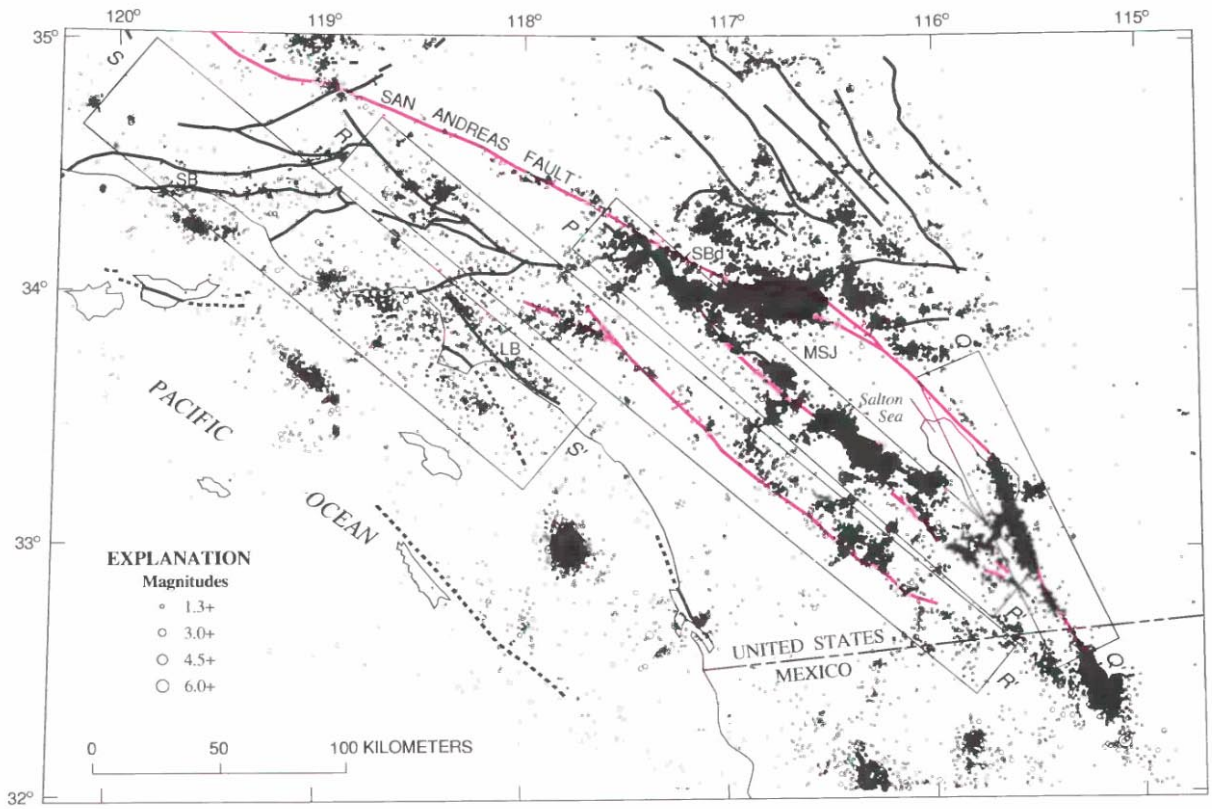
these earthquakes dominate the kinematic pattern along the transform boundary in California. DeMets and others (1987) and Minster and Jordan (1987), for example, argued that the cumulative displacement from earthquakes along the faults in the San Andreas system, together with the contribution from aseismic slip along its creeping segments, accounts for 60 to 70 percent of the total displacement between the Pacific and North American plates.

The fault-parallel strike-slip displacements typical of San Andreas earthquakes are illustrated in figure 5.11*A* by focal mechanisms along the San Andreas fault and its major branches from the United States-Mexican border to north of Clear Lake. In central California, such mechanisms mark the San Andreas fault itself from San Francisco to Cholame (events 26, 36, 38, 45, 46), the Calaveras-Greenville fault (events 23, 28–34) and the Hayward fault (event 27). Farther north, such mechanisms occur along the Green Valley-Bartlett Springs fault (event 15) and the Rodgers Creek-Healdsburg-Maacama faults (events 16, 17, 19, 20). In southern California, such mechanisms mark the San Jacinto fault (events 78, 82–85) and the Imperial fault (event 89). Along the coast west of the San Andreas fault, similar focal mechanisms occur along the San Gregorio-Palo Colorado fault (events 39, 40) in northern California and along the Newport-Inglewood fault zone (events 62, 71), the Rose Canyon fault (event 73), and the San Clemente fault (event 70) in southern California.

Exceptions to this simple pattern for moderate ($M \geq 4$) events along the San Andreas fault and its major branches appear to be limited to regions of unusual complexity, such as the major bends in the San Andreas near Cajon Pass (event 69) and San Gorgonio Pass (event 80). Jones and others (1986) attributed the July 8, 1986, earthquake (event 80) to right-lateral slip on the Banning



A

FIGURE 5.10.—Seismicity along the southern section of the San Andreas fault system. *A*, Earthquake locations, showing major branches of the San Andreas fault system in red; faults dotted where concealed. Magnitude symbols shown in explanation are scaled with enlargement of cross sections. BZ, Brawley seismic zone; LB, Long Beach; MSJ, Mount San Jacinto; SB, Santa Barbara, SBd, San Bernardino. *B*, Depth sections outlined in 5.10*A*. Faults: CU, Cucamonga; NI, Newport-Inglewood; W, Whittier.

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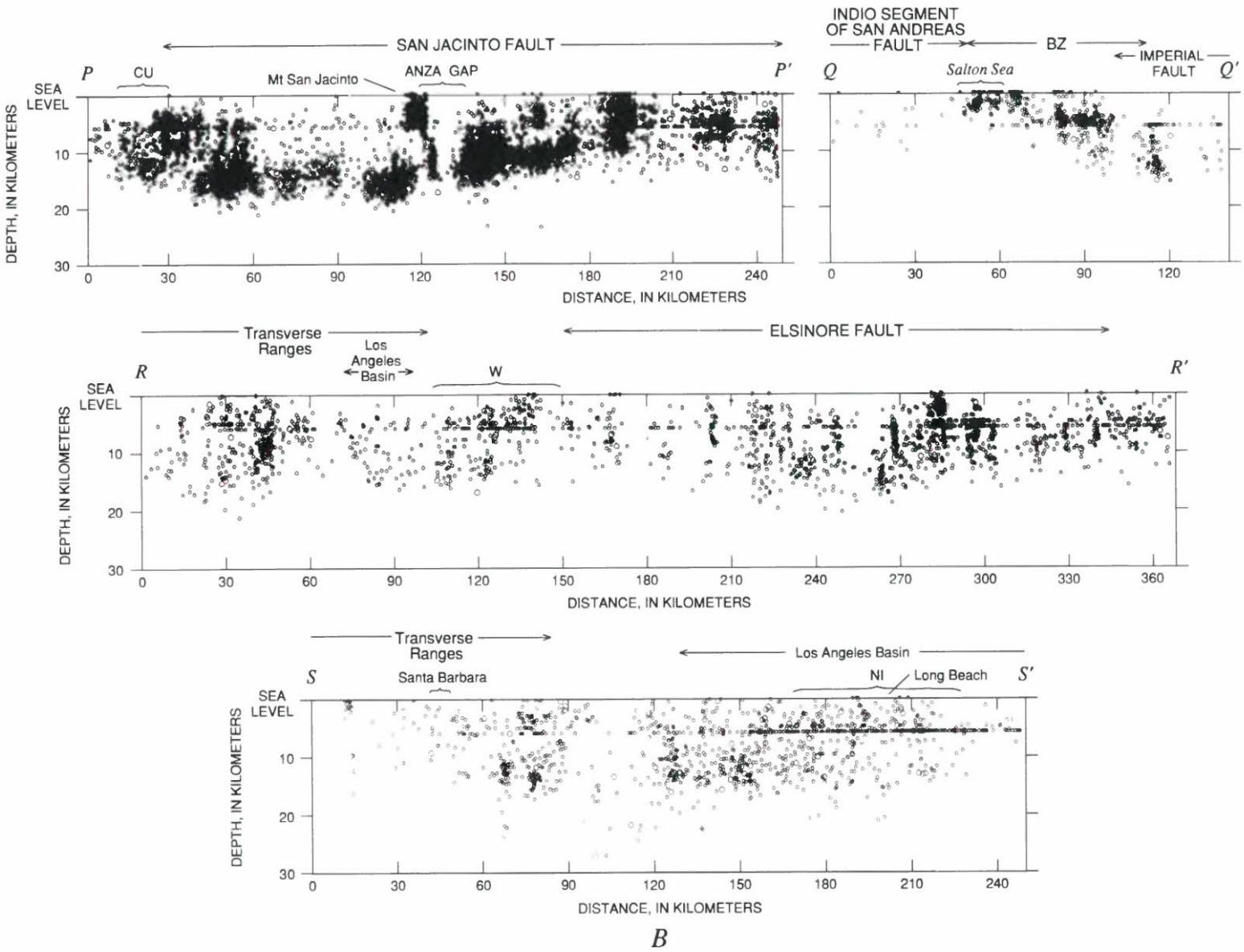

FIGURE 5.10.—Continued.

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segment of the San Andreas fault where it dips 45° N. beneath the San Bernardino Mountains. The October 17, 1989, M=7.1 Loma Prieta earthquake involved nearly equal amounts of right and reverse slip along a section of the San Andreas fault that takes a slight westerly bend through the Santa Cruz Mountains and dips 70° SW. (see chap. 6). Smaller (M<4) events near, but probably not on, the fault show a great variety of focal mechanisms that reflect varying conditions along the fault; these mechanisms range from reverse or reverse-oblique slip

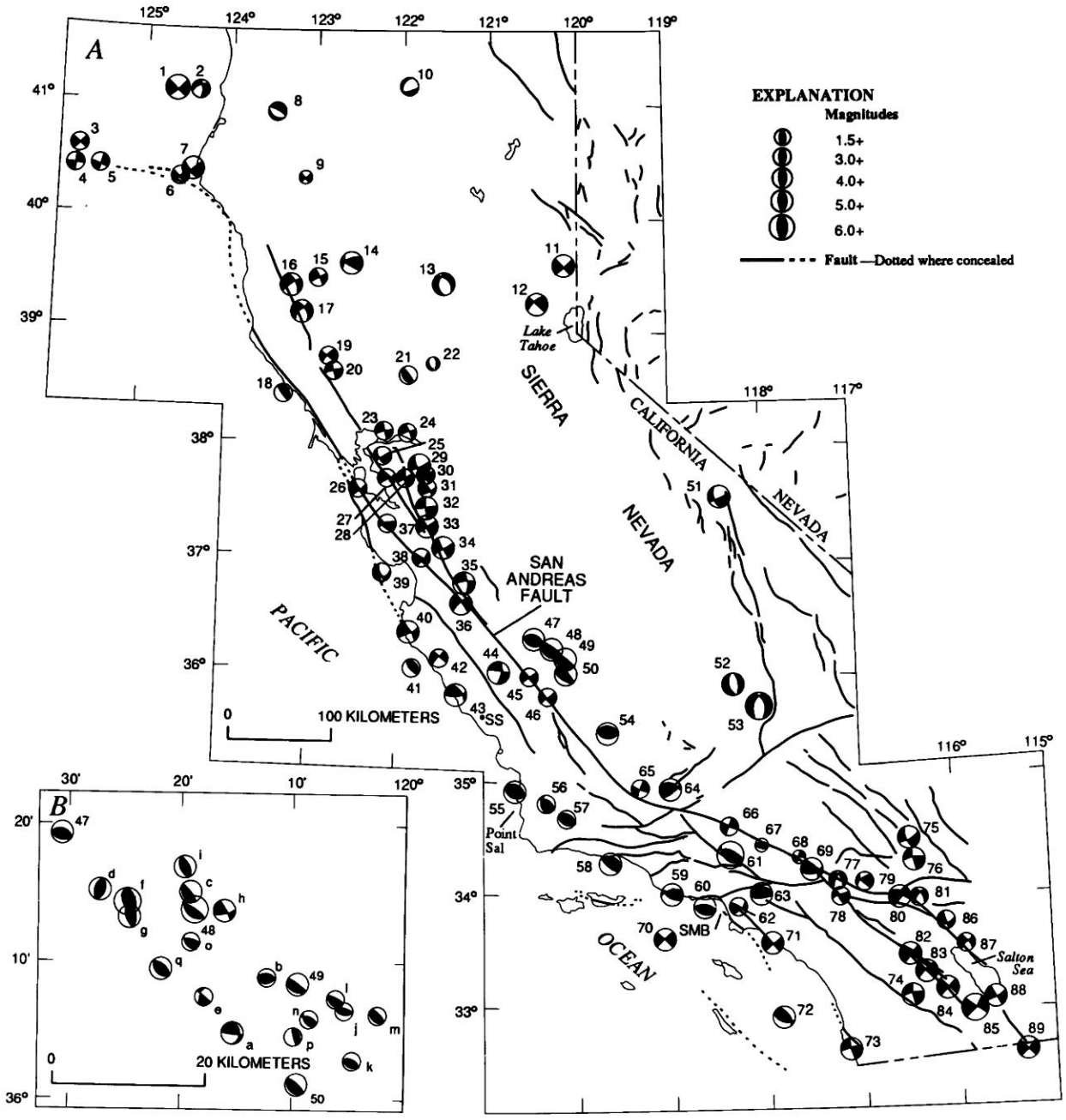

FIGURE 5.11.—Focal mechanisms for larger earthquakes. *A*, California. SMB, Santa Monica Bay; SS, San Simeon. Numbers refer to table 5.2. *B*, Coalinga-Kettleman Hills region (events 47–50, fig. 5.11*A*). Letters and numbers refer to table 5.3. Circle size increases with magnitude from 3.5 to 6.7.

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TABLE 5.2.—*Locations and focal-mechanism parameters for selected earthquakes in California*

[M_L, estimated local magnitude. For M_L<3, estimate is based on coda magnitude (see Lee and Stewart, 1981); for M_L>3, estimate is based on peak amplitude and associated period (see Eaton and others, 1970). Focal-mechanism parameters: DA, dip angle; DD, dip azimuth]

Event	Date (yr/mo/d)	Time (G.m.t.)	Lat N.	Long W.	Depth (km)	M_L	Focal-mechanism parameters		
							DD (°)	DA (°)	Rake (°)
1	801108	1027:32.5	41°06.96′	124°39.87′	6.0	7	138	82	–8
2	801110	0624:07.3	41°06.79′	124°24.06′	7.5	4	337	52	–391
3	801109	0409:07.5	40°35.62′	125°46.45′	15	5.4	134	90	0
4	801108	1125:34.6	40°25.22′	125°48.83′	15	4	5	90	180
5	831220	1041:05.2	40°25.44′	125°31.35′	15	5.7	21	90	180
6	810916	1241:14.7	40°20.38′	124°35.64′	28.9	4.8	319	80	0
7	870731	2356:58.0	40°25.33′	124°26.61′	16.4	5.8	146	90	–20
8	870409	2034:09.0	40°56.32′	123°29.14′	26.2	4.1	27	68	–93
9	820912	0651:31.9	40°21.57′	123°08.52′	50.7	3	52	78	–170
10	820621	0643:37.6	41°10.66′	121°56.64′	7.3	4.3	168	64	–59
11	660912	1641:02.6	39°36.28′	120°09.61′	10	6	134	80	0
12	801128	1821:12.2	39°16.32′	120°27.74′	21.8	5.5	314	60	0
13	750801	2020:12.8	39°26.33′	121°31.71′	5.5	5.7	270	65	–70
14	820903	1858:24.1	39°36.92′	122°34.96′	14.6	4.2	214	74	127
15	781112	1307:57.0	39°29.46′	122°57.09′	10.2	4.3	60	80	180
16	771122	2115:52.2	39°25.10′	123°16.19′	6.6	5.1	65	44	–166
17	780326	0027:03.8	39°11.82′	123°08.49′	6.0	4.7	55	54	–169
18	780331	0103:26.8	38°28.92′	123°20.04′	6.4	3.6	56	20	90
19	820529	1302:23.9	38°47.87′	122°49.35′	4.8	4.3	39	90	–167
20	770911	2346:11.5	38°39.96′	122°45.61′	7.0	3.7	76	90	–167
21	780908	1659:47.6	38°37.86′	121°54.59′	8.1	4.3	239	20	90
22	870103	1354:18.0	38°44.89′	121°37.90′	11.4	1.8	90	56	–68
23	770905	1745:28.0	38°09.68′	122°10.44′	7.5	3.7	76	90	180
24	770604	2057:07.8	38°09.42′	121°54.51′	18.3	3.6	70	80	180
25	770108	0938:07.0	37°54.94′	122°11.58′	10.4	4.5	240	66	180
26	790428	0044:44.7	37°37.32′	122°27.68′	11.6	4.2	49	70	169
27	840327	0336:35.3	37°43.48′	122°08.41′	3.3	4.5	55	56	173
28	770814	1425:34.4	37°43.42′	121°56.40′	6.5	3.5	60	84	180
29	800124	1900:09.1	37°50.20′	121°46.88′	11.9	5.9	247	75	–170
30	800127	0233:35.8	37°45.12′	121°42.54′	12.4	5.3	232	78	180
31	770621	0243:06.7	37°37.83′	121°40.55′	10.3	4.6	59	80	157
32	860331	1155:39.9	37°28.05′	121°41.63′	8.3	5.8	262	80	180
33	840424	2115:18.8	37°18.56′	121°40.68′	8.4	6.2	236	82	180
34	790806	1705:22.3	37°06.70′	121°30.03′	9.6	5.9	240	84	180
35	860126	1920:51.2	36°48.53′	121°16.10′	4.8	5.8	87	70	–170
36	820811	0746:43.0	36°37.60′	121°18.02′	9.2	4.5	53	85	–166
37	770727	2151:17.2	37°19.06′	122°07.24′	6.8	3.5	212	48	124
38	820818	0843:49.5	37°01.34′	121°44.66′	11.8	4.3	38	80	166
39	780702	1157:56.7	36°53.40′	122°10.86′	6.2	4	249	78	–147
40	840123	0540:19.9	36°22.13′	121°52.74′	7.7	5.2	60	78	173
41	860708	0040:23.0	36°03.81′	121°50.17′	11.9	4.4	60	34	90
42	830721	0123:33.0	36°09.17′	121°32.64′	5.2	3.9	41	90	–175
43	830829	1010:30.9	35°50.17′	121°20.70′	6.6	5.4	51	55	139
44	851124	1921:38.6	36°01.16′	120°53.12′	11.3	4.4	102	70	–170
54	820625	0358:23.0	35°57.43′	120°33.11′	9.1	4.2	51	80	180
46	660702	1216:15	35°47.3–′	120°20.6–′	9.1	3.5	231	78	180
47	821025	2226:03.7	36°19.31′	120°30.44′	11.0	5.5	198	28	90
48	830502	2342:38.1	36°13.96′	120°18.57′	10.0	6.7	217	23	90
49	850804	1201:55.8	36°08.59′	120°09.44′	11.4	5.7	217	14	90
50	850807	0016:03.41	36°01.13′	120°09.46′	14.9	4.6	216	20	82
51	860721	1442:26.1	37°31.91′	118°26.67′	9.1	6.5	245	58	180
52	831021	2244:00	35°54.9–′	118°19.9–′	4.4	4.5	83	46	–85
53	460315	1349:35.9	35°43.50′	118°03.27′	22	6.3	76	45	–117
54	880222	0743:12.8	35°29.84′	119°42.13′	19.1	4.2	182	44	90
55	800529	0338:47.5	34°58.65′	120°42.37′	9.2	5.1	28	34	98
56	820923	2042:50.6	34°52.19′	120°21.76′	4.8	4	36	56	63
57	841025	1036:02.4	34°44.21′	120°08.85′	6	4.5	211	43	90
58	780813	2254:53.4	34°20.82′	119°41.75′	12.1	5.1	10	26	57
59	730221	1445:57.3	34°03.89′	119°02.10′	8	5.9	350	36	55
60	790101	2314:38.9	33°56.65′	118°40.88′	11.1	5	10	60	85
61	710209	1400:41.8	34°24.67′	118°24.03′	8.1	6.4	20	54	76

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TABLE 5.2.—*Locations and focal-mechanism parameters for selected earthquakes in California*—Continued

Event	Date (yr/mo/d)	Time (G.m.t.)	Lat N.	Long W.	Depth (km)	M_L	Focal-mechanism parameters		
							DD (°)	DA (°)	Rake (°)
62	790227	1540:58.9	33°56.7–′	118°19.5–′	9.7	3	135	60	20
63	871001	1442:19.8	34°03.11′	118°04.56′	14.7	6.1	175	65	90
64	520721	1152:14	35°00.—′	119°01.—′	0	7.7	140	63	49
65	820421	2119:30.2	35°00.48′	119°20.94′	15.0	3.2	201	76	170
66	781107	0028:45.6	34°39.93′	118°24.27′	13.4	2.6	200	85	176
67	840414	0227:02.6	34°29.51′	118°04.01′	11.9	2.9	357	56	80
68	850719	1617:01.7	34°23.20′	117°39.79′	8.1	2.8	196	80	169
69	700912	1430:53.0	34°16.18′	117°32.40′	8	5.4	55	60	140
70	810904	1550:50.3	33°40.26′	119°06.67′	5	5.3	315	80	0
71	330311	0154:07.8	33°36.99′	117°58.00′	0	6.3	320	90	0
72	860713	1347:08.2	32°58.24′	117°52.19′	6	5.3	50	50	110
73	850618	0428:14.8	32°40.22′	117°10.33′	12.1	4	255	85	175
74	841010	2122:58.9	33°08.26′	116°30.06′	11.6	4.5	260	80	191
75	750601	0138:49.2	34°30.94′	116°29.72′	4.1	5.2	247	70	–165
76	790315	2107:16.5	34°19.63′	116°26.68′	2.1	5.2	258	81	167
77	810912	2123:07.3	34°09.90′	117°15.93′	4.2	3.8	294	63	–52
78	851002	2344:12.4	34°01.40′	117°14.71′	15.2	4.8	242	75	165
79	781120	0655:09.1	34°09.07′	116°58.52′	12.9	4.3	227	75	145
80	860708	0920:44.5	33°59.91′	116°36.38′	11.1	5.6	30	45	170
81	850119	0030:13.0	33°59.64′	116°23.83′	2.9	3.9	310	63	–40
82	800225	1047:38.5	33°30.05′	116°30.79′	13.9	5.5	38	68	191
83	690428	2320:42.9	33°20.60′	116°20.78′	20	5.8	230	80	191
84	680409	0228:59.1	33°11.39′	116°07.72′	11	6.4	42	90	180
85	871124	1315:56.4	33°00.69′	115°51.31′	1.7	6.2	125	80	0
86	831227	2134:37.7	33°46.79′	116°07.32′	2.7	3.1	251	82	–148
87	791204	0828:17.6	33°34.55′	115°54.75′	5.1	2.7	51	71	–165
88	810426	1209:28.4	33°05.90′	115°37.90′	3.0	5.7	150	80	0
89	791015	2316:53.4	32°36.81′	115°19.09′	12.1	6.6	42	90	180

on easterly-striking planes (events 37, 67), through right-lateral strike slip on planes parallel to the San Andreas fault (events 65, 66, 68, 87), to normal or normal-oblique slip on northerly-striking planes (events 77, 81).

Moderate earthquakes with strike-slip focal-mechanisms that are not located on major faults of the San Andreas system but yet are broadly associated with it commonly have right-slip planes, with strikes ranging from northwestward (event 42) to north-southward (events 35, 44, 74, 75, 76, 86). In most cases, these right-slip planes agree in strike with local mapped faults or with alignments of epicenters that strongly suggest active faults (events 75, 76).

CRUSTAL CONVERGENCE ADJACENT TO THE SAN ANDREAS FAULT SYSTEM

One of the more important results to emerge from high-resolution focal-mechanism studies in recent years is that earthquakes occurring even a short distance off faults of the San Andreas system can involve displacements that diverge sharply from local San Andreas strike-slip displacements. This pattern is particularly pronounced in the strong component of reverse slip at large angles (more than 60°) to the local strike of the San Andreas fault on both sides of the San Andreas fault system in both the Transverse and Coast Ranges.

North-south convergence within the Transverse Ranges is dominated by reverse slip on easterly-striking planes. The M=7.7 Kern County earthquake of 1952 (event 64), which occurred on the south-dipping White Wolf fault along the north flank of the Transverse Ranges about 25 km north of the junction of the San Andreas and Garlock faults, and the M=6.6 San Fernando earthquake of 1971 (event 71), which ruptured a 20-km-long stretch of the northeast-dipping San Gabriel-San Fernando thrust faults (Whitcomb, 1971; Heaton, 1982), are two striking examples of this deformation. So, also, is the alignment of M=5–6 reverse-slip earthquakes (events 59, 60, 63) along the southern margin of the Transverse Ranges. The reverse slip on east-west-striking planes associated with these earthquakes suggests that the north-dipping Santa Monica-Cucamonga fault serves as an important convergent boundary between the Peninsular and Transverse Ranges.

Figure 5.11*A* also shows that the east-west-trending zone of convergence associated with these earthquakes

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TABLE 5.3.—*Locations and focal-mechanism parameters for earthquakes in the Coalinga-Kettleman Hills region*

[Same symbols as in table 5.2]

Event	Date (yr/mo/d)	Time (G.m.t.)	Lat N.	Long W.	Depth (km)	M_L	Focal-mechanism parameters		
							DD (°)	DA (°)	Rake (°)
a	760114	2143:59.5	36°04.88′	120°15.09′	9.0	4.7	85	42	168
47	821025	2226:03.7	36°19.31′	120°30.44′	10.9	5.5	198	28	90
48	830502	2342:38.1	36°13.96′	120°18.57′	10.0	6.7	217	23	90
b	830522	0839:21.7	36°09.03′	120°12.09′	10.5	4.2	164	40	73
c	830524	0902:17.7	36°15.24′	120°19.00′	8.9	4.7	256	18	111
d	830611	0309:52.2	36°15.33′	120°27.01′	2.4	5.2	107	50	90
e	830612	0131:27.5	36°07.55′	120°17.71′	14.5	4.0	296	44	168
f	830722	0239:54.1	36°14.44′	120°24.53′	7.3	6.0	85	38	102
g	830722	0343:01.0	36°13.31′	120°24.37′	7.9	5.0	72	30	85
h	830909	0916:13.5	36°13.91′	120°15.90′	6.7	5.3	64	75	161
i	840219	0943:09.4	36°17.10′	120°19.47′	10.7	4.5	66	52	90
49	850804	1201:55.8	36°08.59′	120°09.44′	11.4	5.7	217	14	90
j	850804	1208:41.3	36°06.67′	120°05.23′	10.9	4.3	188	44	85
k	850804	1515:39.3	36°02.85′	120°04.57′	11.1	4.4	203	26	90
l	850805	1445:37.8	36°07.48′	120°05.99′	7.5	4.4	229	20	105
50	850807	0016:03.4	36°01.13′	120°09.46′	14.9	4.6	216	20	82
m	850809	0847:09.7	36°06.36′	120°02.32′	9.9	3.6	218	30	82
n	850809	1242:18.8	36°05.94′	120°08.39′	6.1	3.8	233	38	113
o	850914	0302:44.6	36°11.57′	120°18.89′	9.4	3.6	225	44	112
p	850915	0909:46.8	36°04.72′	120°09.68′	13.1	3.5	77	16	90
q	870214	0726:50.3	36°09.56′	120°21.53′	14.6	5.2	238	48	98

curves northward near Santa Monica Bay and continues northwestward along the coast at least as far as Point Sal and probably as far as San Simeon. Focal mechanisms of earthquakes along this zone from Point Sal to Whittier (events 55–60, 63) are predominantly reverse slip, with slip directions nearly normal to the local trend of the zone. The focal mechanism of event 43 near San Simeon, which indicates right-oblique reverse slip on a northeast-dipping plane parallel to the coast, is intermediate between those of event 40 at Point Sur and event 55 at Point Sal.

Reverse-slip focal mechanisms for offshore events 18 and 41 in central California and for event 72 in southern California suggest that the offshore crust is undergoing compression normal to the coastline throughout the length of the San Andreas fault system. The Coalinga-Kettleman Hills earthquake sequence of 1982–85 (events 47–50, fig. 5.11*A*) emphasizes the important role of crustal convergence along the southern Coast Ranges-Great Valley boundary in central California. The principal events in this sequence (event 48, Coalinga, and event 49, Kettleman Hills, fig. 5.11*A*) involved reverse slip on subparallel planes at depths of 10 to 12 km that dip gently (approx 20°) southwest. Much of the aftershock activity, however, occurred at shallower depths and involved high-angle reverse slip on planes dipping steeply (45°–70°) northeast (events f, g, i, o, q, fig. 5.11*B*). Displacements associated with these earthquakes, which are nearly perpendicular to the San Andreas fault, represent a convergent process in which Franciscan melange on the west is being wedged between crystalline basement and the overlying Great Valley sedimentary sequence on the east (Wentworth and others, 1983; Eaton, 1990).

The boundary between the Coast Ranges and Great Valley is marked by reverse-slip earthquakes throughout much of its length: event 54 southeast of the Kettleman Hills, the Coalinga-Kettleman Hills sequence, event 21 near Winters east of Lake Berryessa, and event 14 west of Oroville. The similarity in focal mechanism of event 21 near Winters to the Coalinga and Kettleman Hills main shocks suggests that the convergent process acting in the southern Coast Ranges is common to the entire eastern margin of the Coast Ranges. Indeed, the strong earthquakes that shook the Winters-Vacaville-Dixon area in 1892, just south of event 21, resemble the Coalinga-Kettleman Hills sequence in both setting and intensity distribution. Focal mechanisms of smaller earthquakes along the Coast Ranges-Great Valley boundary in central California studied by Wong and others (1988) also suggest convergence across that boundary.

Convergence normal to the strike of the San Andreas fault is not limited to the coast and the Coast Ranges-Great Valley boundary described above. In a detailed examination of the focal mechanisms of aftershocks of the 1984 Morgan Hill earthquake, Oppenheimer and others (1988) concluded that the direction of maximum compression immediately adjacent to the Calaveras branch of the San Andreas fault is at an angle of about 80° to the N. 10°

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W. strike of the fault. Along the entire stretch of the San Andreas fault from Parkfield to the Salton Sea, Jones (1988) found a constant angle of 65° between the strike of the fault and the maximum-principal-stress direction for earthquakes occurring off the fault.

This evidence from earthquake focal mechanisms and other stress indicators (such as borehole breakouts and fold axes) that the maximum principal compressive stress may be oriented at a high angle to the local strike of the San Andreas fault seems to contradict long-accepted ideas for brittle failure in the crust based on laboratory experiments in rock mechanics. Zoback and others (1987) and Oppenheimer and others (1988) suggested that these relations can be explained by an exceptionally low average shear strength for the San Andreas fault system. As pointed out by Lachenbruch and McGarr in chapter 10, however, the strength and state of stress along the San Andreas fault are still matters for discussion.

EAST-WEST EXTENSION IN THE SIERRA NEVADA

The three moderate-earthquake focal mechanisms for the Sierra Nevada and its western foothills shown in figure 5.11*A* all indicate normal faulting on northerly-striking planes and suggest pervasive east-west extension throughout the Sierra Nevada. Event 52 is in a dense north-south-trending band of epicenters about 15 km east of the Kern River canyon, and event 53 is in a north-south-trending band of earthquakes about 10 km west of the Sierra frontal fault near Walker Pass. These relations suggest that the east-west spreading and associated normal faulting on northerly-striking faults of the Great Basin are encroaching into the southeast corner of the Sierra Nevada block (Jones and Dollar, 1986).

Event 13 is the main shock (M=5.7) of an earthquake sequence on a north-south-striking, west-dipping normal fault near the Oroville Dam that occurred in 1975. The uplift of the Sierra Nevada relative to the Great Valley to the west indicated by the focal mechanism of this event is also visible in the Chico monocline, which marks the Sierra Nevada-Great Valley boundary northwest of Oroville.

CONJUGATE FAULTING IN THE SIERRA NEVADA-GREAT BASIN BOUNDARY ZONE

The Sierra Nevada-Great Basin boundary zone is represented in figure 5.11*A* by three focal mechanisms. Events 11 and 12 lie northwest of Lake Tahoe along the edge of a minor gap in the band of seismicity along the east edge of the Sierra Nevada. Both events appear to have resulted from left-lateral slip along steeply dipping, northeast-striking faults; both events had aftershock regions that were elongate northeast-southwest. About 250 km southeast, the M=6.4 July 21, 1986, Chalfant Valley earthquake (event 51) resulted from right-lateral strike-slip displacement on a north-northwest-striking surface dipping 60° SW. An M=5.7 foreshock on July 20 resulted from left-lateral strike slip on a northeast-striking, northwest-dipping surface. These two conjugate slip surfaces merge at their north ends (Cockerham and Corbett, 1987; Smith and Priestly, 1988).

The zone of intense seismicity in the vicinity of Long Valley caldera and the Sierra Nevada block to the south produced 11 $M \geq 5.5$ earthquakes from 1978 through 1984 (Savage and Cockerham, 1987), as well as many thousands of smaller events and numerous earthquake swarms. Most of the larger events occurred in the Sierra Nevada block south of Long Valley caldera, involving left-lateral slip along near-vertical, north-south- to north-northeast-striking faults. One of four $M \approx 6$ events that occurred on May 25–27, 1980, however, was located within the south moat of the caldera along the west-northwest-striking fault zone that produced most of the earthquake swarms (see Hill and others, 1985a, b).

FRAGMENTATION OF THE SOUTHEAST CORNER OF THE GORDA PLATE

The 1980 Eureka M=7.2 earthquake occurred along a fault break that extended from the continental slope 40 km west of the coastline at lat 41° N. for a distance of 140 km southwestward to the MFZ, virtually cutting off the southeast corner of the Gorda plate. Focal mechanisms of the main shock and largest aftershock (events 1, 3, fig. 5.11*A*) both indicate left-lateral strike-slip displacement along a vertical fault that coincides with the line of aftershocks. Some early aftershocks, including event 4 and other moderate events farther east along the MFZ, have focal mechanisms that indicate right-lateral slip along the MFZ. Although the main shock occurred beneath the Continental Shelf, it seems clear that the 1980 earthquake primarily involved the Gorda plate because the fault broke well beyond the base of the continental slope and the edge of the North American plate. Moreover, left-lateral slip along the 1980 break stimulated right-lateral slip along the adjacent part of the MFZ. Ongoing right-lateral displacement along the MFZ is also indicated by event 5 (Dec. 1983).

Two moderate earthquakes near Cape Mendocino in 1981 and 1987 (events 6 and 7, respectively) had focal mechanisms similar to that of the 1980 Eureka earthquake, indicating left-lateral strike-slip displacement on steeply dipping, northeast-striking planes. Aftershocks of the 1987 M=5.8 event outlined a narrow, steeply dipping, northeast-trending, 20-km-long zone between about 15- and 25-km depth that extended southwestward from the shoreline just north of Cape Mendocino to the

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MFZ. This aftershock zone appears to cut off the southeasternmost corner of the Gorda plate just north of the abrupt eastward termination of intense seismicity along the MFZ, at a point that might be taken as the Mendocino triple junction from the viewpoint of seismicity.

Relative horizontal extension at seismogenic depths is suggested by events 2 and 8. Event 2 (Nov. 10, 1980; 7 km deep) was the largest in a detached cluster of shallow aftershocks 20 km east of the 1980 main shock, and event 8 (Apr. 9, 1987; 26 km deep) occurred about 100 km east of the 1980 main shock in the zone of seismicity associated with the subducting Gorda plate.

DISCUSSION

The Pacific plate moved northwestward with respect to the North American plate by 300 to 400 mm during the 7-yr interval 1980–86. Earthquakes occurring along the San Andreas fault system during the same interval, however, accommodated only a small fraction of this relative plate motion. Only four earthquakes of $M>5$ occurred along branches of the San Andreas fault system during 1980–86: the pair of $M=5.9$–5.3 Livermore earthquakes (events 29, 30, fig. 5.10*A*) on the Greenville fault (Jan. 24–27, 1980), the $M=6.2$ Morgan Hill earthquake (event 33) on the Calaveras fault (Apr. 24, 1984), and the $M=5.6$ North Palm Springs earthquake (event 80) on the Banning segment of the San Andreas fault (July 8, 1986). Each of these moderate San Andreas earthquakes ruptured fault segments limited to 20 to 30 km in length, with average displacements over the respective rupture surfaces of 100 to 200 mm (see Hartzell and Heaton, 1986). As is typical of earthquakes along the San Andreas fault system, each of these events involved nearly pure right-lateral strike-slip displacement coincident with the local strike of the fault. As is also typical of San Andreas earthquakes, slip on the first three events occurred on near-vertical fault planes with a northwestward to north-northwestward strike. The North Palm Springs earthquake, which ruptured a section of the east-west-striking Banning fault in the structurally complex San Gorgonio bend in the fault system at the southern margin of the Transverse Ranges, represents an important deviation from typical San Andreas earthquakes. Although its displacement was dominantly right-lateral strike slip, it occurred along a plane that dips 45° N. (Jones and others, 1986) and included a small but significant component of reverse slip (Mendoza and Hartzell, 1988). With the arguable exception of the North Palm Springs earthquake (arguable because of the complex section of the fault system in which it occurred), however, none of these $M>5$ earthquakes ruptured the main trace of the San Andreas fault. Indeed, the two most recent $M>5$ earthquakes to clearly do so were the $M=6$ Parkfield earthquake of 1966 (Bakun and McEvilly, 1984) and the $M=7.1$ Loma Prieta earthquake of 1989 (see chap. 6).

Thus, aside from the displacement accommodated by steady aseismic slip at a rate of 32 to 37 mm/yr along the creeping section of the fault in central California, most relative plate motion across the San Andreas transform boundary during this 7-yr interval accumulated as elastic shear strain. Accordingly, the earthquakes plotted in figures 5.3 through 5.9 are symptomatic of accumulating strain along the San Andreas fault system rather than of effective strain release. The latter requires rupture with a major earthquake along one of the locked stretches of the San Andreas fault.

SEISMICITY PATTERNS AND THE EARTHQUAKE CYCLE

What changes in spatial-temporal patterns of earthquake occurrence might we expect to see as the next great earthquake on the San Andreas fault approaches? Both historical and instrumental seismicity records indicate that the spatial distribution of earthquakes in California changes only slowly over periods of decades to centuries, although the intensity of activity within this distribution fluctuates year to year (Ellsworth and others, 1981; Hill and others, in press; Hutton and others, in press). Temporal fluctuations in activity during the interval 1980–86, for example, were dominated by a short-lived aftershock sequence following the 1980 Eureka $M=7.2$ earthquake and by the long-lived aftershock sequence following the 1983 Coalinga $M=6.7$ earthquake. The overall spatial distribution of earthquakes in California, however, remained nearly stationary throughout this 7-yr interval. Furthermore, the spatial pattern defined by 1980–86 seismicity is much the same as that outlined by the record of $M\geq5$ earthquakes that extends back nearly 200 yr (see chap. 6).

Variations in the historical rate of moderate to large ($M>5$) earthquakes in central California before and after the 1906 San Francisco earthquake appear to mimic those described by Fedotov (1965) and Mogi (1968) for the earthquake cycle associated with great, subduction-zone earthquakes in Japan, Kamchatka, and the Kurile Islands (see chap. 6; Ellsworth and others, 1981). The history of instrumentally recorded $M<5$ earthquakes in California is too short, however, to indicate whether we might expect to see distinctive changes in the seismicity pattern a short time (months to years) before the next great earthquake on the San Andreas fault. We have yet to see, for example, whether the quiescent (locked) segments of the San Andreas fault remain aseismic except for the rupture of a great earthquake, or whether these segments become active with small to moderate earthquakes as foreshock activity to great earthquakes.

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DISTRIBUTED SEISMICITY AND DEFORMATION OF THE PLATE MARGINS

The two largest earthquakes in California during the interval 1980–86 occurred off the faults of the San Andreas system, and their occurrence emphasizes the importance of deformation within the plate margins along the San Andreas transform boundary. The M=7.2 Eureka event (Nov. 8, 1980), for example, involved deformation internal to the Gorda plate; and the M=6.7 Coalinga event (May 2, 1983) involved crustal shortening with reverse slip perpendicular to the San Andreas fault. These two earthquakes and the many smaller, "off fault" events (fig. 5.4*A*) reflect local deviations from the simple rigid-plate approximation of plate tectonics.

DEFORMATION OF THE GORDA PLATE

As the small, youthful Gorda plate is subducted obliquely northeastward beneath the North American plate, it is being subjected to north-south compression in response to a component of convergence between the larger, older Juan de Fuca plate to the north and the Pacific plate to the south (Jachens and Griscom, 1983; Wilson, 1986). Distorted marine magnetic anomalies within the Gorda plate indicate that it has undergone progressive internal deformation over the past 5 Ma in response to this compression (Silver, 1971), and current seismicity within the plate (fig. 5.4) indicates that this deformation continues to the present.

The 1980 Eureka M=7.2 earthquake emphasizes that part of this deformation occurs with left-lateral slip on northeast-striking faults within the plate. The seismicity map and cross sections (fig. 5.4) demonstrate that deformation associated with the Gorda plate terminates abruptly against the Pacific plate in a steeply north-dipping zone of interaction along the MFZ, which can be followed on shore beneath the North American plate as a gently east-dipping, subhorizontal zone of widely scattered small to moderate earthquakes. Thus, convergence between the Gorda and Pacific plates across the MFZ apparently occurs by crushing and thickening of the southern margin of the Gorda plate as it is jammed against the anvil-like mass formed by the thicker and colder Pacific plate. Diminished east-west stress in the Gorda plate resulting from the subducting limb of the plate farther east serves to increase the difference between the maximum (north-south) and minimum (east-west) compressive stresses within the plate, leading to left-lateral strike-slip displacements along northeast-striking faults, as in the M=7.2 Eureka earthquake. This process accommodates the convergent component of Gorda-Pacific plate motion along the east end of the MFZ at the expense of fragmentation and eastward expansion of the Gorda plate north of the MFZ.

THE SAN ANDREAS DISCREPANCY

Much of the seismicity adjacent to the San Andreas fault system is attributable to differences between the long-term slip rate and direction (slip vector) along the San Andreas fault system and that predicted for relative motion between the Pacific and North American plates along the San Andreas transform boundary on the basis of global models of plate motion. Minster and Jordan (1978, 1987) predicted that the direction of dextral slip between the Pacific and North American plates along the San Andreas transform boundary in central California is N. 35° W. The main trace of the San Andreas system, however, strikes N. 41° W. through central and northern California and N. 65°–70° W. through the Transverse Ranges in southern California. DeMets and others (1987) concluded that the marine magnetic anomalies at the mouth of the Gulf of California constrain the slip rate to an average of 49 mm/yr over the past 3 to 4 Ma. Both long-term geologic offset data and geodetic data measured over the past several decades, however, indicate that the average slip rate along the San Andreas fault system is only about 35 mm/yr. The contribution to deformation of the western margin of the North American plate from spreading across the Basin and Range province is about 10 mm/yr in a N. 56° W. direction (Minster and Jordan,1987). Ellsworth (see chap. 6) suggests that most of the San Andreas discrepancy can be explained if the component of dextral slip associated with historical Basin and Range earthquakes reflects a long-term trend superimposed on the N. 56° W. spreading direction. If so, then the residual component of Basin and Range extension perpendicular to the San Andreas fault system is approximately balanced by convergence across the Coast Ranges and continental margin.

CONVERGENCE NORMAL TO THE SAN ANDREAS FAULT SYSTEM

Focal mechanisms of earthquakes occurring off the San Andreas fault system suggest that the component of the San Andreas discrepancy normal to the fault system may, indeed, be accommodated by distributed brittle deformation on either side of the fault system. These mechanisms range from dextral strike slip on planes subparallel to the San Andreas fault, through oblique-reverse slip, to nearly pure reverse slip with a slip direction perpendicular to the San Andreas fault.

The Coalinga-North Kettleman Hills earthquake sequence provides clear evidence for crustal convergence perpendicular to the San Andreas fault system in the

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Coast Ranges. The several smaller events with similar mechanisms to the north along both the eastern and western (coastal) margins of the Coast Ranges (fig. 5.11) suggest that the convergence responsible for the Coalinga earthquake may be active the length of the Coast Ranges (Wong and others, 1988; Eaton and Rymer, 1990). The subparallelism of fold axes within the Coast Ranges with the San Andreas fault indicates that fault-normal convergence has been important for the past 3 Ma in central California (fig. 5.12; Page and Engebretson, 1984). Namson and Davis (1988) proposed that the entire system of Coast Range folds may be genetically related to

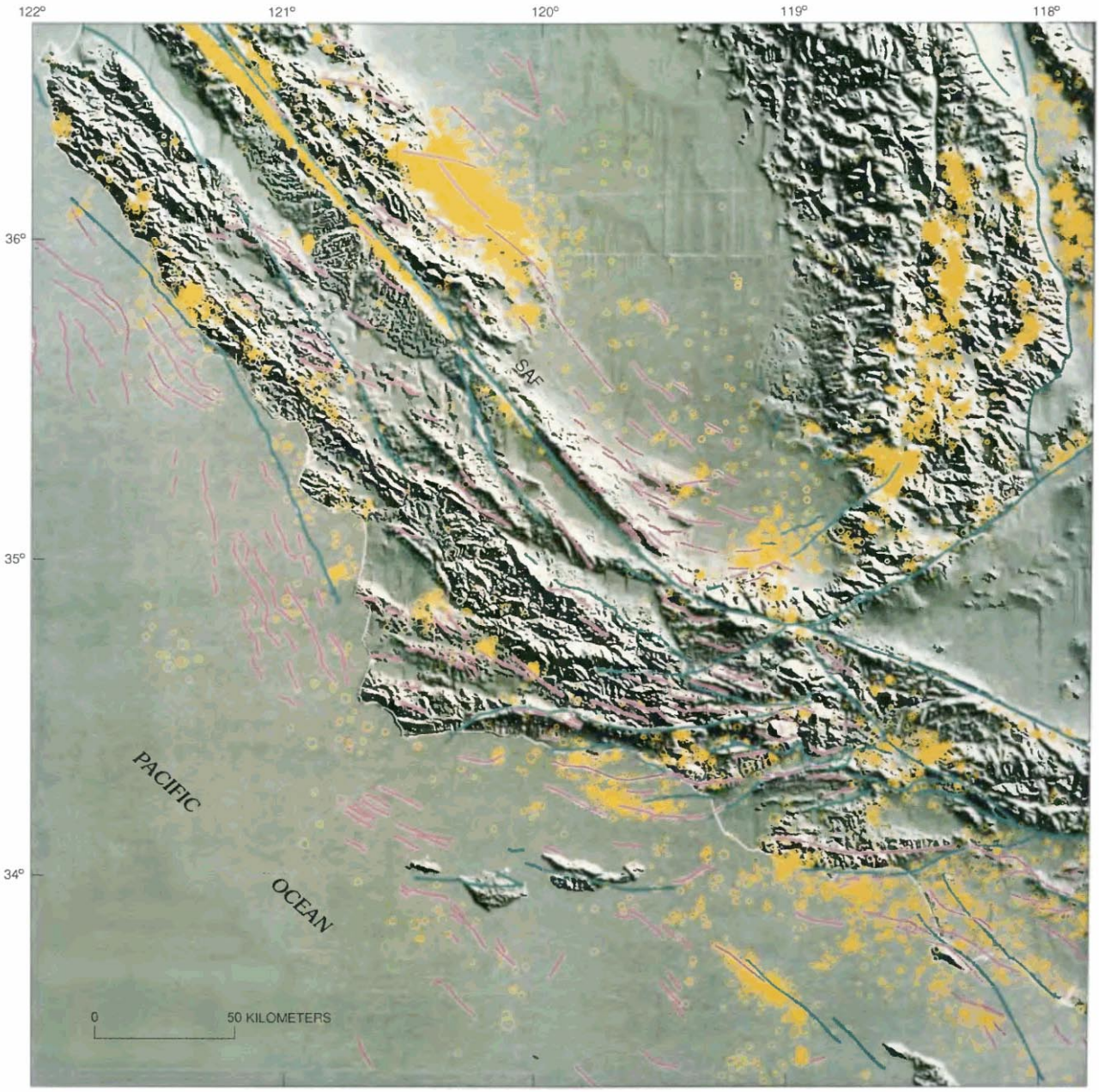

FIGURE 5.12.—Seismicity from 1980 to 1986 superimposed on digital shaded-relief image of central California, showing faults (blue) and fold axes (red). Size of symbol for epicenters (yellow) increases with magnitude from 1 to 6. Shaded relief by Raymond Batson, U.S. Geological Survey (illumination from north at 30°); overlays from Ross Stein (unpub. data, 1989). SAF, San Andreas fault.

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Coalinga-like earthquake sequences and low-angle (blind) thrust faults that are rooted in a decollement near the base of the seismogenic crust. The reverse focal mechanisms for earthquakes associated with offshore faults along the western margin of the Coast Ranges suggest that, here, convergence involves westward thrusting of the Coast Ranges over oceanic crust of the Pacific plate.

The pronounced discrepancy in the strike of the San Andreas fault through the Transverse Ranges with respect to the Pacific-North American plate slip direction provides an obvious source of local crustal convergence (Hill and Dibblee, 1953; Atwater, 1970), and the associated structural complexities serve to distribute brittle deformation (seismicity) much more widely about the San Andreas fault system in southern California than about the relatively straight sections of the fault system in central and northern California. The largest earthquake in California since the great 1906 San Francisco earthquake occurred near the northern margin of this convergent regime; this M=7.7 Kern County earthquake ruptured some 35 km of the southeast-dipping White Wolf fault with left-oblique reverse slip on July 21, 1952.

The focal mechanisms of larger Transverse Range earthquakes, together with the mapped attitudes of major faults with Holocene offsets, show that much of this convergence occurs with slip on north-dipping thrust faults within and along the southern margin of the central Transverse Ranges (fig. 5.11*A*). For earthquakes in the western Transverse Ranges, the direction of reverse slip is more southwestward, consistent with thrusting of the western Transverse Ranges over the Pacific plate similar to that in the Coast Ranges to the north.

EXTENSIONAL DEFORMATION AND THE SOUTHERN SECTION OF THE SAN ANDREAS FAULT SYSTEM

The fault-normal convergence that dominates deformation adjacent to the San Andreas fault system through both the Coast Ranges and Transverse Ranges gives way rather abruptly to the extensional regime of the Salton Trough near the southern margin of the intensely active San Gorgonio bend in the fault. Focal mechanisms of earthquakes occurring on secondary structures adjacent to the seismically quiescent Indio segment of the San Andreas fault, for example, show a mix of strike- and dip-slip mechanisms. As is the case farther north, however, P-axes for these earthquakes tend to be oriented at a high angle (60°–65°) to the fault, suggesting that the Indio segment of the fault may also be relatively weak (Jones, 1988).

One particularly noteworthy aspect of seismicity south of the Transverse Ranges is the tendency for earthquakes to occur along conjugate strike-slip structures. Recall that the Sierra Nevada-Great Basin boundary zone also shows this tendency and that both regions are subject to extensional deformation, earthquake swarms, and late Quaternary volcanism. Earthquake sequences within the southern section of the San Andreas fault system commonly produce epicenter lineations that intersect at nearly a 90° angle with the northwest-striking right-slip plane and the northeast-striking left-slip plane. Earthquake-swarm sequences in the Brawley seismic zone, for example, typically occur along northeast-striking lineations normal to the trace of the adjacent Imperial fault (Johnson, 1979), and the M=5.7 Westmorland earthquake of 1981 involved left-lateral slip along several subparallel, northeast-striking planes (Johnson and Hutton, 1982). The diffuse lineations of epicenters spanning the area of the Peninsular Ranges between the San Jacinto and Elsinore faults also tend to be orthogonal to these two branches of the San Andreas fault system (fig. 5.10*A*). An impressive recent example of this orthogonal conjugate pattern is the M=6.2 and 6.6 Superstition Hills earthquakes of November 24, 1987 (Magistrale and others, 1988).

The kinematics of these conjugate structures remains a matter of conjecture. Dextral slip along throughgoing faults of the San Andreas system must certainly dominate deformation, and the shorter, northeast-striking structures must play only a secondary role. Nicholson and others (1986) proposed that the northeast-striking lineations represent the boundaries between blocks rotating clockwise much like roller bearings, between subparallel pairs of dextral strike-slip faults. Hill (1977) and Weaver and Hill (1978/79) suggested that within local spreading centers, such as the Brawley seismic zone, conjugate strike-slip structures form miniature triple junctions with a dike or normal fault that subtends the acute angle between the conjugate strike-slip faults.

MAXIMUM FOCAL DEPTHS AND THICKNESS OF THE SEISMOGENIC CRUST

Maximum focal depths of earthquakes beneath the San Andreas transform boundary range from less than 5 km beneath the Geysers geothermal field in the northern Coast Ranges to more than 20 km beneath the Transverse Ranges, the eastern margin of the Coast Ranges, and the San Jacinto and Elsinore faults in southernmost California. Beneath relatively straight segments of the San Andreas fault system through central California, maximum focal depths range from 12 to 15 km (figs. 5.7, 5.8). Sibson (1983) pointed out that these variations in maximum focal depth along the San Andreas fault system are inversely correlated with surficial heat flow, and he argued that the maximum depth of earthquakes coincides with the temperature-dependent transition from brittle failure in the upper crust to aseismic, quasi-plastic flow in

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the lower crust and upper mantle. For quartz-bearing rocks typical of the upper crust and deformation rates typical of the San Andreas fault system (1×10^{-14} to 1×10^{-13} s^{-1}), this brittle/ductile transition occurs at about 300 °C (Sibson, 1983). By this interpretation, the thin seismogenic crust beneath both the Geysers and Brawley geothermal fields in northern and southern California, respectively, reflects elevated temperatures in the shallow crust, whereas the relatively thick seismogenic crust beneath the Transverse Ranges and the eastern margin of the Coast Ranges reflects depressed temperatures in the midcrust associated with crustal convergence. Although temperature may dominantly influence the thickness of the seismogenic crust, local variations in rock composition (particularly the presence or absence of modal quartz and structural water) and in strain rate can also be important. These variations, for example, may help explain isolated clusters of deep earthquakes, such as the 20- to 24-km-deep events north of San Pablo Bay in central California (see cross secs. *F–F′*, *G–G′*, fig. 5.8*B*).

In any case, the thickness of the seismogenic crust beneath the San Andreas transform boundary seems to be much more strongly related to temperatures in the crust than to the structural thickness of crust defined by the depth to the Moho (see chap. 8). This relation is strikingly illustrated by the twofold increase in thickness of the seismogenic crust beneath the rootless Transverse Ranges.

DECOLLEMENT AT THE BASE OF THE SEISMOGENIC CRUST?

A theme common to models of crustal convergence along the San Andreas fault system involves low-angle reverse slip on decollement surfaces near the base of the seismogenic crust (Wentworth and others, 1983; Webb and Kanamori, 1985; Namson and Davis, 1988; Eaton and Rymer, 1990). A natural extension of this theme leads to a view of the seismogenic crust as a conglomeration of relatively rigid blocks interacting by frictional slip along weak preexisting faults (block boundaries) in response to regional stresses transmitted through both the brittle crust and quasi-plastic deformation in the underlying lithosphere (Hill, 1982). However, the nature of a decollement surface at the base of the brittle crust and the relation of the seismogenic San Andreas fault system to the aseismic transform boundary in the underlying lithosphere remain speculative. It is not yet clear, for example, whether the San Andreas fault continues below the seismogenic crust as a narrow, near-vertical boundary (possibly offset a substantial distance from the seismogenic fault by slip on the horizontal decollement surface) that slips by quasi-plastic, mylonitic deformation or whether it broadens rapidly with depth into a wide shear zone spanning, say, the entire width of the Coast Ranges (see chap. 7; Sibson, 1983).

CONCLUSIONS

The spatial-temporal pattern of earthquake occurrence within the seismogenic crust along the San Andreas fault system is the brittle manifestation of distributed deformation of the lithosphere between the Pacific and North American plates along the San Andreas transform boundary. As we develop a more complete model of the long-term behavior of the seismogenic crust, including relations between great, plate-boundary earthquakes that periodically rupture the principal strand of the San Andreas fault system and the persistent background of small to moderate earthquakes on adjacent structures, our image of the deeper deformation will improve. Together will come a more complete understanding of the processes controlling deformation along the transform boundary and of the earthquake cycle.

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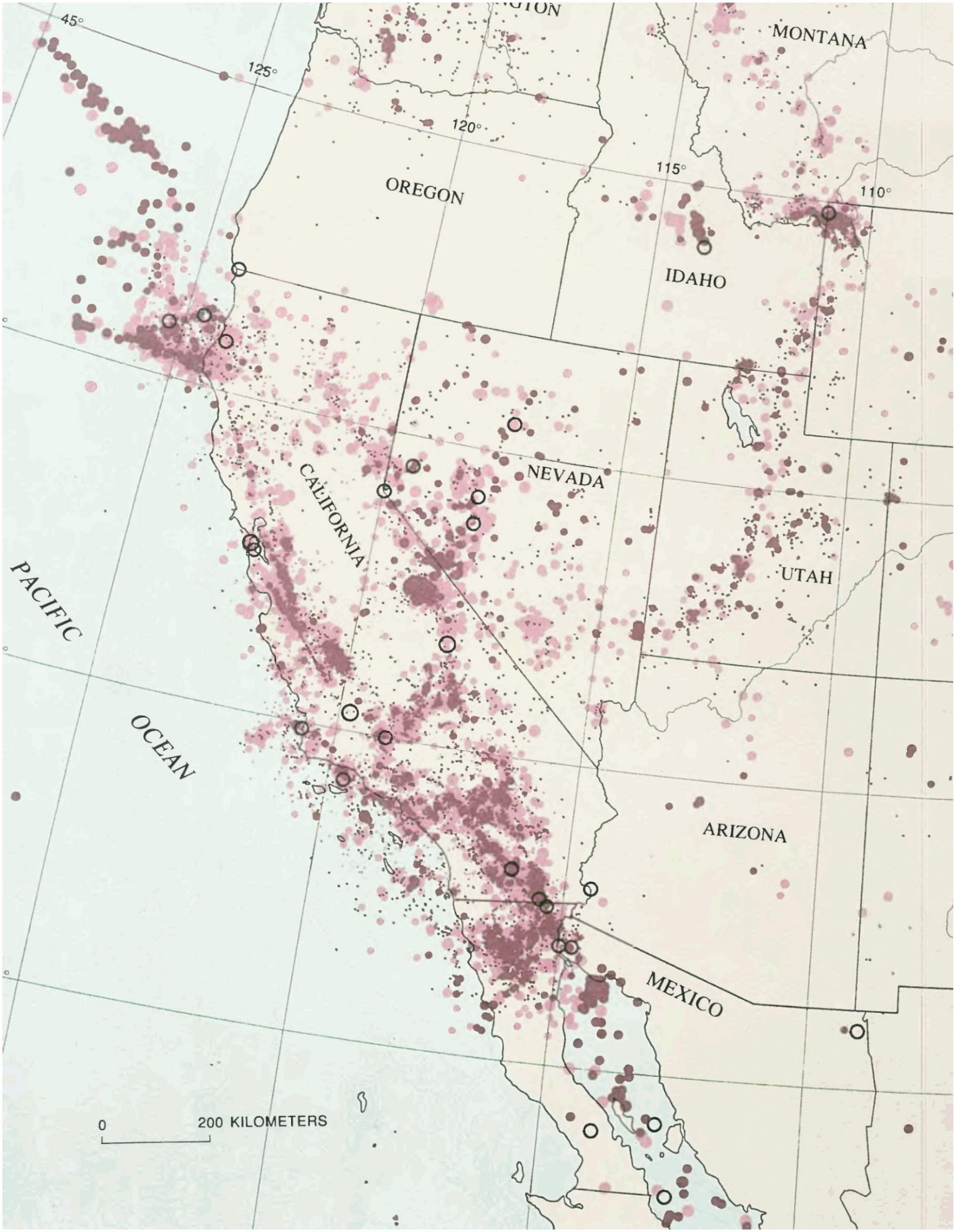

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Motion between the North American and Pacific plates at the latitude of the San Andreas fault produces a broad zone of large-magnitude earthquake activity extending more than 500 km into the continental interior. The San Andreas fault system defines the western limits of plate interaction and dominates the overall pattern of seismic strain release. Few of the M≥6 earthquakes that have occurred in the past 2 centuries were located on the San Andreas fault proper, an observation emphasizing the importance of secondary faults for both seismic-hazard assessment and tectonic processes.

6. EARTHQUAKE HISTORY, 1769–1989

By WILLIAM L. ELLSWORTH

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◀ FIGURE 6.1.—Seismicity highlights broad and complex zones of active tectonism in the western United States. Dots, earthquakes scaled by magnitude in unit-magnitude steps, smallest for M<4; circles, earthquakes of M>7; red dots, recent events, generally since 1975; pink symbols, historical events. From Engdahl and Rinehart (1988).

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INTRODUCTION

Between Punta Gorda on the northern California coast and the head of the Gulf of California, 1,350 km to the southeast, lies the active transform boundary that forms the modern San Andreas fault system (fig. 6.1). Dextral motion between the North American and Pacific plates along this system is accommodated within an elongate zone, broadening from about 100 km at its north end to about 300 km in southern California. The San Andreas fault proper hugs the east side of this zone at its south terminus and gradually migrates across the zone, lying on the west edge of the zone at its north terminus. The San Andreas fault system transmits about three-fourths of the relative motion across the plate boundary, as shown by various geologic and geodetic evidence. Much of this motion is stored elastically in the upper crust along the major faults in the system, ultimately to be released in large plate-boundary earthquakes. These large earthquakes and their implications for the mechanics of North American-Pacific plate interactions are the subject of this chapter.

Earthquake activity in California and Nevada at the latitude of the San Andreas fault extends well beyond the confines of the San Andreas system (fig. 6.2). In the past century alone, only about half of the $M \geq 6$ activity has

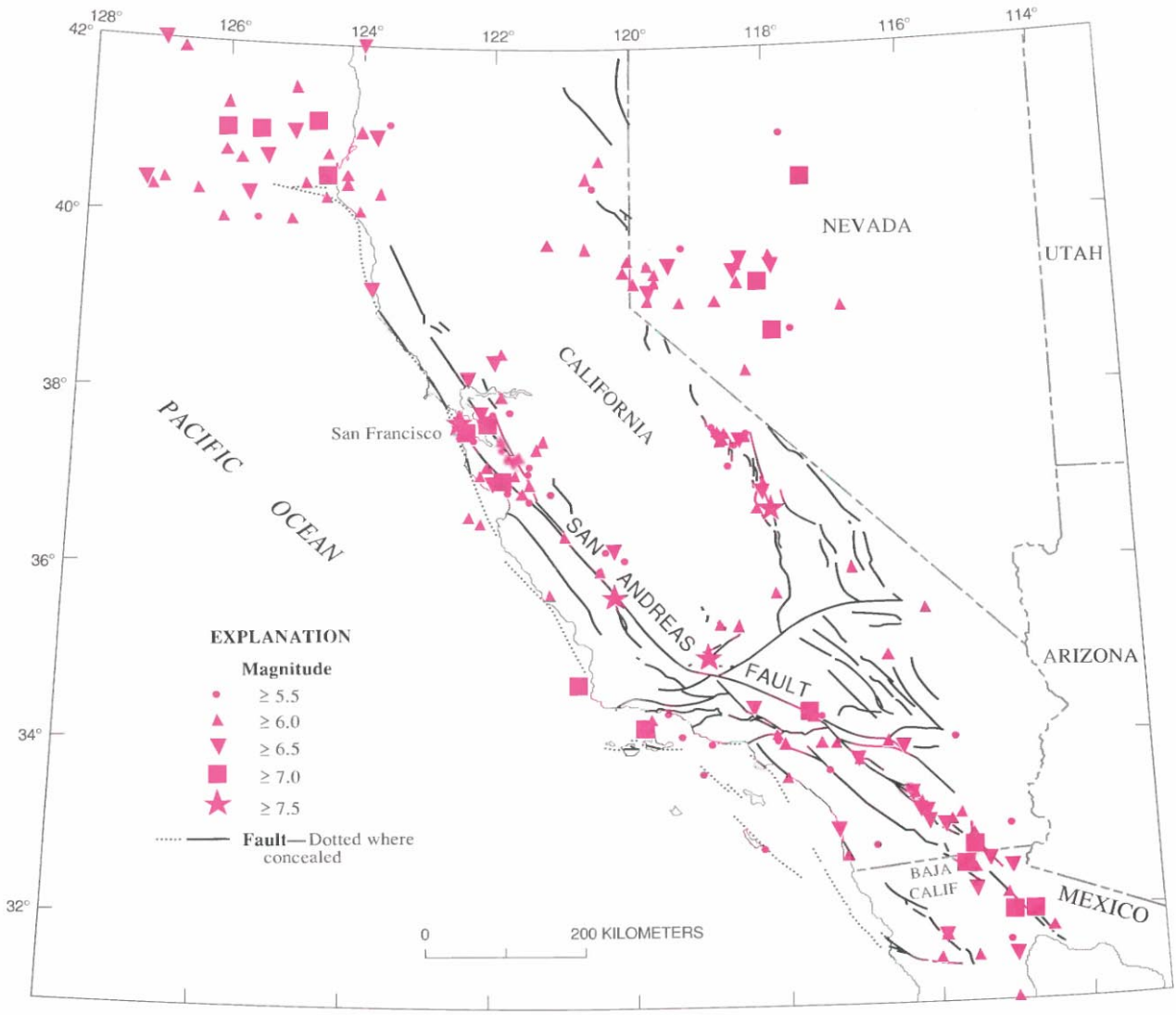

FIGURE 6.2.—Seismicity of California, Nevada, and northern Baja California, 1769–1989. Earthquakes are listed in table 6.1 and plotted by magnitude class.

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fallen within the San Andreas system; of the rest, half is associated with the western Basin and Range province, and the other half with the Mendocino triple junction and the Gorda plate. Although activity in the latter region reflects the tectonics of the triple junction and the collision of the Gorda plate with the North American plate, seismicity east of the San Andreas system along the east flank of the Sierra Nevada and in the Basin and Range province reflects the incomplete accommodation of plate motion along the San Andreas fault system. A significant proportion of this "missing" motion occurs in the Basin and Range, the seismicity of which plays an integral role in the tectonics of the plate boundary.

EARTHQUAKE HISTORY OF THE SAN ANDREAS FAULT SYSTEM

The historical record of major earthquakes affecting California, western Nevada, and northernmost Baja California (table 6.1) includes basic seismologic data on 206 of the largest earthquakes occurring between 1769 and 1989. This catalog lists all known events of $M \geq 6$ and includes new and updated information on their locations.

The record of seismicity within the San Andreas fault system and surrounding regions is both geographically and temporally uneven and incomplete before the introduction of practical seismographic instrumentation around the turn of the 20th century. In general, the density and distribution of people who left written accounts of their experiences determines the reliability of the catalog during the preinstrumental period. From the establishment of the Franciscan missions beginning in 1769 until their secularization in the 1830's, detailed accounts of events that damaged the missions are available, and these accounts form the primary source material for earthquakes occurring during this period. Life in California was a constant struggle for survival at that time; posting to a mission evidently was considered a hardship assignment, and so essentially nothing was recorded about events that were only felt, even when they were destructive at nearby missions. After secularization and before the gold rush, the quality of the record degrades with the cessation of the annual reports of the missions. Other sources of records also are notably weak during the Mexican period, from the early 1830's until 1846.

The discovery of gold in 1848 transformed the written record of earthquakes with the advent of newspapers throughout the gold fields in the Sierran foothills and in the San Francisco Bay region. Printed accounts of earthquakes have been extensively used, notably by Toppozada and others (1988), to quantify the seismicity of California from 1850 onward. They estimated that their historical catalog is probably complete for the San Francisco Bay region and central Sierra Nevada from 1850 on for earthquakes of $M \approx 6$. The same level of completeness is not achieved, however, for the San Andreas fault system in southern California until the 1890's. Statewide, the catalog of earthquakes is substantially complete for earthquakes of $M \approx 7$ after about 1850 (see Agnew, 1985). The quality of the catalog for central Nevada, where much significant 20th century seismicity has occurred, is less complete. Questions remain today about purported events as late as 1903 in this region (Slemmons and others, 1959).

Reports of the local effects of earthquakes continue to play a major role in determining the locations and sizes of earthquakes well into the 20th century. The earliest seismographs capable of systematically detecting California and Nevada earthquakes were installed throughout the world by John Milne beginning in 1896. Seismograms from these instruments and their successors provide useful instrumental magnitudes from 1898 onward. However, not until the development of the Wood-Anderson seismograph and its deployment throughout California beginning in 1926 do instrumental measurements fully supplant noninstrumental magnitudes and epicentral locations.

The objective in assembling a single catalog from these many sources, spanning many different types and qualities of information, has been to achieve uniform spatial coverage without sacrificing any events of historical significance. $M=6$ was chosen as the threshold magnitude because probably all events of this magnitude are known from the instrumental period beginning in 1898, and the preinstrumental record is reasonably complete at this level in some areas for an additional half-century. All earthquakes with at least one reported magnitude of at least 6.0 have been included in the catalog. Because magnitude is an estimated quantity and has some inherent uncertainty, events with reported magnitudes within a few tenths of a unit of 6.0 are also included. In addition to those earthquakes with cataloged magnitudes, original documents for others with reported high intensities or of particular historical significance have been reexamined in an attempt to refine their locations and magnitudes.

A word of introduction should be added about earthquake locations and magnitude scales and their use in this chapter. Earthquakes are complex physical processes generated by sudden slip on faults, and as such they can only be grossly characterized by simple concepts. Two seismologic conventions are in common use for assigning a single geographic coordinate to an earthquake: One measures the center of energy release, frequently as estimated from the intensity distribution for preinstrumental events; the other measures the location of the initial point of rupture, or hypocenter, as determined from seismic traveltime measurements. Either point on

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the Earth's surface above the hypocenter or the center of the intensity distribution is sometimes referred to as the epicenter, and each type of location appears in table 6.1, with preference given to instrumental epicenters. Fortunately, the geographic differences between these distinct physical measures become significant only for the largest events, $M \approx 7$, when viewed at the scale of the entire San Andreas fault system.

Magnitude, as commonly used to compare the sizes of different earthquakes, also represents an extreme simplification of the earthquake process and by itself cannot fully characterize the size of any event. Traditionally, seismologists have developed a suite of magnitude scales, each with its own purpose and range of validity to measure an earthquake. Because no single magnitude scale can be systematically applied to the entire historical record, a summary magnitude, M, is introduced here to facilitate comparisons between events. As described below in the subsection entitled "Quantification of Earthquakes and Magnitude Scales," M is taken as the surface-wave magnitude (M_S), when available, and as a modified intensity magnitude (M_I) during the preinstrumental era. Generally speaking, M provides a better relative measure of the static, geologic increment of fault slip in the earthquake than it does of the severity of shaking.

The earthquake history of California, western Nevada, and northern Baja California presented here has apparent limitations and can doubtlessly be improved through further research. Nevertheless, it provides a firm observational basis for assessing the tectonic implications of the 2-century-long seismic history, as well as of the prospects for future earthquake activity.

PRINCIPAL EARTHQUAKES

In this section, we briefly discuss some events of particular historical, social, or scientific significance. Although each of the 117 San Andreas fault system events in table 6.1 merits discussion, this task is far beyond the scope of this review, and so the reader is referred to the reports by Richter (1958), Coffman and others (1982), and Townley and Allen (1939) for an introduction to many of these events. Table 6.1 also omits several historically significant events with magnitudes well below the nominal threshold of $M=6$ adopted here, and so it something less than a complete reference on San Andreas seismicity.

My major effort in constructing this catalog has gone into identifying and validating all reported events of $M \geq 6$. Two conspicuous omissions from table 6.1, events that are commonly mentioned in the literature but that could not be substantiated upon further inspection, should be noted. The first is the 1852 earthquake alleged to have ruptured the Big Pine fault (for example, Jennings, 1975). Toppozada and others (1981) failed to find any evidence supporting the occurrence of a major earthquake at that time in the region. Geologic inspection of the surface trace of the fault by M.M. Clark (oral commun., 1988) similarly failed to provide evidence of any historical activity. The other deleted event appears on the seismicity map by Goter (1988) at lat 35° N., long 125° W., with an epicenter from the catalog of Abe and Noguchi (1983). Although a large ($M_S=6.8$) earthquake certainly took place on March 22, 1902, no evidence has been uncovered to support a location anywhere on shore in California or, for that matter, in the Western United States. The original location determined by Milne in 1903 placed the event well off the California-Oregon coast at lat 42° N., long 130° W.

JULY 28, 1769 ($M=6$)

The earthquake history of California serendipitously begins with the first overland expedition through the State in 1769. In response to the perceived threat posed by Russian expansion into the northern Pacific and growing British presence in the northwestern Pacific, Spain embarked on the colonization of present-day California through the establishment of a series of Franciscan missions, supported by military garrisons at San Diego and Monterey. In the summer of 1769, Gaspar de Portolá led the first expedition from San Diego to establish a land route to Monterey.

On July 28, while camped along the Santa Ana River, about 50 km southeast of Los Angeles, a sharp earthquake was felt that "* * * lasted about half as long as an Ave Maria" (fig. 6.3). From the diaries of three members of the expedition, we know that earthquakes were felt on nearly a daily basis through August 3, as the party traveled northwestward to near San Gabriel and then westward across Los Angeles to the Pacific. The diary of Fray Juan Crespi (Bolton, 1927) mentions no fewer than a dozen aftershocks, some described as violent. After August 4, no further earthquakes were mentioned as the expedition traveled into the San Fernando Valley and exited to the north.

These sketchy reports suggest that the explorers traveled near or through the epicentral area of a moderate earthquake (Richter, 1973; Toppozada and others, 1981). Comparisons between the accounts of the aftershocks and more recent events suggest an event of similar size and location to the 1933 Long Beach, 1971 San Fernando, or 1987 Whittier Narrows earthquake. If significance is placed on the absence of aftershocks while crossing the source region of the 1971 San Fernando earthquake, the evidence would seem to favor a source in the Los Angeles Basin. An event on either the San

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Andreas or San Jacinto faults, some 50 km to the northeast, could conceivably have been the source of the 1769 earthquake. The description of the duration of strong shaking, however, suggests a magnitude more of 5–6 than of 7–8.

A more distant source would make the long, felt aftershock sequence even more remarkable because it would be well removed from the expedition route.

DECEMBER 8, 1812 (M=7)

The first of two significant earthquakes to occur in southern California in 1812 occurred on December 8 and destroyed the church at Mission San Juan Capistrano, killing 40 neophytes (fig. 6.4); damage was also sustained at San Gabriel. The accounts of this earthquake and the later one on December 21 cannot be readily disentangled at San Fernando Rey and at San Buenaventura, considerably complicating the interpretation of this event.

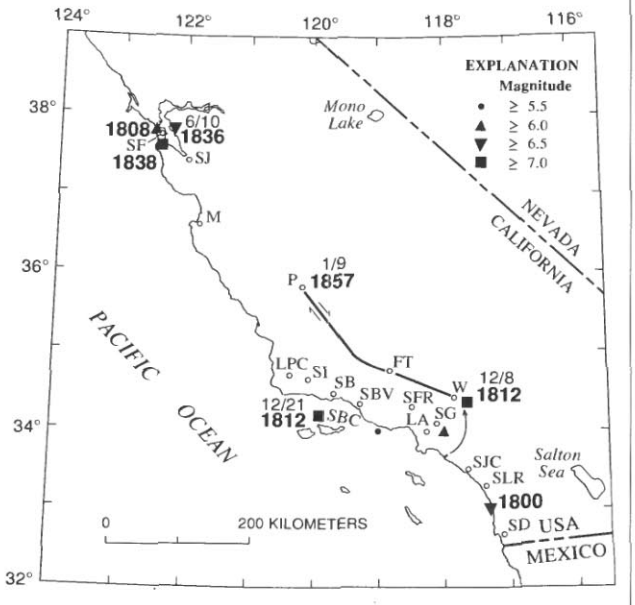

FIGURE 6.3.—Early accounts of significant earthquakes reflect the sparse settlement of California in a narrow coastal corridor before the population explosion accompanying the gold rush in 1849. Accounts of the few well-documented events (dates shown) principally derive from mission records at San Diego (SD), San Luis Rey (SLR), San Juan Capistrano (SJC), San Gabriel (SG), San Fernando Rey (SFR), San Buenaventura (SBV), Santa Barbara (SB), Santa Inez (SI), and La Purisima Concepción (LPC), and from the towns of Los Angeles (LA) and Fort Tejon (FT) in southern California. Accounts from the Spanish capital Monterey (M), San Francisco (SF), and San Jose (SJ), as well as mission sources, detail events in north half of the State. Uncertainties in the interpretation of every event before the great earthquake of 1857 (rupture shown; arrows indicate direction of relative movement) are well illustrated by newly uncovered evidence suggesting a San Andreas origin for the December 8, 1812, shock near Wrightwood (head of connecting arrow), well inland of traditional location along the coastal Newport-Inglewood fault (tail of arrow). Earthquake of December 21, 1812, locates in the Santa Barbara Channel (SBC). Foreshocks of the great earthquake of 1857 locate near Parkfield (P), suggesting unilateral rupture propagation to the southeast.

Analyses of these scanty data by Toppozada and others (1981) and Evernden and Thompson (1985) place the epicenter along the south half of the Newport-Inglewood fault zone (fig. 6.3). This location is somewhat constrained by the interpretation of no damage at Buenaventura during the event. The Los Angeles Star of January 10, 1857, however, stated that the December 8 event severely damaged the church tower (Agnew and Sieh, 1978). The same story attributed the collapse of the stone arch roof of the church at San Juan Capistrano to poor construction, a possibility made credible by the death of the master mason before completion of the church (fig. 6.3; Duncan Agnew, oral commun., 1988).

Recently, Jacoby and others (1988) proposed that this event ruptured the San Andreas fault at Wrightwood (fig. 6.3), on the basis of dendrochronologic dating of distress to trees growing on the fault trace. Sieh and others (1989) argued that this rupture extended at least 25 km northwestward into the peat bog at Pallet Creek. The fault rupture in this event preserved at Pallet Creek is comparable in size to the rupture formed in the 1857 earthquake.

The preferred location of the December 8, 1812, earthquake on the San Andreas fault as proposed by Jacoby and others appears in table 6.1. A magnitude of about 7 is consistent with the inferred extent of damage. The lateral extent of rupture is unconstrained to the southeast and may well have extended into the San Bernardino Valley. However, the accounts of the earthquake from Indians living in the San Bernardino Valley that were thought to place some constraint on the rupture are now believed to be fictitious (Harley, 1988), leaving Mission San Gabriel, some 40 km from the rupture, as the nearest point of observation.

DECEMBER 21, 1812 (M=7)

The second major episode of earthquake activity in 1812 damaged the missions along the Santa Barbara Channel and western Transverse Ranges just 13 days later, on December 21 (fig. 6.3). All investigators place this event in the Santa Barbara Channel and assign a magnitude of about 7 (see Toppozada and others, 1981, and Evernden and Thompson, 1985, for two recent analyses). This sequence appears to have involved two events of comparable magnitude separated in time by about 15 minutes. A vigorous aftershock sequence accompanied the earthquakes and lasted until the end of the year at Mission Santa Barbara and Mission La Purisima Concepción. Reports of a tsunami appear to be exagger-

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ated, although some kind of wave activity probably accompanied the earthquake (Toppozada and others, 1981; McCulloch, 1985).

JUNE 10, 1836 (M=6¾)

Little is known about the strong earthquake of June 10, 1836, that struck the then lightly populated San Francisco Bay region. An account of the event, published in the aftermath of the 1868 earthquake, provides the principal rationale for associating this event with the Hayward fault. Louderback (1947) systematically compared the two events and concluded that the 1836 earthquake probably ruptured the Hayward fault. Lindh (1983) proposed that the 1836 event ruptured the north half of the fault, whereas the 1868 event is known to have ruptured the south half, thereby avoiding the paradox of two large events on the same segment separated by a scant 32 years.

JUNE 1838 (M=7)

The pioneering historical work of Louderback (1947) reveals that a major earthquake with probable rupture of the San Andreas fault occurred in June 1838. Documentation of the event is so poor that its date cannot be fixed more precisely than "late June." Louderback concluded that the shock was comparable in magnitude to the 1906 earthquake. Current opinion suggests a smaller event involving only the 60+-km-long segment of the fault on the San Francisco peninsula (Working Group on Earthquake Probabilities, 1988).

JANUARY 9, 1857 (M=8¼)

The great Fort Tejon earthquake of January 9, 1857, ruptured 300 km of the San Andreas fault from near Parkfield to Wrightwood and offset the fault by as much as 9½ m on the Carrizo Plain. The fault rupture and the effects of the earthquake have been extensively studied, notably by Agnew and Sieh (1978) and Sieh (1978b). The epicenter of this event appears to have been at the extreme northwest end of the fault rupture, as determined by the intensity patterns of two M=6 foreshocks centered near Parkfield (Sieh, 1978a). Strong shaking lasted from 1 to 3 minutes, consistent with unilateral rupture propagation to the southeast (fig. 6.3).

The earthquake caused only two deaths in the sparsely settled southern California region. Damage was most severe along the fault zone; nearly every building sustained damage at Fort Tejon. In Los Angeles, then a city of about 4,000 people located approximately 60 km from the fault, some houses were cracked, but none were severely damaged (Agnew and Sieh, 1978). Modified Mercalli intensities (MMI's) of VII or more occurred in the San Fernando Valley, San Gabriel Valley, and Ventura region.

It is natural to compare the 1857 and 1906 earthquakes, the two greatest earthquakes of the San Andreas fault in historical time. The 1906 fault break was longer, whereas maximum and average surface offsets were larger in 1857. These differences approximately balance each other, and so the seismic moments of the two events are approximately equal. Moment magnitudes computed using comparable data are **M**=7.8 for the 1857 earthquake

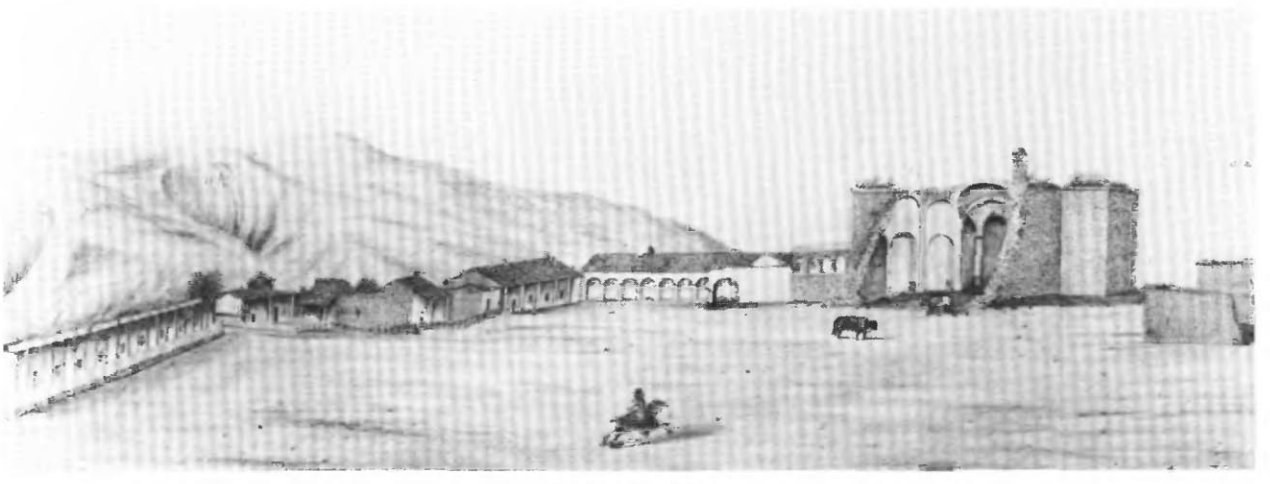

FIGURE 6.4.—Mission San Juan Capistrano as drawn by Henry Miller in 1856, 43 years after the December 8, 1812, earthquake. Vaulted stone church at right collapsed in that earthquake, killing 40 worshipers. Photograph courtesy of the Bancroft Library.

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and **M**=7.7 for the 1906 event. A summary magnitude of M=8¼ was assigned by analogy with the 1906 earthquake.

OCTOBER 21, 1868 (M=7)

Known as the "great San Francisco earthquake" until 1906, one of California's most destructive earthquakes occurred on October 12, 1868, resulting from slip on the Hayward fault. Heavy damage occurred in communities situated along the fault and in San Francisco and San Jose (fig. 6.5). Sadly, many of the engineering lessons learned from this earthquake and openly discussed at the time, such as the hazards of building on "made ground" reclaimed from the San Francisco Bay or the admonition to "build no more cornices," were long forgotten by the time of the 1906 earthquake.

FEBRUARY 24, 1892 (M=7)

The strong earthquake of February 24, 1892, located near the United States-Mexican border was assigned to the Agua Caliente fault north of the border by Toppozada and others (1981) and to the Laguna Salada fault in Baja California by Strand (1980). The literature on earthquakes in Baja California contains numerous references to this earthquake as having originated near the Agua Blanca fault, about 100 km southwest of Strand's epicenter (for example, Richter, 1958). The two recent intensity maps clearly rule out this epicenter and place it on the southern section of the Elsinore fault system.

APRIL 19 AND 21, 1892 (M=6½ AND 6¼)

A pair of strong earthquakes rocked the west side of the Sacramento Valley on April 19 and 21, 1892, heavily damaging the towns of Vacaville, Dixon, and Winters. The first shock was stronger and caused heavy damage at Vacaville; the aftershock was more severe at Winters. The earthquakes are reminiscent of the 1983 Coalinga, Calif., earthquake, in that both sequences were positioned along the western margin of the Central Valley. Focal mechanisms of small earthquakes located along this boundary zone show numerous examples of low-angle-thrust focal-mechanism solutions of similar orientation to the Coalinga earthquake, in addition to strike-slip mechanisms (see chap. 5; Wong and others, 1988), suggesting the possibility of a similar mechanism for these 1892 earthquakes.

DECEMBER 25, 1899 (M=6.4)

Heavy damage occurred in the towns of San Jacinto and Hemet, located along the San Jacinto fault, from an earthquake on Christmas Day 1899. Six fatalities were attributed to the earthquake.

APRIL 18, 1906 (M=8¼)

The California earthquake of April 18, 1906, ranks as one of the most significant earthquakes of all time. Today, its importance comes more from the wealth of scientific knowledge derived from it than from its sheer size. Rupturing the northernmost 430 km of the San Andreas fault from northwest of San Juan Bautista to the triple junction at Cape Mendocino (fig. 6.6), the earthquake confounded contemporary geologists with its large, horizontal displacements and great rupture length. Indeed, the significance of the fault and recognition of its large cumulative offset would not be fully appreciated until the advent of plate tectonics more than half a century later. Analysis of the 1906 displacements and strain in the surrounding crust led Reid (1910) to formulate his elastic-rebound theory of the earthquake source, which remains today the principal model of the earthquake cycle.

As a basic reference about the earthquake and the damage it caused, geologic observations of the fault rupture and shaking effects, and other consequences of the earthquake, Lawson's (1908) report remains the authoritative work, as well as arguably the most important study of a single earthquake. In the public's mind, this earthquake is perhaps remembered most for the fire it spawned in San Francisco, giving it the somewhat misleading appellation of the "San Francisco earthquake" (fig. 6.7). Shaking damage, however, was equally severe in many other places along the fault rupture. The frequently quoted value of 700 deaths caused by the earthquake and fire is now believed to underestimate the total loss of life by a factor of 3 or 4. Most of the fatalities occurred in San Francisco, and 189 were reported elsewhere.

At almost precisely 5:12 a.m. local time, a foreshock occurred with sufficient force to be felt widely throughout the San Francisco Bay area. The great earthquake broke loose some 20 to 25 s later, with an epicenter near San Francisco (Bolt, 1968; Boore, 1977). Violent shocks punctuated the strong shaking, which lasted some 45 to 60 s. The earthquake was felt from southern Oregon to south of Los Angeles and inland as far as central Nevada (fig. 6.6). The highest MMI's of VII to IX paralleled the length of the rupture, extending as far as 80 km inland from the fault trace. One important characteristic of the shaking intensity noted in Lawson's (1908) report was the clear correlation of intensity with underlying geologic conditions. Areas situated in sediment-filled valleys sustained stronger shaking than nearby bedrock sites, and the strongest shaking occurred in areas where ground

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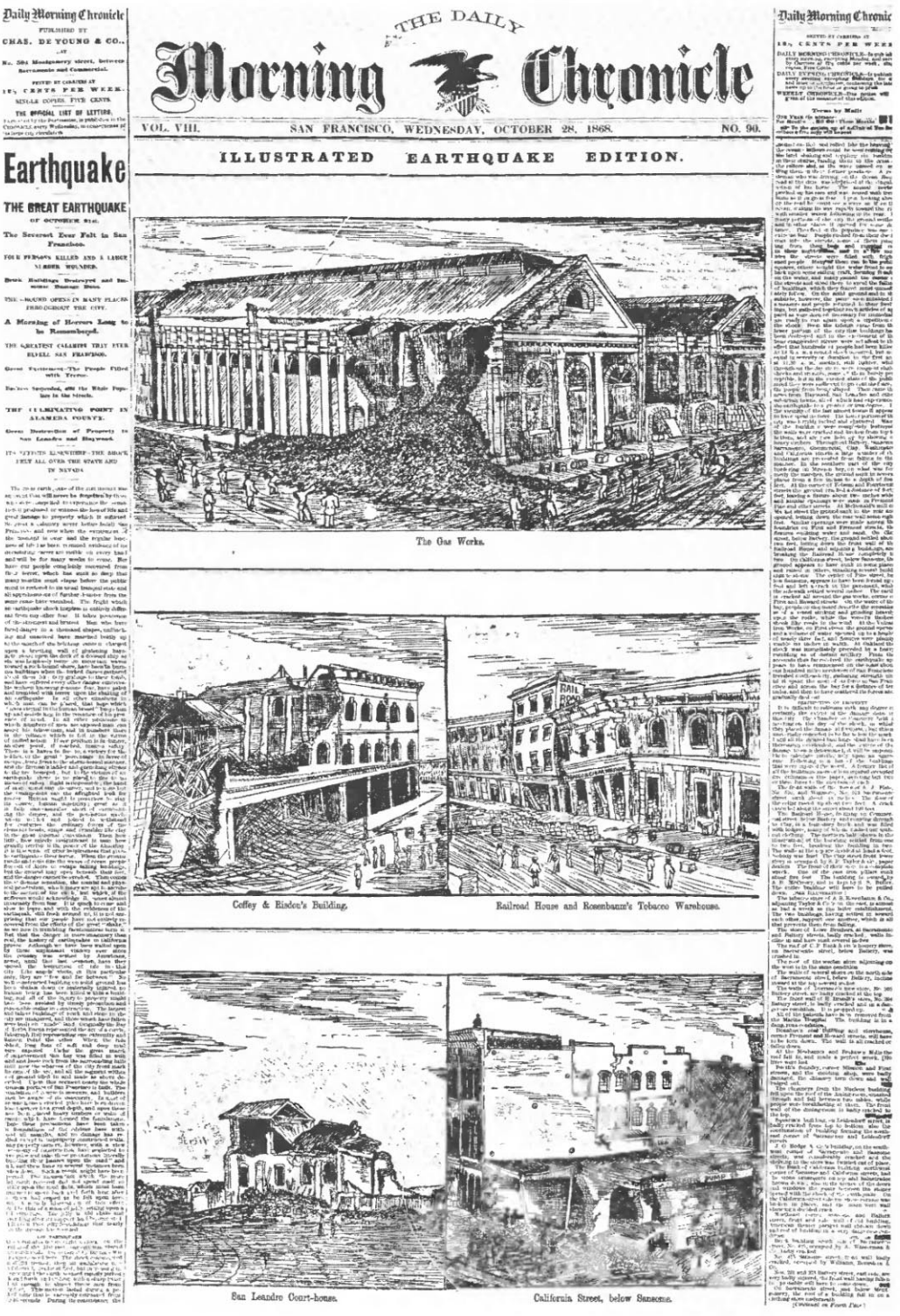

FIGURE 6.5.—San Francisco *Morning Chronicle* of October 28, 1868, richly illustrates severe damage sustained by buildings of poor design or located on filled land during earthquake on the Hayward fault. Reduction of this figure from its original publication size has made some type illegible; it is not needed to convey information intended by this illustration. Photograph courtesy of the Bancroft Library.

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reclaimed from San Francisco Bay failed in the earthquake. Modern seismic-zonation practice accounts for the differences in seismic hazard posed by varying geologic conditions (see Borcherdt, 1975, and Ziony, 1985, for analyses of the San Francisco Bay and Los Angeles regions, respectively).

The characteristics and amount of surface fault slip in this earthquake varied to a remarkable degree along the length of the rupture. Peak displacements of 6 m were measured near Olema on the Point Reyes peninsula, where the surface trace of the rupture formed a sharp, well-defined break (fig. 6.8). In contrast, the fault break was extremely difficult to recognize along its southernmost 90 km, where the surface offset averaged only about 1½ m or less (see chap. 7).

The magnitude of 8.3 commonly quoted for the 1906 earthquake comes from Richter (1958) and, within the precision of reporting, is identical to the 8¼ listed by Gutenberg and Richter (1954). Table 6.1 also lists other magnitudes for this earthquake, derived from recent analyses of both the same data used by Gutenberg and Richter and new data. Strictly speaking, a "Richter magnitude" (M_L) for the earthquake cannot be determined because no appropriate seismographs were in operation at the time. Jennings and Kanamori (1979) used related measurements extracted from simple pendulums at Yountville, Calif., and Carson City, Nev., to derive M_L=6.9, substantially smaller than the traditionally quoted value. M_L, which is based on the single largest peak on a seismogram at approximately 1-s period and takes into account neither the duration of the event nor longer period motions, is saturated for this event.

Geller and Kanamori (1977) used the unpublished worksheets of Gutenberg and Richter to compute a body-wave magnitude of m_b=7.4, using the procedure of Gutenberg and Richter (1956). Because long-period (14 s) *P*-waves were used in this calculation, it cannot be directly compared to the short-period m_b values routinely reported today.

Other workers since Gutenberg and Richter have studied the long-period surface waves of the 1906 earthquake and computed M_S values. Bolt (1968) confirmed an M_S of about 8¼, whereas Lienkaemper (1984) found M_S= 8.3 from an analysis of all the records collected by Reid (1910). Lienkaemper's magnitude combined data from both damped and undamped instruments, correcting each for magnification at the appropriate period of motion. Abe (1988), who analyzed only the undamped Milne seismograms, obtained M_S= 7.8, using slightly different procedures and a systematic set of station-magnitude corrections. Also, the four damped seismometers (all in Europe) give M_S=8.1. Longer period (50–100 s) surface waves analyzed by Thatcher (1975) indicate a seismic moment of 4×10^{27} dyne-cm, equivalent to **M**=7.7, in agreement with the seismic moment of 5×10^{27} dyne-cm obtained from geodetic data, thus giving **M**=7.8 (Thatcher and Lisowski, 1987). Finally, Toppozada and Parke (1982) assigned an intensity magnitude (M_I) of 7.8 on the basis of the total area (48,000 km^2) undergoing shaking of MMI VII or higher.

The "traditional" magnitude of 8¼ is retained here, except where seismic moment is used for quantitative purposes.

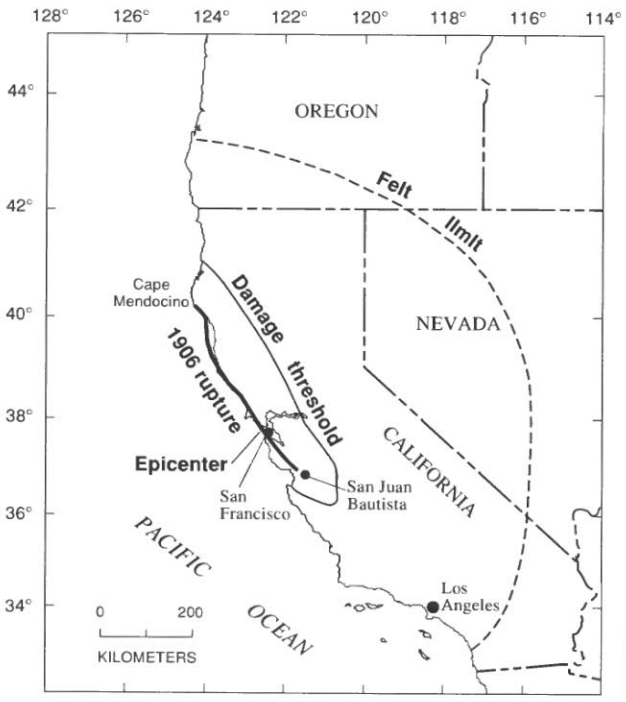

FIGURE 6.6.—California earthquake of 1906 showing extent of fault rupture along the San Andreas fault, location of epicenter near San Francisco, maximum extent of structural damage, and limits of perception of shock. Modified from Lawson (1908) and Toppozada and Parke (1982).

NOVEMBER 21, 1915 (M=7.1)

The major earthquake of November 21, 1915, triggered a spectacular steam eruption of a mud volcano, creating a 100+-m crater in Volcano Lake, Baja California, near the north terminus of the Cerro Prieto fault. Extensive cracking of the levee around the lake was noted at the time of the shock, but no tectonic ground displacements were found (Seismological Society of America Bulletin, 1916). This event may well be related to the November 29, 1852, earthquake (M=6½±), which also triggered a mud-volcano eruption at Volcano Lake that was observed at Fort Yuma, Ariz. Each of these events was probably associated with the Cerro Prieto fault.

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APRIL 21, 1918 (M=6.9)

The communities of Hemet and San Jacinto were severely damaged for the second time in 19 years by the large earthquake of April 21, 1918, on the San Jacinto fault. Both the 1899 and 1918 earthquakes produced similar intensity patterns throughout the southern California region, and these two events have been compared to each other. However, surface waves on Milne seismograms at common stations (Victoria, British Colombia, and Toronto, Ontario, Canada; San Fernando, Spain) average 3 times larger for the 1918 earthquake, corresponding to a difference in M_S of ½ unit. As with the 1836 and 1868 earthquakes on the Hayward fault, the relation between the rupture zones in these two events is unclear. Surprisingly, no surface rupture was found for an event of this size, despite a specific search for it.

NOVEMBER 4, 1927 (M=7.3)

The Lompoc earthquake of November 4, 1927, is the largest known event in the San Andreas system west of the San Andreas fault proper. This event produced a tsunami with local runup heights of 1.5 to 1.8 m (McCulloch, 1985). The exact location of the earthquake and its association with any causative structure remain the subject of a spirited debate (Gawthrop, 1978, 1981; Hanks 1979, 1981).

MARCH 11, 1933 (M=6.3)

Rupture of the Newport-Inglewood fault on March 11, 1933, caused major damage and a loss of 115 lives in Long Beach and surrounding parts of the Los Angeles Basin. Structural damage to public schools was particularly serious, and had the event occurred when schools were in session, the calamity would have been far worse. The Field Act, mandating construction standards for schools in California, was enacted as a consequence of the earthquake.

DECEMBER 30 AND 31, 1934 (M=6.5 AND 7.0)

The major sequence that occurred along the Cerro Prieto fault on December 30 and 31, 1934, appears to



FIGURE 6.7.—San Francisco, Calif., on the morning of April 18, 1906. This famous photograph by Arnold Genthe shows Sacramento Street and approaching fire in the distance. Although some buildings sustained heavy damage in the earthquake, this and many other photographs taken of the city before fire swept through show no visible evidence of damage in most structures. Photograph courtesy of the Fine Arts Museums of San Francisco, Achenbach Foundation for Graphic Arts.

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have ruptured the surface trace of the fault near where it enters the Gulf of California. Aerial photographs of the fault crossing a tidal flat taken in 1935 show very fresh appearing fault morphology; subsequent photographs display a substantially subdued morphology (Kovach and others, 1962).



FIGURE 6.8.—Trace of 1906 earthquake rupture near point of maximum offset (6 m) near Olema on the Point Reyes peninsula north of San Francisco. Photograph by G.K. Gilbert. View northwestward.

MAY 19, 1940 (M=7.1)

The Imperial fault was discovered from its 60+-km-long rupture in the Imperial Valley earthquake of May 19, 1940. Faulting was predominantly right-lateral strike slip and attained a peak offset of more than 6 m at the United States-Mexican border (fig. 6.9). The first instrumental measurement of strong ground motion adjacent to a fault rupture was obtained from an accelerograph located about 7 km from the surface trace. This record, which provides clear evidence of irregular seismic-energy release during the course of the event (Trifunac and Brune, 1970), has played a major role in shaping building codes for earthquake-resistant design.

JULY 21, 1952 (M=7.7)

The Kern County or Arvin-Tehachapi earthquake of July 21, 1952, ruptured the White Wolf fault in the largest event to strike California since 1906. The earthquake led to 12 fatalities, and 2 more occurred during a large aftershock on August 22. Field studies of the earthquake (Oakeshott, 1955) describe the geologic, seismologic, and engineering aspects of the earthquake. From a tectonic standpoint, this event is notable for its conjugate relation to the San Andreas fault. Left-lateral slip with a significant reverse-slip component occurred on the northeast-striking, south-dipping fault plane.



FIGURE 6.9.—Surface faulting in 1940 Imperial Valley earthquake offset (6 m) regular rows of orange trees. Fault displacement along this section of the Imperial fault was confined to a narrow zone.

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FEBRUARY 9, 1956 (M=6.8)

More than 19 km of the hitherto-unknown San Miguel fault in Baja California ruptured in the earthquake sequence of February 9, 1956. The fault offset was consistently right lateral and up to the northwest, and attained maximum horizontal and vertical separations of 78 and 91 cm, respectively (Shor and Roberts, 1958). The sequence contained numerous aftershocks, including three of $M \geq 6$. About 2 years earlier, a pair of M=6 events that occurred to the south and west of the San Miguel fault may have been associated with the Agua Blanca fault.

APRIL 9, 1968 (M=6.5)

The Borrego Mountain earthquake of April 9, 1968, produced the first documented rupture of the San Jacinto fault system when right-lateral displacements of nearly 0.4 m occurred along a 30-km-long segment of the Coyote Creek fault. The U.S. Geological Survey (1972) published a detailed description of the event.

FEBRUARY 9, 1971 (M=6.5)

The San Fernando earthquake of February 9, 1971, ranks as one of the most serious California earthquakes in historical time. The event claimed 58 lives and caused more than half a billion dollars in property damage, including the destruction of two hospitals, a freeway interchange, and the Van Norman Dam. The earthquake ruptured north-dipping, high-angle reverse faults beneath the southern margin of the San Gabriel Mountains and broke the surface along a discontinuous, 15-km-long zone. Surface displacements averaged about 1 m. Seismograms of the earthquake reveal a steeply dipping deep fault and a more shallowly dipping near-surface fault (Langston, 1978; Heaton, 1982). Numerous publications report on detailed investigations of this event, including the summary report published by the U.S. Geological Survey (1971).

OCTOBER 15, 1979 (M=6.5)

The Imperial fault ruptured for the second time in less than 40 years in a major surface-faulting earthquake on October 15, 1979 (U.S. Geological Survey, 1982). The event broke the north 30 km of the fault, or approximately half the length of the 1940 fault break. However, it was clearly much smaller than the earlier event; maximum surface offsets were well under 1 m, in contrast to 6 m observed in 1940, and the seismic moment was smaller by nearly an order of magnitude. Within the zone of overlapping surface rupture, the two events display nearly identical displacement profiles (Sharp, 1982), suggesting that the 1979 earthquake represents a characteristic rupture of this segment of the fault. Strong-ground-motion records for the 1979 earthquake form an unparalleled suite of near-field recordings and have stimulated numerous investigations into the dynamics of the source.

MAY 2, 1983 (M=6.5)

Our understanding of the nature of the earthquake hazard posed by active faults in the San Andreas fault system was fundamentally altered by the occurrence of the Coalinga earthquake of May 2, 1983, on a low-angle thrust fault deep beneath the western margin of the San Joaquin Valley (Rymer and Ellsworth, 1990). Before this event, it had been thought that the major, seismically active faults in California could be recognized on the basis of their surface exposures and record of late Quaternary activity. However, no surface expression exists for the fault system responsible for either this event or the M=5.9 North Kettleman Hills earthquake of August 4, 1985, that adjoins it to the southeast. Instead of a surface fault, the buried deformation is expressed at the surface by active folds (the Coalinga anticline and the Kettleman Hills) that grew during the earthquakes (Stein and King, 1984).

The orientation of the fault and the style of movement on it present another major challenge to prevailing models of the San Andreas system, because this earthquake resulted from a release of compressive forces oriented nearly perpendicular to the trace of the San Andreas fault. Accumulating evidence on the orientation of the stress field astride the San Andreas fault suggests that only a small component of the total stress acts to accommodate the plate motion along the San Andreas fault itself (Mount and Suppe, 1987; Zoback and others, 1987).

NOVEMBER 24, 1987 (M=6.6)

The Superstition Hills fault ruptured in its entirety on November 24, 1987. The total amount of separation substantially increased by persistent afterslip in the months after the main shock; in fact, the rate of afterslip was so great on the south half of the surface break as to leave open the possibility that all of its displacement occurred as afterslip. The earthquake was preceded by a major foreshock (M=6.2), on a conjugate, northeast-trending, left-lateral strike-slip fault that intersected the Superstition Hills fault at the main-shock epicenter. The surface-faulting pattern of the entire sequence was particularly remarkable for the occurrence of numerous breaks on other conjugate faults in the north quadrant around the main break (see Hanks and Allen, 1989).

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OCTOBER 18, 1989 (M=7.1)

In the late afternoon of October 17, 1989, the San Andreas fault ruptured in its first major earthquake since 1906 at 5:04 p.m. P.d.t. (0004 G.m.t. on Oct. 18). Centered along a remote segment of the fault in the southern Santa Cruz Mountains, the Loma Prieta earthquake reruptured the southernmost 40 km of the 1906 fault break, producing the Nation's most costly natural disaster. The earthquake claimed 62 lives and injured an additional 3,757 people. It destroyed 963 homes and damaged more than 18,000 others, displacing 12,000 people from their residences. The combined dollar loss to the private and public sectors exceeded $6 billion (Plafker and Galloway, 1989).

Damage in the epicentral region was most severe where the earthquake shaking was compounded by local ground failures, commonly involving landslide movement but also including some fractures of probable tectonic origin; the shaking clearly reactivated some fissures observed in 1906. Primary fault displacement, however, did not reach the surface. In the hard-hit communities of Santa Cruz, Watsonville, and Los Gatos, unreinforced-masonry buildings bore the brunt to the damage, and ground conditions played a significant role in the damage patterns.

The earthquake also caused grave damage and claimed the greatest number of lives far to the north, in San Francisco and Oakland, about 100 km from the epicenter. There, the earthquake selectively destroyed structures known to be at risk or located on poor ground (Plafker and Galloway, 1989). The root cause of the devastation in the Marina District of San Francisco (fig. 6.10), as well as at most other sites along the margin of the San Francisco Bay, was liquefaction-induced ground failure. All of these localities sit on land reclaimed from the bay and are underlain by young, water-saturated sedimentary deposits. As we know from the clear lessons of history, provided by the earthquakes of 1865, 1868, and 1906 (Lawson, 1908), such materials perform poorly even under modest levels of earthquake shaking. The collapse of the double-decked section of California Interstate Highway 880 in Oakland (fig. 6.10), where 41 people died, resulted principally from design defects. The section of the viaduct that collapsed was founded on soft estuarine sedimentary deposits that amplified the strong ground motion; the adjoining section, founded on alluvium, rode through the earthquake.

The earthquake broke the San Andreas fault where it makes a conspicuous leftward bend, connecting straighter subparallel segments to the north and south. The fault plane dips 70° SW., and movement in the earthquake involved comparable amounts of right-lateral strike slip and reverse slip, a kinematic response driven by the need to remove material from this compressional fault bend as the Pacific plate moves to the northwest around it. The rupture nucleated at the base of the seismic zone, at 18-km depth, and spread unilaterally upward and bilaterally along strike, filling a conspicuous void in the preevent seismicity. Geodetic data collected immediately after the event suggest an average strike-slip displacement of 1.6 m and an average reverse-slip displacement of 1.2 m, rising from the hypocenter at 18 km to within 6 km of the surface.

The Loma Prieta earthquake fulfilled a long-term forecast for the rupture of this specific segment of the San Andreas fault (Lindh, 1983; Sykes and Nishenko,



FIGURE 6.10.—Damage in October 18, 1989, Loma Prieta earthquake occurred at distances as far as 100 km from the epicenter in areas underlain by water-saturated, unconsolidated material. *A*, Liquefaction-induced ground failure in the Marina district of San Francisco (top) was restricted to land reclaimed from the San Francisco Bay. *B*, In Oakland, the second deck of Interstate Highway 880 collapsed onto the first deck. Here, poor design was the principal culprit, although failed section sits atop estuarine sedimentary deposits that amplified the shaking.

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1984; Working Group on California Earthquake Probabilities, 1988). The high earthquake potential assigned to this segment stemmed from its behavior in the 1906 earthquake, when the fault displacement, as measured at the surface, averaged about 1.5 m, far less than the average for the entire rupture. Estimates of the long-term slip rate along this segment of the San Andreas fault suggested that the strain released in the 1906 earthquake would be renewed in 75 to 136 years, implying that another earthquake was possible in the coming decades. With its occurrence, the Loma Prieta earthquake became the second event in 2 years to fill a recognized seismic gap along the San Andreas; the first was the 1987 Superstition Hills earthquake. The Loma Prieta earthquake also represents the third historical rupture of this segment of the San Andreas fault; the first was the October 8, 1865, earthquake, nominally assigned $M=6\frac{1}{2}$, which also caused liquefaction-induced ground failure in San Francisco.

SEISMICITY OF THE WESTERN BASIN AND RANGE PROVINCE

The advent of plate tectonics and its application to western North America by Atwater (1970) provided a unifying framework for the contemporary tectonics of the western Basin and Range and its interaction with the San Andreas fault system to the west. Deformation within the province reflects soft coupling of the San Andreas fault system to the North American craton and distribution of the relative plate motion—by mechanisms yet unknown—well over 500 km into the continental interior. The ubiquity of normal-fault-bounded ranges throughout the province tends to belie the underlying nature of present-day deformation within the region. Within historical time, this region has undergone nearly equal proportions of extension on normal faults and dextral shear on strike-slip faults.

The earthquake history of the western Basin and Range province is poorly known before the instrumental period, owing to sparse settlement of this high-desert region. The deficiencies of this record are illustrated by the uncertainties associated with fresh-appearing fault scarps discovered in 1911 near the north end of what would become the rupture zone of the 1954 Fairview Peak earthquake. Upon reviewing the scant historical evidence, Slemmons and others (1959) concluded that these scarps formed about 1903. The absence of an event of sufficient size in the instrumental record, however, suggests that the scarp forming event is older (or substantially smaller than $M=6$). Current understanding of 19th-century seismicity includes an episode of activity along the California-Nevada State line, including a probable rupture of the Olinghouse fault on December 27, 1869 (Sanders and Slemmons, 1979), although this conclusion was questioned by Toppozada and others (1981).

Surface faulting has accompanied numerous earthquakes in the region, the most significant of which are discussed below. Notable additional surface-faulting events include the $M=6.3$ Excelsior Mountain, Nev., earthquake of 1934 and the $M_L=5.6$ Fort Sage Mountain earthquake of December 14, 1950, located in northeastern California (Gianella, 1957). Ground rupture may have also accompanied the $M=6$ earthquake of January 24, 1875 (see Gianella, 1957). If so, this observation would move the epicenter listed in table 6.1 to lat 39¾° N., long 120½° W.

PRINCIPAL EARTHQUAKES

MARCH 26, 1872 ($M=7.6$)

The town of Lone Pine, Calif., was virtually leveled when the entire 100 to 110-km length of the Owens Valley fault ruptured on March 26, 1872, in one of the largest earthquakes in U.S. history. This fault, which lies in the middle of Owens Valley, is distinct from the normal faults bounding the front of the Sierra Nevada to the west. Considerable confusion has existed in the literature regarding the style of faulting in the 1872 earthquake, including interpretations of right-lateral, left-lateral, and normal-fault movement. A recent study of the earthquake offsets by Beanland and Clark (in press) unambiguously demonstrates that fault movement was predominately right-lateral strike slip, with an average horizontal displacement of 6 m (fig. 6.10). The vertical offsets were clearly smaller and averaged about 1 m down to the east. Beanland and Clark estimate a moment magnitude of **M**=7.5–7.7. Faulting in 1872 largely reactivated earlier Holocene scarps, as recognized by G.K. Gilbert when he visited the area in 1883.

The event was felt throughout most of California and Nevada, and as far east as Salt Lake City, Utah. Adobe and brick buildings in Owens Valley sustained the brunt of the damage. Minor damage also occurred in the San Joaquin and Sacramento Valleys on the opposite side of the Sierra Nevada, at distances of as far as 400 km. In Yosemite Valley, John Muir witnessed a spectacular rockfall triggered by the earthquake. As severe as the ground shaking must have been, it was noted in the Inyo, Calif., *Independent* of April 6, 1982, "* * * that not a person would have been killed or hurt had their houses all been made of wood." It is of some historical interest that the first long-term earthquake forecast, made by G.K. Gilbert in 1883 to the citizens of Salt Lake City, was based in part on his observations of the 1872 earthquake. In it, he noted that the rebuilding of Independence with wood-frame buildings was an extravagance, because this

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great shock had relieved the accumulated strain, and so many generations would pass before conditions would permit another similar shock to occur (Gilbert, 1884):

> The old maxim, "Lightning never strikes in the same spot twice" is unsound in theory and false in fact; but something similar might truly be said about earthquakes. The spot which is the focus of an earthquake (of the type here discussed [1872 Owens Valley]) is thereby exempted for a long time.

Many comparisons have been drawn between the Owens Valley earthquake and the great San Andreas earthquakes of 1857 and 1906. The size of the regions shaken in all three events are comparable, as are the maximum fault displacements. The two San Andreas events have significantly longer rupture lengths, and their seismic moments are larger by a factor of 2 to 3. Whether or not any or all of these earthquakes can be classified as "great" earthquakes becomes a question of semantics. All of them can be classified as great on the basis of their rupture lengths of 100 km or more (Kanamori, 1977), but they all have seismic moments more than 100 times smaller than the largest known earthquakes, such as the **M**=9.2 Alaska earthquake of 1964. Practically speaking, these events are among the largest known strike-slip events, and they must be close to the size of the largest possible strike-slip events along the San Andreas fault system.

OCTOBER 3, 1915 (M=7.3)

The 1915 Pleasant Valley, Nev., earthquake of October 15, 1915, created a series of spectacular normal-fault scarps in the central Nevada seismic zone of the Basin and Range province (figs. 6.11, 6.12). Four major scarps formed during the earthquake, with an aggregate length of 59 km, and reruptured Holocene scarps at the base of the mountain blocks (Wallace, 1984). Fault movement in the earthquake appears to have been purely dip slip and averaged about 2 m on the steeply dipping fault plane. The earthquake was felt from western Utah to the Pacific coast and from northeastern Oregon to the United States-Mexican border. Instrumental measures of the magnitude range from 7.3 to 7¾ and exceed the moment magnitude of 7.2 derived from field measurements (M_0=6.1×10^{27} dyne-cm).

The Pleasant Valley earthquake lies at the north end of a 500-km-long belt of historical surface-faulting earthquakes within the central Nevada seismic zone and Owens Valley fault system. The four major earthquake sequences in this zone since 1872 leave two conspicuous seismic gaps that have been discussed as the potential loci of future major earthquake activity (fig. 6.11; Wallace, 1984).

DECEMBER 21, 1932 (M=7.2)

The second historical surface-faulting event in the central Nevada seismic zone on December 21, 1932, produced a discontinuous zone of surface faulting and fissures in the valleys west and north of Cedar Mountain (Gianella and Callaghan, 1934). Within the 60-km-long, north-northwest-trending zone where faulting was observed, most breaks struck east of north and showed clear evidence of right-lateral displacements (fig. 6.11).

JULY 6, 1954 (M=6.6), AND AUGUST 24, 1954 (M=6.8)

The Rainbow Mountain earthquakes of July 6 and August 24, 1954, produced a zone of east-facing normal-fault scarps along the base of Rainbow Mountain, extend-

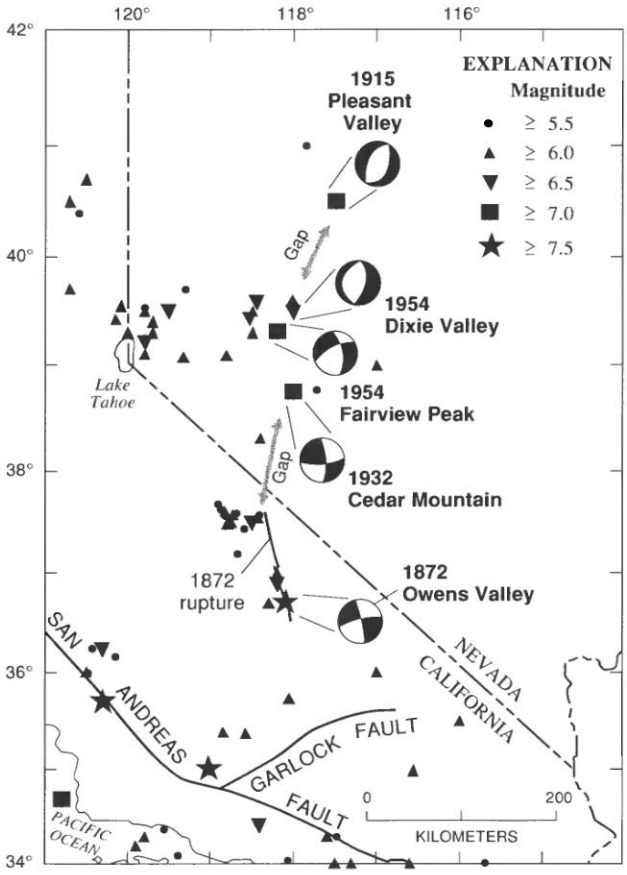

FIGURE 6.11.—California-Nevada region, showing locations of major historical earthquakes in the western Basin and Range province, 1857–1989. Focal mechanisms of five largest events in lower-hemisphere projection show compressional quadrant shaded and indicate significant shear as well as extensional strain in province. Seismic gaps (labeled) are potential loci of future major earthquake activity (Wallace, 1984).

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ing northward into the Carson Sink. The July 6 event produced an 18-km-long surface rupture at the south end of this zone striking N. 15° E., with maximum displacements of about 30 cm. The August 24 shock extended the zone by 22 km in a N. 20° E. direction, with as much as 75 cm of normal-fault slip. Tocher (1956) noted that the displacement on the northern part of the July 6 break approximately doubled in amplitude between July 16 and September 9; the timing of the additional slip could not be determined.

DECEMBER 16, 1954 (M=7.1 AND 6.8)

The Dixie Valley-Fairview Peak earthquakes of December 16, 1954, produced a 90-km-long zone of right-lateral oblique and normal faulting in the central Nevada seismic zone (fig. 6.11; Slemmons, 1957). The first shock, which occurred east of Fairview Peak, produced lateral displacements of more than 4 m and vertical displacements of as much as 3 m. Faulting along this 50-km-long zone was predominantly down to the east opposite Fairview Peak and changed polarity to the north. The second shock, which occurred 4 minutes later, had an epicenter on the east side of Dixie Valley in a left-stepping echelon arrangement with the earlier event. Normal-fault scarps formed along a 40-km-long zone at the base of the Stillwater Range some 20 km west of the Rainbow Mountain faulting. Vertical displacements exceeded 2 m, and consistent strike-slip displacements were absent.

JULY 21, 1986 (M=6.2)

The Chalfant Valley earthquake of July 21, 1986, is the largest event to date in a series of 33 earthquakes of $M_L \geq 5$ to occur since 1978 in the White Mountain seismic gap (Savage and Cockerham, 1987). Other principal events in this series include the May 25–27, 1980, Mammoth Lakes earthquakes (M=6.1, 5.9, 5.8, 6.0) and the November 23, 1984, Round Valley earthquake (M=5.7). The series of shocks is of interest not only because of its wide geographic distribution in the White Mountain seismic gap but also because of the contemporaneous uplift of Long Valley caldera (Hill and others, 1985). The Chalfant Valley earthquake created a 10+-km-long zone of fractures with as much as a few centimeters of dextral slip on the frontal-fault zone of the White Mountains (Lienkaemper and others, 1987). The earthquake focal mechanism and aftershock distribution show that the predominately dextral strike-slip displacement associated with this event occurred on a west-dipping fault plane that projects upward to meet the surface break.



FIGURE 6.12.—Fault trace of 1915 Pleasant Valley, Nev., earthquake remains clearly visible in this photograph by R.E. Wallace more than 60 years after event (Wallace, 1984).

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SEISMICITY OF THE MENDOCINO TRIPLE JUNCTION AND THE GORDA PLATE

The San Andreas fault terminates at its north end in a transform/transform/trench triple junction just seaward of Punta Gorda. Major earthquake activity lies along the Mendocino Fracture Zone, where it is an active transform fault, and to the north within the Gorda plate, which is undergoing intense internal deformation. The Wadati-Benioff zone is well defined to a depth of 30 km and can be traced eastward to a depth of more than 80 km (see fig. 5.5; Walter, 1986). Strong earthquakes within the Gorda plate locate off shore and span the position of the megathrust; these events appear to lie entirely within the oceanic lithosphere. The 1980 Eureka earthquake, for example, ruptured the Gorda plate from the landward to the seaward side of the megathrust. Despite the high level of seismicity, underthrusting events are rare.

PRINCIPAL EARTHQUAKES

NOVEMBER 23, 1873 (M=6¾)

The severe earthquake of November 23, 1873, was felt from San Francisco to Portland, Oreg.; it inflicted the heaviest damage to Crescent City, Calif., and surrounding communities in the Klamath Mountains. The macroseismic epicenter near the California-Oregon State line and probably inland of the coastline is unique within both the historical and instrumental records.

APRIL 16, 1899 (M=7)

Little is known about the large earthquake of April 16, 1899, with an epicenter seaward of Eureka, where it was described as "one of the severest shocks of earthquake ever experienced." Toppozada and others (1981) corrected the origin time of this event and assigned a nearshore epicenter and an M_I of 5.7. The earthquake was assigned an epicenter in the Gulf of Alaska by Milne (1901) on the basis of the traveltime of the maximum amplitude from the five reporting stations; however, a California location satisfies his data equally well. The absence of significant damage along the coast suggests an epicenter well out to sea. An instrumental magnitude (M_S) of 7.0 is derived from the surface-wave amplitudes reported by Milne (see Abe and Noguchi, 1983).

JANUARY 31, 1922 (M=7.3)

The intensity pattern of the large earthquake of January 31, 1922, is generally similar to that of the 1899 event. This event was well recorded throughout the world.

JANUARY 22, 1923 (M=7.2)

The earthquake of January 22, 1923, strongly shook the Cape Mendocino region and toppled many chimneys in the area. This earthquake was probably associated with the Mendocino Fracture Zone.

DECEMBER 21, 1954 (M=6.6)

The strong earthquake of December 21, 1954, apparently was located in the crust of the North American plate above the descending Gorda plate. The relocation of this event by Smith and Knapp (1980) suggests a possible association with the active Mad River fault zone. One fatality is attributed to the earthquake.

NOVEMBER 8, 1980 (M=7.2)

The Eureka earthquake of November 8, 1980, resulted from 100-km-long, left-lateral strike-slip rupture of the Gorda plate along a northeast-striking fault (see fig. 5.5). Aftershocks of the earthquake extended from within 30 km of the coastline southwestward to the Mendocino Fracture Zone. The focal mechanism of the earthquake is thus conjugate to the San Andreas, with its tension axis aligned in the downdip direction. This event argues for high rates of internal deformation within the subducting oceanic lithosphere and against the extension of San Andreas-style faulting northward of the triple junction.

DISCUSSION

The spatial distribution of large earthquakes during the past 2 centuries defines the San Andreas fault system as a 100- to 300-km-wide zone containing numerous active faults in addition to the San Andreas fault proper (fig. 6.1). Except for the two largest events, the great 1857 and 1906 earthquakes that together ruptured two-thirds of the total length of the San Andreas fault, large earthquakes are conspicuously absent along the master fault itself. Although these two great earthquakes account for half of the seismic-strain release since 1769, most of the rest occurs on other, smaller elements of the fault system. Major historical events on these secondary faults, such as the 1927 Lompoc and 1952 Kern County earthquakes, serve to define the boundaries of the San Andreas system. Their mechanisms differ significantly from right-lateral strike slip parallel to the plate-motion vector and illustrate the diversity and complexity of seismic-strain release within the plate-boundary zone.

Over the timespan of the historical catalog, the most enduring characteristic of the earthquake distribution may be the spatial clustering of activity at specific localities along the plate boundary. Notable hotspots

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include the Cerro Prieto, Imperial, San Jacinto, and Calaveras faults, all of which are major branches of the San Andreas fault, and the Parkfield segment of the San Andreas fault in the transition zone between the 1857 rupture and the 150-km-long central, creeping segment of the fault. In each of these areas, the seismic activity coincides with these high-slip-rate faults (1–3.5 cm/yr), and in some places it clearly represents recurrent rupture of the same segment of the fault. At greater distances from the San Andreas fault, the historical events (or sequences) tend to represent isolated occurrences on slower moving faults. Thus, although the overall seismicity spans the broad plate-boundary zone, seismic-strain release over the past 2 centuries correlates with the local rate of fault movement.

In general, the locations of historical earthquakes resemble the overall distribution of microearthquake activity, despite more than six orders of magnitude difference in average seismic moment (fig. 6.13; see chap. 5). One important difference between the distribution of large and small earthquakes is the virtual absence of smaller events along the San Andreas fault segments that ruptured in 1857 and 1906. Similarly, seismic activity is distinctly absent on the potentially dangerous segment between the 1857 break and the Imperial Valley. Except for the central, creeping segment, where numerous small events occur, the San Andreas fault is almost completely aseismic during the long intervals between its rupture in major earthquakes (see figs. 5.6, 5.9).

This inverse correlation between the source regions of large earthquakes and the distribution of smaller events can also be observed for smaller main shocks. Recent studies of the rupture dynamics of $M=6$ events occurring within seismically active regions indicate that the rupture zones of these events are similarly aseismic, with smaller events occurring predominantly outside the slip surface, even during the aftershock sequence (Reasenberg and Ellsworth, 1982; Hartzell and Heaton, 1986; Mendoza and Hartzell, 1988). Thus, the sites of future large earthquakes cannot be identified on the basis of minor seismicity alone.

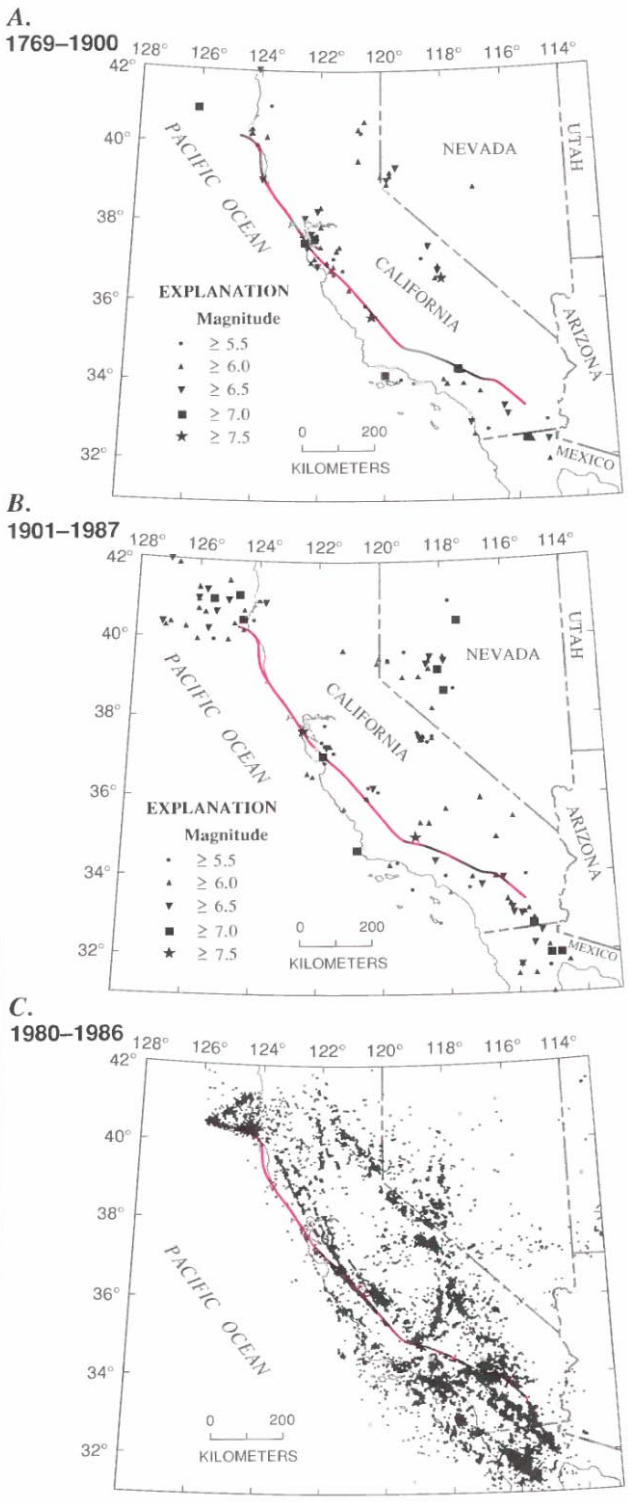

FIGURE 6.13.—Distribution of large and small earthquakes along the San Andreas fault system. In general, modern instrumental data (*C*; see chap. 5) portray same pattern of activity seen in large earthquakes from preinstrumental (*A*) and instrumental (*B*) eras. Some areas characterized by high levels of microearthquakes, such as well-defined faults east of northern section of the San Andreas fault (red line), have not produced significant earthquakes in historical time and so are considered probable sites of future activity.

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RATE OF SEISMICITY

The average rate of earthquake activity within the San Andreas system can be estimated from the Gutenberg-Richter frequency-magnitude relation $\log N = a - bM$, where N is the cumulative number of events of magnitude equal to or greater than M during a given time period. For the 77 events along the fault system with summary magnitudes $M \geq 6$ since 1852, this relation well describes the population with $a = 5\frac{3}{4}$ and $b = 1$ (fig. 6.14). Comparable results are obtained for subsets of $M = 6$ events, such as the instrumental period (1898–1989).

It is useful to compare these results from the historical record with the frequency-magnitude relation determined from systematic microearthquake observations. If the historical rate of activity applies today and the frequency-magnitude relation for microearthquakes ($M \geq 3$) is described by the same relation, then about 5,600 $M \geq 2$ events should be observed each year. This prediction exceeds the number of events observed during the interval 1980–87 by about a factor of 2 (see chap. 5) and suggests that a somewhat smaller value of $b = 0.93$ may be more appropriate for the extended magnitude range.

For the catalog as a whole, the rate of earthquake occurrence is well described by a Poisson process, in which the probability of finding one or more events in any interval of t years is $P = 1 - e^{-\lambda t}$, where λ is the average rate of earthquake occurrence. It follows from the observed frequency-magnitude relation that the odds of having at least one $M \geq 6$ event per year are 0.43. There is also an even chance of at least one $M \geq 6$ event within any 15-month interval, one $M \geq 7$ within any 12½-year interval, or one $M \geq 8$ within any 125-year interval.

The rate of earthquake activity along the plate boundary can also be usefully compared with plate-motion estimates derived from plate-tectonic theory. Current estimates of the relative velocity across the North American-Pacific plate boundary, determined from the spreading rate in the Gulf of California of 5 cm/yr (DeMets and others, 1987), imply an annual seismic-moment rate of 2×10^{26} dyne-cm/yr for a 10-km-thick brittle crust, equivalent to a single **M**=6.8 earthquake. Earthquakes of this size occur far less often, and the principal seismic contribution to the plate motion comes from infrequent large events. The erroneous notion that the smaller events substantially contribute to the total is demonstrably false, as shown by summing the contributions of all the earthquakes below some magnitude. The innumerable events of **M**≤6 occurring each year contribute less than 10 percent to the total seismic-strain release.

Within the San Andreas fault system, the total seismic-moment release since 1852 corresponds to 70 percent of the total North American-Pacific plate motion predicted by plate-tectonic models. This proportion is somewhat inflated because not all of the earthquakes act to transmit slip along the plate boundary; for example, the 1952 Kern County earthquake, the third largest in historic time, directly accommodated little plate-parallel motion. Although aseismic displacements account for some of the deficit, notably along the central, creeping section of the San Andreas fault, deformation occurring elsewhere, notably within the Basin and Range, contributes substantially to the relative motion between the North American and Pacific plates.

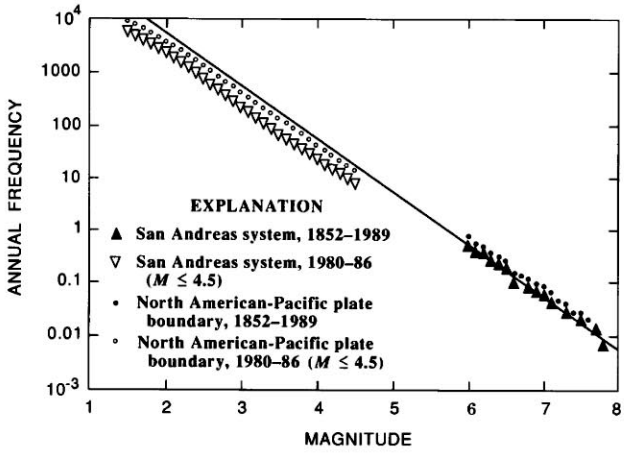

FIGURE 6.14.—Annual frequency of earthquakes of magnitude $\geq M$ as derived from historical and modern instrumental catalogs. Gutenberg-Richter frequency-magnitude relation, $\log N = a - bM$ with $a = 5\frac{3}{4}$/yr and $b = 1$, describes observed distribution of earthquakes of $M \geq 6$ within the San Andreas fault system during 138-yr interval from 1852 to 1989. Also shown are annual frequency of $M \geq 6$ events from the broader Pacific-North American plate boundary, including the San Andreas fault system and the western Basin and Range province, and of $M = 2$–4.5 events in both regions during 1980–86.

PARADOX OF THE MISSING PLATE MOTION

The discrepancy between plate-tectonic estimates of relative motion across the North American-Pacific plate boundary and seismic estimates also holds for geologic and geodetic estimates of motion along the San Andreas fault system. The explanation of this apparent paradox is thought to include deformation within the Basin and Range province in western Nevada and eastern California (Atwater, 1970), which has been the locus of major seismic activity in historical time, including the third

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largest event, in 1872, and 3 of the 11 $M \approx 7$ events in the 20th century.

It has long been recognized that the Basin and Range province has undergone substantial extension during the Cenozoic and is presently opening in a N. 60° W. direction (Zoback and Zoback, 1980). Historical seismicity partly agrees with this geologically derived pattern; however, it also indicates a significant component of dextral shear in nearly every well-studied historical event (Shawe, 1965; Doser, 1986). Because the geologic expression of strike-slip displacement is much more difficult to recognize and quantify than vertical slip, a major question is raised about the significance of the historic seismicity for the total strain within the western Basin and Range.

Since the 1872 earthquake, the net seismic strain within the Basin and Range province can be estimated by summing the contributions of individual events. The net shear strain thus determined indicates nearly equal components of extensional strain in a N. 60° W. direction and dextral shear trending N. 10° W. The resulting average-motion vector nearly coincides with the orientation of the San Andreas fault, and the lateral slip largely balances the coastward expansion of the province that results from extension alone. If both the rate and style of historical faulting accurately portray the long-term deformation within the region, they diminish the discrepancy between the predicted and observed rates of motion across the North American-Pacific plate boundary.

EARTHQUAKE RECURRENCE AND CHARACTERISTIC EARTHQUAKES

Over geologic time, the net displacement across a fault accumulates through the action of countless individual slip events. Measured over many displacement cycles, the average interval between events must equal the average event displacement divided by the remote slip rate. First principles, however, provide little guidance as to the properties of the recurrence, which might range from a totally random distribution of events in both space and time to identical earthquakes repeating at fixed intervals. If recurrence is essentially random, then long-term seismic hazard is described by the Poisson rate of activity, as discussed above. Greater regularities and systematics in recurrence imply that useful time-dependent forecasts of future activity can be derived from knowledge of the past behavior of the fault system.

Results for San Andreas earthquakes have played a central role in establishing the existence of broad regularities in the recurrence process. At Parkfield, the San Andreas fault has ruptured six times since 1857 in $M \approx 6$ events with highly repeatable characteristics every 22 ± 6 years. The latest three events, in 1922, 1934, and 1966, for which instrumental records exist, are virtually identical (fig. 6.15; Bakun and McEvilly, 1984). Amplitude data from Milne seismographs uncovered in the preparation of table 6.1 show that the 1901 and 1922 events produced the same surface-wave amplitudes on common stations, strengthening earlier speculations that all the 20th-century events are similar. Intensity data for the 1881 event (Toppozada and others, 1981) and for foreshocks to the great 1857 earthquake (Sieh, 1978b) place them along the Parkfield segment as well. These regularities in the size, location, and timing of all known events at Parkfield led Bakun and Lindh (1985) to propose a specific recurrence model for Parkfield earthquakes. On the basis of this model, the next in the series of characteristic events is anticipated before 1993, and its forecast represents the first formally endorsed earthquake prediction in the United States.

Geodetic analysis of the strain released in the 1966 earthquake and its subsequent reaccumulation led Segall and Harris (1987; see Harris and Segall, 1987) to identify the zone where strain accumulates and is released, the

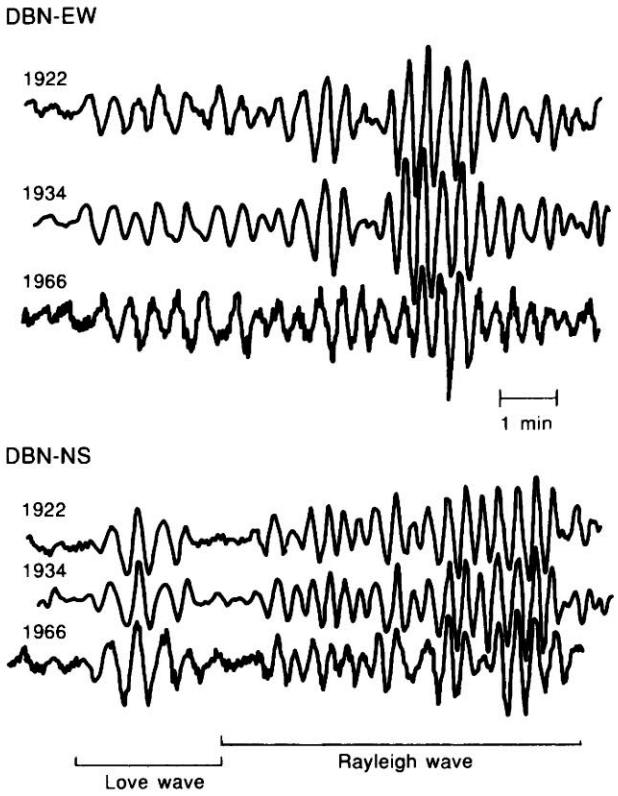

FIGURE 6.15.—Surface waves of 1922, 1934, and 1966 Parkfield, Calif., earthquakes as recorded on same seismograph in DeBilt, The Netherlands (DBN; EW, east-west; NS, north-south). These nearly identical waveforms and amplitudes led Bakun and McEvilly (1984) to propose recurrent rupture of same segment of the San Andreas fault as mechanism of Parkfield earthquakes.

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"Parkfield asperity," as the center of the 1966 rupture zone. This zone of strain accumulation appears to be effectively locked during the interseismic period and corresponds to the center of the 1966 aftershock zone (Eaton and others, 1970) between about 4- and 10-km depth. The significantly fewer events in this part of the aftershock zone than in its periphery suggests that Parkfield earthquakes occur when this locked zone suddenly releases. Aftershocks appear to result from transfer of stress to the perimeter of the asperity.

This same pattern of concentrated coseismic slip occupying a quiet region within the overall aftershock distribution characterizes several recent, well-studied events (Mendoza and Hartzell, 1988), three of which, the Coyote Lake earthquake (Aug. 6, 1979), the Imperial Valley earthquake (Oct. 15, 1979), and the Morgan Hill earthquake (Apr. 24, 1984), all have probable antecedents within the historical record. Reasenberg and Ellsworth (1982) identified the June 20, 1897, earthquake as a predecessor to the 1979 event and noted that the 82-year interval between events equaled the 1.2 m of coseismic slip determined by Liu and Helmberger (1983) divided by the long-term slip rate of 1.5 cm/yr for the Calaveras fault. Similarly, the 73-year interval between the July 11, 1911, event and the 1984 Morgan Hill earthquake (Bakun and others, 1984) well predicts the 0.8 to 1.0 m of maximum coseismic slip determined by Hartzell and Heaton (1986). The 1979 Imperial Valley earthquake is more complex because it reruptured only the northern 30 km of the May 19, 1940, fault break. Again, both the time interval between events and the fault-slip rate compare favorably with the fault slip at depth, as determined from seismograms (Hartzell and Heaton, 1983; Archuleta, 1984). Earlier ruptures of this or other segments of the Imperial fault may well be in the historical record, possibly including the April 19, 1906, event, which occurred the afternoon of the great 1906 earthquake in northern California.

Similar observations of recurrent faulting in events with characteristic magnitudes and locations from around the world (Nishenko and Buland, 1987) suggest a simple, first-order model for seismic potential. In this model, the future behavior of a specific segment of a fault can be forecast from knowledge of the size of past earthquakes, the timing and amount of slip in the latest event, and the long-term rate of fault movement (Lindh, 1983; Sykes and Nishenko, 1984). Accordingly, the probability of an event on a recently ruptured fault segment is low until the elastic strain rebuilds, which may be estimated from the geologic slip rate. As the strain rebuilds, the probability of another earthquake increases. Empirically, the time intervals between successive ruptures of a specific fault segment define a bell-shaped distribution that may be used to estimate the odds of the next event within some future time interval, given that it has not yet occurred.

Probabilities for large earthquakes along the major branches of the San Andreas fault derived from this methodology differ markedly from Poisson estimates (Working Group on California Earthquake Probabilities, 1988). For example, the chance of a repetition of the great 1906 earthquake within the next 30 years (1988–2018) is less than 0.1. In contrast, the chance of an $M=7½$–8 earthquake on the southern section of the San Andreas fault is 0.6. When the Working Group's report was written, the southernmost part of the 1906 fault break was assigned the highest chance of failure of any segment of the north half of the San Andreas fault. Now that it has ruptured in the October 18, 1989, Loma Prieta earthquake, the probability of another rupture will be small for several decades. A clearer understanding of past seismicity can only help to improve and refine estimates of future seismicity.

THE SEISMIC CYCLE

An important implication of the characteristic-earthquake model is the existence of a repetitive cycle of strain accumulation and release (Fedotov, 1968). Mogi (1981) suggested the existence of definite stages in the cycle, including a low level of seismicity in the first part of the cycle once aftershock of the latest event subside, a rise in regional activity as strain accumulates, and ultimately the occurrence of another earthquake with its attendant foreshocks and aftershocks, which initiates the next cycle.

The long-term seismicity within the San Andreas fault system displays these characteristics along the rupture zone of the great 1906 earthquake (figs. 6.16, 6.17; Ellsworth and others, 1981). Activity was relatively high during the 19th century, as becomes particularly apparent after 1850, when the record is virtually complete. After the great 1906 earthquake, the level of seismicity changed drastically, and moderate events essentially ceased for 50 years. Since the mid-1950's, the activity level has increased and begun to approach the 19th-century level (Tocher, 1959). This change in activity associated with the 1906 earthquake has been noted many times (for example, Gutenberg and Richter, 1954), and it is an open question whether it represents a premonitory increase (Toppozada and others, 1988) or whether the long quiescent period since 1906 is the essential feature (Ellsworth and others, 1981).

Comparable variations in seismicity appear to be present in southern California, although the historical record there is less reliable until about 1890. Along the rupture zone of the great 1857 earthquake, the available data suggest a similar period of low activity for several

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decades after the event (fig. 6.17). Farther south, along the section of the fault that has not ruptured in 3 centuries, the activity level since at least the 1880's is reminiscent of the activity in the San Francisco Bay region before the 1906 earthquake (fig. 6.18). As a potential long-term indicator of high seismic potential, the seismicity surrounding the dormant southern section of the San Andreas fault agrees with independent estimates of long-term potential derived from paleoseismology.

FUTURE USES OF EARTHQUAKE HISTORY

At this stage in our understanding of the San Andreas fault system, seismicity is still best described as a random

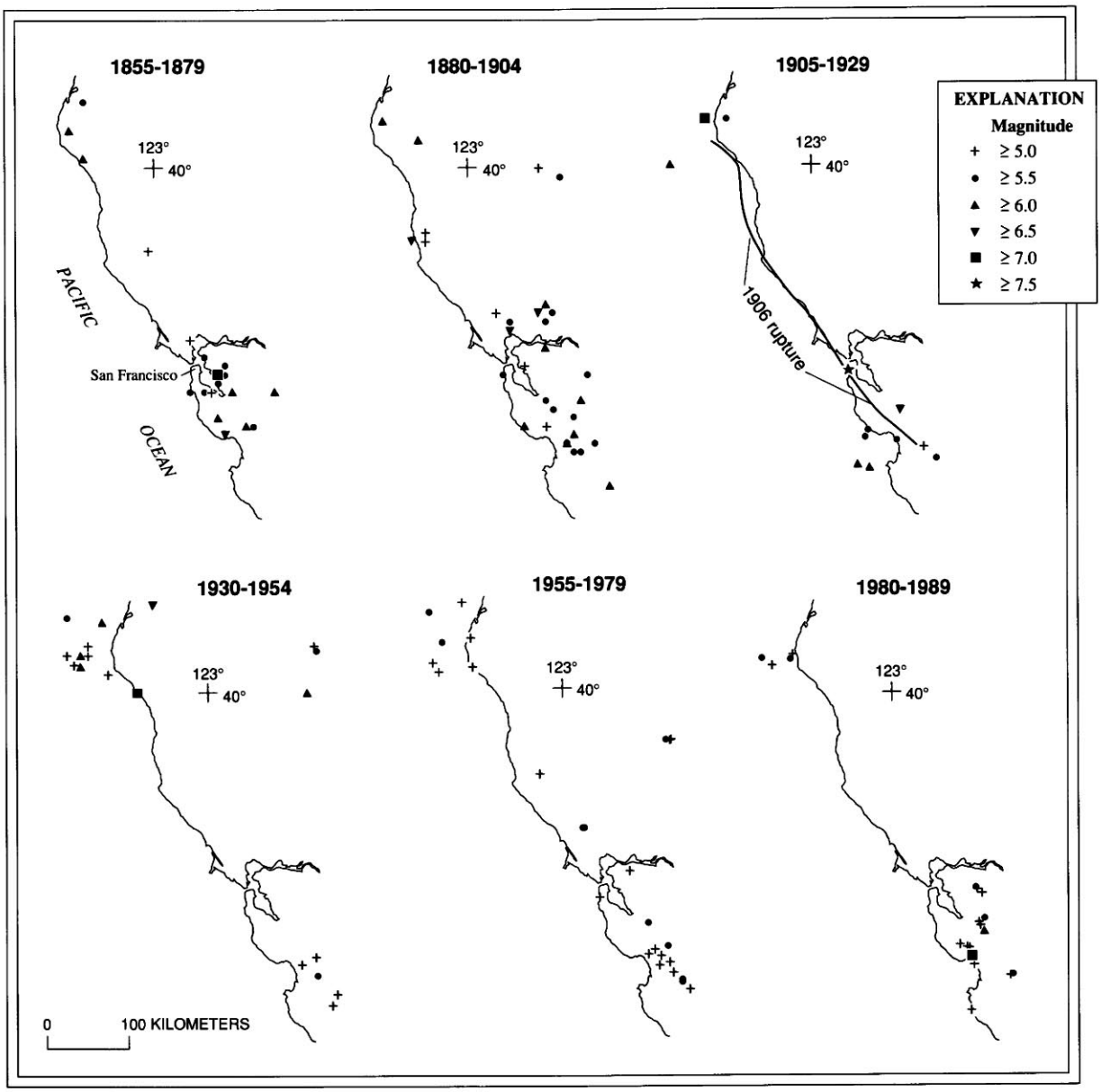

FIGURE 6.16.—Seismicity of the San Francisco Bay region in quarter-century epochs. Activity was high in the region during at least a half-century before 1906 earthquake and drastically declined afterward for the next half-century. Since the mid-1950's, activity has begun to approach levels last seen in the 19th century. However, both geologic and geodetic evidence suggest that the next great earthquake will not occur for a century or more.

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process over time, with a highly clustered spatial distribution. There are, however, tantalizing hints of underlying regularities, such as those in the characteristic earthquakes at Parkfield, or in the striking changes in seismicity associated with the 1906 earthquake. The next generation of refinements to this history will assuredly make comparable contributions by reducing the uncertainty in earthquake locations and magnitudes. Modern seismologic methods for extracting new information on the mechanisms of earthquakes have already proved practical for many events from the early instrumental period. Systematic treatment of the full instrumental catalog with these methods will provide a new basis for understanding the tectonics of the plate boundary and the mechanics of earthquakes.

CATALOG OF MAJOR EARTHQUAKES, 1769–1989

CATALOG COMPILATION

The publication of Edward S. Holden's catalog of Pacific coast earthquakes in 1898 represented the first systematic scientific inquiry into the seismic history of California and surrounding regions. This catalog, and its extension by McAdie (1907), formed the primary basis for the monumental catalog of Townley and Allen (1939) covering the years 1769–1928. These catalogs provide detailed descriptive accounts of virtually all the earthquakes that are now known from this period, and all subsequent analyses of seismicity up to the modern instrumental period build on these foundations.

Recent studies of preinstrumental seismicity have focused on quantification of the historical record. The catalog presented here relies heavily on the research of Tousson Toppozada and his associates (Toppozada and others, 1981; Toppozada and Parke, 1982), who developed extensive new information on seismic intensities from newspaper accounts and other original sources, and determined locations and magnitudes from the resulting isoseismal maps. In addition, several special studies of important events by other workers have contributed to the catalog.

The development of practical seismographic instrumentation around the turn of the 20th century led to the rapid growth of seismologic data, particularly for those events large enough to register at teleseismic distances on the early instruments. The publication of the Circulars of the Seismological Committee of the British Association for the Advancement of Science (1899–1912) and their continuation as the International Seismological Summary from 1913 on indicate a detection threshold of about M≈6 for the Western United States as early as 1898. Data from these and other sources enabled Gutenberg and Richter (1954) to systematically catalog seismicity from 1904 onward.

Modern seismographic instrumentation first installed in California in 1910 ushered in the era of earthquake

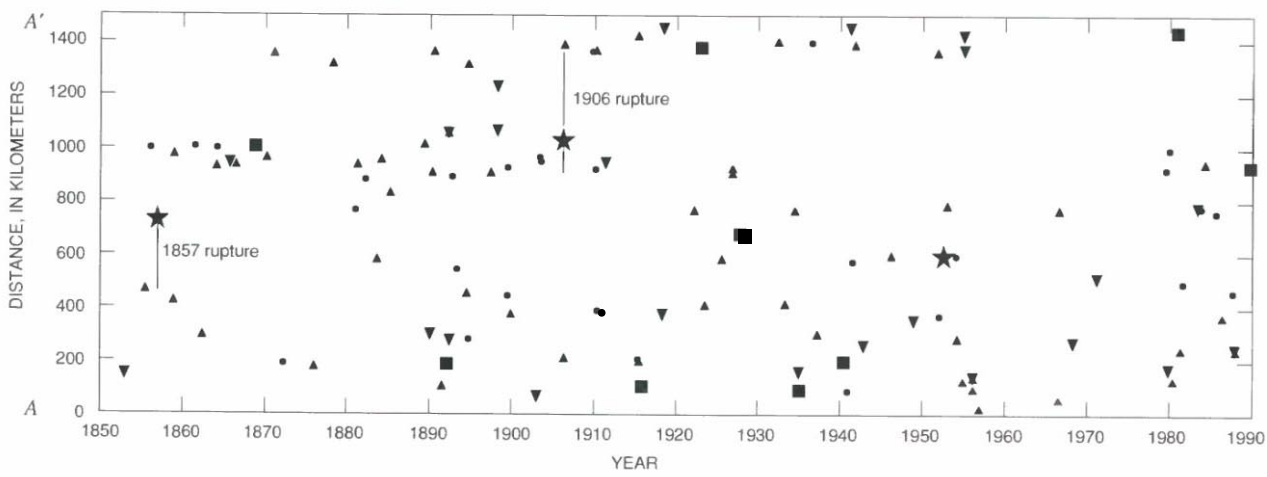

FIGURE 6.17.—Space-time diagram of seismicity since 1850 along the San Andreas fault system between head of the Gulf of California (*A*) and Punta Gorda (*A′*). Change in seismicity rate along northern section of the San Andreas fault associated with 1906 earthquake (fig. 6.13) may also be tentatively identified along 1857 earthquake rupture. Persistent activity characterizes south third of the plate boundary since 1890, spanning the entire interval of reliable earthquake reporting in this region.

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observation at regional distances. The Bulletins of the Seismographic Stations of the University of California, Berkeley, from 1910 to the present form the principal source for events in northern California and adjoining areas. Routine epicentral determinations and magnitude assignments for earthquakes in the southern California region date from 1932 and are taken from the catalog of the Seismological Laboratory of the California Institute of Technology, Pasadena. Additional instrumental results come from various other sources, chiefly the U.S. Geological Survey and the University of Nevada, Reno.

The resulting catalog of major earthquakes in California, western Nevada, and northernmost Baja California from 1769 to 1989 (table 6.1) contains 206 entries. This catalog omits several earthquakes listed in earlier catalogs where this or other recent studies have failed to corroborate previous interpretation as significant events or even, in some cases, their occurrence.

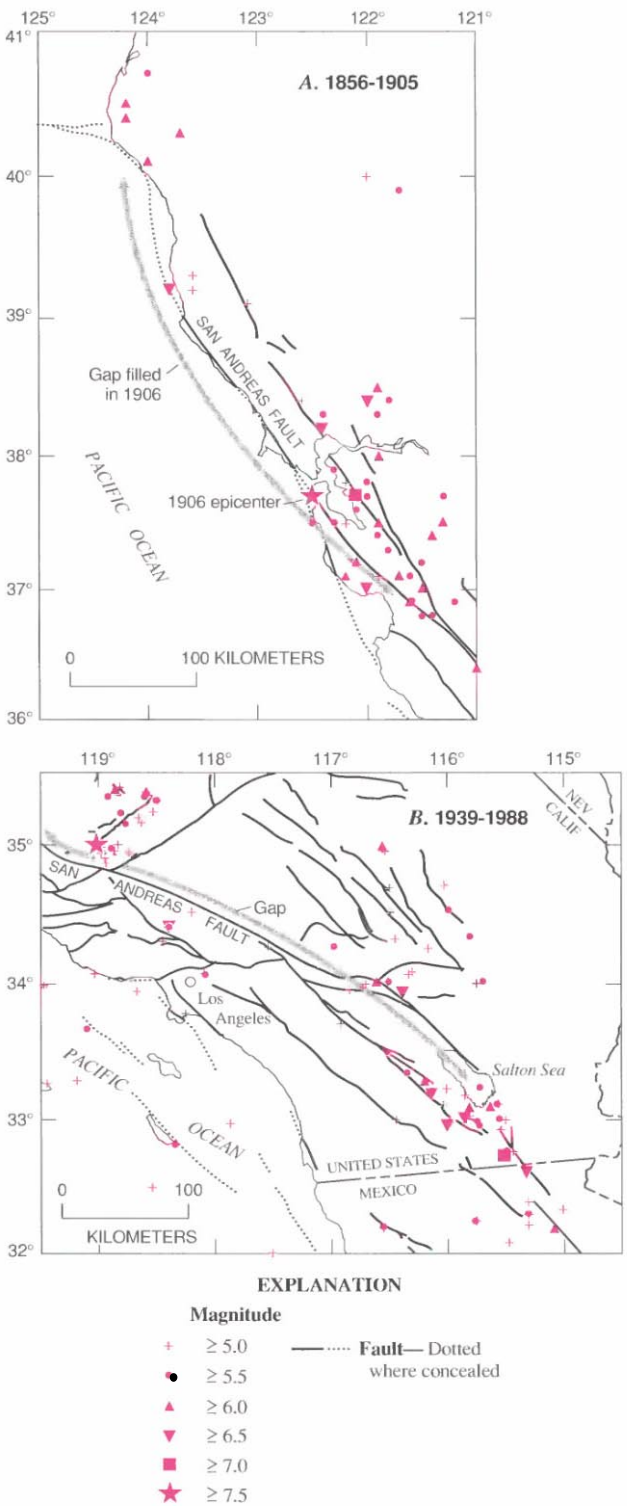

FIGURE 6.18.—Where will the next great earthquake strike along the San Andreas fault system? Numerous lines of evidence point to its long-dormant southernmost segment (*B*) as having the highest potential. Large earthquake activity in this region shares many similarities with activity in the San Francisco Bay region before 1906 earthquake (*A*). In both cases, absence of activity directly on the San Andreas fault is pronounced, and a high regional level of activity is concentrated along other major branches of the fault system.

QUANTIFICATION OF EARTHQUAKES AND MAGNITUDE SCALES

Physical measures of the complex mechanical event producing the earthquake take many forms, including the dimensions of the faulted region, the amount of slip, and the strength of the radiated elastic waves. To relate the characteristics of one event to another, the observed quantities must generally be summarized through the use of either an empirical relation, such as magnitude, or a quantity derived from a physical model, such as seismic moment. Both procedures have their place, and the choice of one metric over another depends principally on the purposes of the comparison and the availability of common data.

Because no single procedure for determining magnitude can be applied to the entire historical record, the catalog must be quantified by using various magnitude scales. Each scale is briefly described below to define its origin and to clarify its relation to the other scales. I emphasize that each scale has a particular range of validity and that different magnitude scales will, in general, yield slightly different values for the same event. Such differences in magnitude seem to provide a never-ending source of interest and controversy for the news media, who commonly lump all scales together under the heading of "Richter scale." To the seismologist,

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such differences are neither surprising nor controversial and can, in fact, provide information on the underlying physical processes of the earthquake source.

I also emphasize that intensity scales characterize the effects of the earthquake at a particular location and are not magnitude scales. Strictly speaking, intensity values (or, for that matter, instrumentally measured values of ground-motion parameters) describe the vibratory motions that are the actual earthquake as observed at a particular location, whereas magnitude values describe the faulting event that generates the earthquake.

THE RICHTER SCALE (M_L)

The original magnitude scale of Richter (1935) was introduced for the purpose of providing an objective measure of the energy of each earthquake in the initial listing of earthquakes in the southern California region compiled by the Seismological Laboratory in Pasadena. Rather than attempting to measure the energy of the earthquake source directly, he chose to construct an empirical scale derived from a simple measure of the complex seismic waveform. Using only the maximum excursion of the seismogram as measured on a single type of instrument, the Wood-Anderson seismograph, he defined the local magnitude of an earthquake as

$$M_L = \log_{10} A - \log_{10} A_0(\Delta) ,$$

where the empirical function A_0 depends only on the epicentral distance of the station, Δ. The zero point was arbitrarily set by Richter to avoid negative magnitudes in the course of routine work. Use of common logarithms means that two earthquakes located at the same distance from a station and having peak amplitudes differing by a factor of 10 will differ by 1 magnitude unit. In practice, readings from all observing stations are averaged after adjustment with station-specific corrections to obtain the M_L value. Although Richter (1935) predicted that the local-magnitude scale "cannot hold to any high accuracy," history has proved it to be a powerful quantitative tool for ordering the relative sizes of earthquakes.

Several points about M_L should be emphasized. First, it is strictly defined only for the southern California region, although its applicability to coastal central and northern California has since been shown. Recent studies of the A_0 curve suggest that it will require revision and regionalization. Second, because M_L has no actual physical units associated with it, other empirical magnitude scales may be freely adjusted to coincide with it. The local-magnitude scale has, in fact, been used as the basis for establishing essentially all other magnitude scales. Finally, because M_L is derived from measurements taken from a single, band-limited seismograph, M_L values saturate once an earthquake becomes large enough. Thus, the "correct" Richter magnitude M_L=6.9 for the great 1906 earthquake obtained by Jennings and Kanamori (1979) reflects the amplitude of seismic waves at periods near 1 s but not the total energy of this earthquake. Uniformly valid characterization of the "size" of an earthquake requires use of magnitude scales based on longer-period measures of the event.

SURFACE-WAVE MAGNITUDE (M_S) AND BODY-WAVE MAGNITUDE (m_b)

The successful development of the local-magnitude scale encouraged Gutenberg and Richter to develop magnitude scales based on teleseismic observations of earthquakes. Two scales were developed, one based on surface waves, M_S, and one on body waves, m_b.

Surface waves with a period near 20 s generally produce the largest amplitudes on a standard long-period seismograph, and so the amplitude of these waves is used to determine M_S, using an equation similar to that used for M_L.

The body-wave magnitude, m_b, which was developed specifically to treat deep-focus earthquakes, presents yet another alternative scale for magnitude determination. Although it presently is the most commonly reported teleseismic magnitude, current practice in its determination differs from that employed by Gutenberg, and so it is omitted from table 6.1. As a short-period magnitude, modern m_b values measure the same part of the earthquake energy spectrum as M_L.

The magnitudes listed by Gutenberg and Richter (1954) that appear in table 6.1 as M_{G-R} are essentially M_S according to Geller and Kanamori (1977); magnitudes attributed to Richter (1958) are based on M_L or M_S.

Useful estimates of M_S can be obtained from many different types of long-period seismographs, including the undamped instruments deployed by Milne beginning in 1897. Abe and Noguchi (1983) constructed estimates of M_S from Milne seismograms to resolve a longstanding controversy concerning an apparent peak in global seismicity between 1904 and 1912. Abe (1988) later used the Milne data to determine magnitudes for smaller earthquakes in California between 1898 and 1912. His procedures have been used to compute M_S for additional California events occurring between 1898 and 1934, which are listed in table 6.1.

SEISMIC INTENSITY AND EARTHQUAKE MAGNITUDE (M_I)

Before the development of seismographs in the late 19th century, descriptions of the effects of earthquakes provided the only means for assessing earthquake size in all but the rare cases where surface faulting was well

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described. A robust method for relating the area undergoing shaking of a given intensity or greater to M_L was developed by Toppozada (1975) for California and western Nevada. Using these relations, Toppozada and others (1981, 1982) successfully assigned an intensity magnitude, M_I, to many earthquakes. The isoseismal maps developed in the course of their research also generally provide our best estimates of epicentral locations. New M_I values have been determined for several events, using the same procedures as part of this study.

SEISMIC MOMENT (M_0), RADIATED ENERGY, AND MOMENT MAGNITUDE (**M**)

Magnitude scales based on finite-bandwidth seismographs approach a maximum near which events of clearly different size or energy are indistinguishable. Saturation of M_L is apparent for both the 1906 and 1952 earthquakes listed in table 6.1. Recent work by Hutton and Boore (1987) suggests that the local-magnitude scale may begin to saturate at about M_L=6. Such saturation, which is understood to arise from the scaling law of the seismic spectrum (Aki, 1967), occurs when the peak of the energy spectrum lies below the frequency range of the Wood-Anderson seismograph.

By using the well-known properties of the seismic spectrum, magnitude scales can be constructed with uniform validity. One such scale, M_w, proposed by Kanamori (1977) is based on the seismic energy radiated in the form of elastic waves by the source. Another nearly equivalent magnitude scale, **M**, the moment magnitude, is based on the seismic moment, $M_0=\mu Au$ (Aki, 1966), where A is the area of the earthquake rupture surface, u is the average fault displacement, and μ is the shear modulus of the crustal volume containing the fault. Hanks and Kanamori (1979) took advantage of the nearly identical relations between M_0 and both M_L and M_S to define $\mathbf{M}=\frac{2}{3}\log_{10} M_0-10.7$, where M_0 is measured in dyne-centimeters.

These two magnitude scales, though closely related, are not identical. Singh and Havskov (1980) showed that $M_w=\frac{2}{3}(\log_{10} M_0+\log_{10} \Delta\sigma/\mu-12.1)$, where $\Delta\sigma$ is the stress drop. Earthquake stress drops generally fall in a narrow range over the entire magnitude spectrum, and so with $\Delta\sigma/\mu\approx10^{-4}$ (Kanamori, 1977), M_w=**M**. One advantage to **M** for the purpose at hand is its dependence on only the static fault offset and rupture area, which can be determined for the 1857 and 1872 earthquakes.

SUMMARY MAGNITUDE (M)

To construct a single, summary-magnitude scale, M, to characterize the relative size of all the events listed in table 6.1, I use each of the scales described above, being careful to consider such factors as the historical period and event location, as well as the quality of individual determinations. Where choices between several magnitude estimates are possible, the summary magnitude, M, is weighted toward long-period estimates of magnitude. Specifically, M_S *and* $M_{G\text{-}R}$ are selected when judged reliable (110 events). Many local magnitudes have thus been superseded by surface-wave magnitudes; this effect is most noticeable for the largest events, where saturation of M_L becomes important. M_L is the principal contributor to 20 summary magnitudes, half of which also have reported **M** values that agree well. For all but two events before 1898 (1857 and 1872) and for two 20th-century events, M is based on M_I. In effect, the summary magnitude is an intensity magnitude before 1898 and a teleseismic surface-wave magnitude thereafter.

If M is to be uniformly validity across the entire timespan of the catalog, M_I must be an unbiased estimator of M_S or $M_{G\text{-}R}$. To test this absence of bias, the correlation between M_I and the two surface-wave magnitudes has been examined for 23 events with reliable M_S *or* $M_{G\text{-}R}$ estimates, and an M_I value determined from the isoseismal maps of Toppozada and others (1981) and Toppozada and Parke (1982). This comparison shows that although the two magnitude scales are well correlated, M_I systematically underestimates M_S and $M_{G\text{-}R}$ by 0.3±0.3 units. If the sample is restricted to $M_S\leq6.5$ (n=18), the bias is 0.2±0.3 units. To further investigate this apparent bias, M_L was compared with M_I for 10 common events, for which the bias was 0.25±0.2 units. As a final check, the difference between M_S or $M_{G\text{-}R}$ and M_I for the 12 events listed in table 6.1 also used by Toppozada (1975) to develop M_I relations was found to be 0.10±0.19 units.

On the basis of these results, the summary magnitudes from M_I values of Toppozada and others (1981) have been adjusted upward by 0.15 units and then rounded to the nearest quarter magnitude unit. Thus, events of M_I=5.7 become M=5¾, and those of M_I=5.8 become M=6. No magnitude adjustment exceeded a quarter unit. M_I values from other sources have simply been rounded to the nearest quarter unit, because they average 0.2 units higher than the values of Toppozada and others (1981) and Toppozada and Parke (1982), where comparisons can be made. Summary magnitudes for events before 1850 have not been adjusted upward, owing to the imprecision of the original estimates.

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EEC ORIGINAL PKG

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TABLE 6.1

Earthquake origin times, magnitudes, and locations before 1990 principally derived from interpretations of felt reports by Toppozada and others (1981); after 1900, data principally derived from Gutenberg and Richter (1954) and bulletins of the California Institute of Technology, University of California, Berkeley, University of Nevada, Reno, and U.S. Geological Survey. See text for discussion of summary magnitude M. Other magnitude scales are M_L, local-magnitude scale of Richter (1935); M_{G-R}, magnitudes from Gutenberg and Richter (1954), generally based on 20-s surface waves; M_S, 20-s surface-wave magnitude; M_I, magnitude estimated from felt area at various intensity levels; and **M**, moment magnitude, defined as $\mathbf{M}=\frac{2}{3}\log_{10} M_0-10.7$, where M_0 is in dyne-centimeters—parenthetical values based on seismogram envelope. M_S values before 1935 generally derived from undamped Milne seismographs, using the formula of Abe (1988)—parenthetical values based on one or two amplitudes; M_S values since 1968 measured from vertical seismograms. Absence of reported amplitudes on Milne seismographs (*) suggests $M_S<6$.

EEC ORIGINAL PKG

TABLE 6.1.—*Major California and Nevada earthquakes, 1769–1989*

Date and origin time (GMT)		*M*	Lat N. and Long W.		Locality	M_L	M_{G-R}	M_S	M_I	M
1769/07/28		6?	34°	118°	Los Angeles Basin	—	—	—	6	—
1800/11/22	21:30	6½?	33°	117°18′	San Diego region	—	—	—	≥6½	—
1808/06/21		6?	37°48′	122°30′	San Francisco region	—	—	—	6	—
1812/12/08	15:00	7	34°22′	117°39′	Wrightwood	—	—	—	6.9	—
1812/12/21	19:00	7	34°12′	119°54′	Santa Barbara Channel	—	—	—	7.1	—
1827/09/24	04:00	5½?	34°	119°	Los Angeles region	—	—	—	5½ to 6	—
1836/06/10	15:30	6¾	37°48′	122°12′	Hayward fault	—	—	—	6.8	—
1838/06/?	p.m.	7	37°36′	122°24′	San Francisco Peninsula	—	—	—	≥7.0	—
1852/11/29	20:00	6½	32°30′	115°	Volcano Lake, B.C.	—	—	—	6 to 7	—
1855/07/11	*04:15*	6?	*34° 6′*	*118° 6′*	*Los Angeles region*	—	—	—	6	—
1856/02/15	13:25	5¾	37°30′	122°18′	San Francisco Peninsula	—	—	—	5.5	—
1857/01/09	16:00	8¼	35°42′	120°18′	Great Fort Tejon earthquake	—	—	—	7.6	7.8
1857/09/03	03:05	6¼	39°18′	120°	Western Nevada or eastern Sierra Nevada	—	—	—	6.0	—
1858/11/26	08:35	6¼	37°30′	121°54′	San Jose region	—	—	—	6.1	—
1858/12/16	10:00	6	34°	117°30′	San Bernadino region	—	—	—	6	—
1860/03/15	19:00	6½	39°30′	119°30′	Carson City, Nev. region	—	—	—	6.3	—
1861/07/04	00:11	5¾	37°48′	122° 0′	San Ramon Valley	—	—	—	5.6	—
1862/05/27	20:00	6	32°42′	117°12′	San Diego region	—	—	—	5.9	—
1864/02/26	13:47	6	37° 6′	121°42′	Southern Santa Cruz Mountains	—	—	—	5.9	—
1864/03/05	16:49	5¾	37°42′	122°	East of San Francisco Bay	—	—	—	5.7	—
1865/10/08	20:46	6½	37° 0′	122° 0′	Southern Santa Cruz Mountains	—	—	—	6.3	—
1866/07/15	06:30	6	37°30′	121°18′	Western San Joaquin Valley	—	—	—	5.8	—
1868/05/30	05:10	6	39°18′	119°42′	Virginia City, Nev.	—	—	—	5.8, 6	—
1868/10/21	15:53	7	37°42′	122° 6′	Hayward fault	—	—	—	6.8	—
1869/12/27	01:55	6¼	39°24′	119°42′	Olinghouse fault, Nev. (?)	—	—	—	6.1	—
1869/12/27	10:00	6	39° 6′	119°48′	Carson City, Nev. region	—	—	—	5.9	—
1870/02/17	20:12	6	37°12′	122° 6′	Los Gatos	—	—	—	5.8	—
1871/03/02	21:05	6	40°24′	124°12′	Cape Mendocino	—	—	—	5.9	—
1872/03/26	10:30	7.6	36°42′	118° 6′	Owens Valley	—	—	—	7.3	7.6
1872/03/26	14:06	6¾	36°54′	118°12′	Owens Valley	—	—	—	6.5	—
1872/04/03	12:15	6¼	37°	118°12′	Owens Valley	—	—	—	6.1	—
1872/04/11	19:00	6¾	37°30′	118°30′	Owens Valley	—	—	—	6.6	—
1872/05/03	01:00	5¾	33°	115°	Imperial Valley (?)	—	—	—	≥5.5	—
1872/11/12	00:00	6	39°?	117°?	Austin, Nev. region (?)	—	—	—	6	—
1873/11/23	05:00	6¾	42°	124°	Crescent City	—	—	—	6.7	—
1875/01/24	12:00	6	40°12′	120°30′	Honey Lake	—	—	—	5.8	—
1875/11/15	22:30	6¼	32°30′	115°30′	Imperial Valley to Colorado River delta (?)	—	—	—	6.2	—
1878/05/09	04:25	6	40° 6′	124°	Punta Gorda region	—	—	—	5.8	—
1881/02/02	00:11	5¾	36° 0′	120°30′	Parkfield	—	—	—	5.6	—
1881/04/10	10:00	6	37°24′	121°24′	Western San Joaquin Valley	—	—	—	5.9	—
1882/03/06	21:45	5¾	36°54′	121°12′	Hollister	—	—	—	5.7	—
1883/09/05	12:30	6¼	34°12′	119°54′	Santa Barbara Channel	—	—	—	6.0	—
1884/01/28	07:30	5¾	41°6′	123°36′	Klamath Mountains	—	—	—	5.7	—
1884/03/26	00:40	6	37°6′	122°12′	Santa Cruz Mountains	—	—	—	5.9	—
1885/01/31	05:45	5¾	40°24′	120°36′	Susanville	—	—	—	5.7	—
1885/04/12	04:05	6¼	36°24′	121°	Southern Diablo Range	—	—	—	6.2	—
1887/06/03	10:48	6½	39°12′	119°48′	Carson City, Nev. region	—	—	—	6.3	—
1888/04/29	04:48	6	39°42′	120°42′	Mohawk Valley	—	—	—	5.9	—
1889/05/19	11:10	6¼	38° 0′	121°54′	Antioch	—	—	—	6.0	—
1889/06/20	06:00	6	40°30′	120°42′	Susanville	—	—	—	5.9	—
1889/09/30	05:20	5¾	37°12′	118°42′	Bishop region	—	—	—	5.6	—
1890/02/09	12:06	6½	33°24′	116°18′	San Jacinto or Elsinore fault region (?)	—	—	—	6.3	—
1890/04/24	11:36	6¼	36°54′	121°36′	Pajaro Gap	—	—	—	6.0	—
1890/07/26	09:40	6¼	40°30′	124°12′	Cape Mendocino	—	—	—	6.0	—
1891/07/30	14:10	6	32°	115°	Colorado River delta region	—	—	—	6.0	—

EEC ORIGINAL PKG

TABLE 6.1.—*Major California and Nevada earthquakes, 1979–1989*—Continued

Date and origin time (GMT)		*M*	Lat N. and Long W.		Locality	M_L	M_{G-R}	M_S	M_I	M
1892/02/24	07:20	7	32°33′	115°38′	Laguna Salada, B.C.	—	—	—	6.7, 7.2	—
1892/04/19	10:50	6½	38°24′	122° 0′	Vacaville	—	—	—	6.4	—
1892/04/21	17:43	6¼	38°30′	121°54′	Winters	—	—	—	6.2	—
1892/05/28	11:15	6½	33°12′	116°12′	San Jacinto or Elsinore fault region (?)	—	—	—	6.3	—
1892/11/13	12:45	5¾	36°48′	121°30′	Hollister	—	—	—	5.6	—
1893/05/19	00:35	5¾	34° 6′	119°24′	Pico Canyon	—	—	—	5.5, 5.9	—
1894/07/30	05:12	6	34°18′	117°36′	Lytle Creek region	—	—	—	5.9, 6.0	—
1894/09/30	17:36	6	40°18′	123°42′	Cape Mendocino region	—	—	—	5.8	—
1894/10/23	23:03	5¾	32°48′	116°48′	East of San Diego	—	—	—	5.7	—
1896/08/17	11:30	6	36°42′	118°18′	Southeastern Sierra Nevada	—	—	—	5.9	—
1897/06/20	20:14	6¼	37° 0′	121°30′	Gilroy	—	—	—	6.2	—
1898/03/31	07:43	6½	38°12′	122°24′	Mare Island	—	—	(6.5)	6.2	—
1898/04/15	07:07	6½	39°12′	123°48′	Mendocino	—	—	(6.7)	6.4	—
1899/04/16	13:40	7	41°?	126°?	West of Eureka	—	—	7.0	5.7	—
1899/07/06	20:10	5¾	37°12′	121°30′	Morgan Hill	—	—	(4.7)	5.8	—
1899/07/22	20:32	5¾	34°18′	117°30′	Lytle Creek region	—	—	(5.6)	6.5, 6.4	—
1899/12/25	12:25	6.4	33°48′	117° 0′	San Jacinto and Hemet	—	—	6.4	6.6, 6.7	—
1901/03/03	07:45	6.4	36° 0′	120°30′	Parkfield	—	—	6.4	5.8	—
1903/01/24	05:27	6.6	31°30′	115°	Colorado River delta region	—	7+	6.6	—	—
1903/06/11	13:12	5½	37°24′	121°54′	San Jose	—	—	(5.4)	5.8	—
1903/08/03	06:49	5½	37°18′	121°48′	San Jose	—	—	(5.3)	5.8	—
1906/04/18	13:12	8¼	37°42′	122°30′	Great 1906 earthquake	6.9	8¼, 8.3	7.8, 8.3	7.8	7.7
1906/04/19	00:30	6.2	32°54′	115°30′	Imperial Valley	—	6+	6.2	5.8	—
1906/04/23	09:10	6.4	41°	124°	Arcata	—	—	6.4	—	—
1907/09/20	01:54	5.3	34°12′?	117° 6′?	San Bernadino region	—	6	*	5.3	—
1908/11/04	08:37	6?	36°?	117°?	Death Valley region	—	6½	*	—	—
1909/10/29	06:45	5.8	40°30′	124°12′	Cape Mendocino	—	6+	5.8, (5.1)	6.4	—
1910/03/11	06:52	5.8	36°54′	121°48′	Watsonville	—	—	5.8	5.5	—
1910/03/19	00:11	6.0	40°?	125°?	West of Cape Mendocino	—	—	6.0	6.2	—
1910/05/15	15:47	5½	33°42′	117°24′	Glen Ivy Hot Springs	—	—	(5.5)	6.0, 5.3	—
1910/08/05	01:31	6.6	42°	127°	West of Crescent City	—	6.8	6.6	—	—
1911/07/01	22:00	6.5	37°15′	121°45′	Calaveras fault	—	6.6	6.5	6.2	—
1914/02/18	18:17	5½?	39°30′	119°48′	Truckee region	—	—	*	6	—
1914/04/24	08:34	6	39°30′	119°48′	Truckee region	—	—	(5.5), (5.6)	6.4	—
1915/05/06	12:09	6.2	40°	126°	West of Cape Mendocino	—	6¾	6.2, (6.0)	—	—
1915/06/23	03:59	6.0	32°48′	115°30′	Imperial Valley	—	6¼	6.0, (5.6)	5.6, 5.5	—
1915/06/23	04:56	5.9	32°48′	115°30′	Imperial Valley	—	6¼	5.9	5.6, 5.5	—
1915/10/03	06:52	7.3	40°30′	117°30′	Pleasant Valley, Nev.	—	7¾	7.6, 7.4, 7.3	—	7.2
1915/11/21	00:13	7.1	32°	115°	Volcano Lake, B.C.	—	7.1	7.1, 6.8	—	—
1915/12/31	12:20	6.5	41°	126°	West of Eureka	—	6½	6.5, (6.4)	—	—
1916/02/03	05:03	5.9	41°	117°48′	North of Pleasant Valley, Nev.	—	—	(5.1)	5.9	—
1916/10/23	02:44	5.3	34°54′	118°54′	Tejon Pass region	—	5½±	6	5.2, 5.3	(5.3)
1916/11/10	09:11	6.1	35°30′	116° 0′	South of Death Valley	—	6.1	(5.7, 5.9)	—	—
1918/04/21	22:32	6.9	33°48′	117° 0′	San Jacinto	—	6.8	7.2, 6.9	6.6	(6.8)
1918/07/15	00:23	6.5	41°	125°	West of Eureka	—	6½	6.5	5.9	—
1922/01/26	09:31	6.0	41°	126°	West of Eureka	—	6	(6.1)	—	—
1922/01/31	13:17	7.3	41°	125°30′	West of Eureka	—	7.3	7.4	—	—
1922/03/10	11:21	6.3	36° 0′	120°30′	Parkfield	—	6½	6.3	6.3	6.1
1923/01/22	09:04	7.2	40°30′	124°30′	Cape Mendocino	—	7.2	7.3	6.5, 6.8	—
1923/07/23	07:30	6.0	34° 0′	117°18′	San Bernadino region	—	6¼	—	6.0	6.0
1925/06/04	12:02	6	41°30′	125°	West of Eureka	—	6	(5.8)	—	—
1925/06/29	14:42	6.3	34°18′	119°48′	Santa Barbara	—	6¼	—	6.3	(6.9)
1926/10/22	12:35	6.1	36°37′	122°21′	Monterey Bay	—	6.1	—	6.1	—
1926/10/22	13:35	6.1	36°33′	122°11′	Monterey Bay	—	6.1	—	—	—
1926/12/10	08:38	6.0	40°45′	126°	West of Cape Mendocino	—	6.0	(6.2)	—	—

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TABLE 6.1.—*Major California and Nevada earthquakes, 1979–1989*—Continued

Date and origin time (GMT)		M	Lat N. and Long W.		Locality	M_L	M_{G-R}	M_S	M_I	M
1927/09/18	02:07	6	37°30′	118°45′	Bishop region	—	6	—	5.5	—
1927/11/04	13:50	7.3	34°42′	120°48′	Southwest of Lompoc	—	7.3, 7.5	(7.2)	6.2	(7.3)
1932/06/06	08:44	6.4	40°45′	124°30′	Eureka	—	6.4	(6.4)	5.9	—
1932/12/21	06:10	7.2	38°45′	118°	Cedar Mountain, Nev.	—	7.2	(7.4)	—	—
1933/01/05	06:51	5.9	38°46′	117°44′	Cedar Mountain, Nev.	5.7	5.9	—	—	—
1933/03/11	01:54	6.3	33°37′	117°58′	Long Beach	6.3	6¼	(6.5)	6.2	6.2
1933/06/25	20:45	6.1	39° 4′	119°20′	Yerington, Nev.	—	6.1	—	—	—
1934/01/30	20:16	6.3	38°18′	118°24′	Excelsior Mountain, Nev.	—	6.3, 6.3	(6.4)	—	—
1934/06/08	04:47	6.0	36° 0′	120°30′	Parkfield	5.2, 6.0, 6.1	6.0	—	5.6	6.1
1934/07/06	22:48	6.5	41°15′	125°45′	West of Eureka	—	6.5	—	—	—
1934/12/30	13:52	6.5	32°15′	115°30′	Laguna Salada, B.C.	6.5	6.5	—	—	(6.4)
1934/12/31	18:45	7.0	32°	114°45′	Colorado River delta	7.1	7.0	—	—	(7.1)
1935/02/24	01:45	5.3	31°59′	115°12′	Colorado River delta	6.0	5¼	—	—	(≤5.3)
1936/06/03	09:15	5.9	40°	125°30′	West of Cape Mendocino	—	5.9	—	—	—
1937/03/25	16:49	6.0	33°28′	116°25′	Buck Ridge	6.0, 5.9	6.0	—	5.9	—
1940/02/08	08:05	6	39°45′	121°15′	Chico	5.7	6	—	—	—
1940/05/19	04:36	7.1	32°44′	115°30′	Imperial Valley	6.2	6.7, 7.1	7.2	6.4, 6.6	6.9, 7.1
1940/12/07	22:16	5½	31°40′	115° 5′	Colorado River delta	6.0	5¾	—	—	(≤5.3)
1941/02/09	09:44	6.6	40°42′	125°24′	West of Cape Mendocino	6.4	6.6	—	—	—
1941/04/09	17:08	5.3	31°	114°	Gulf of California	6.0	5¼	—	—	—
1941/05/13	16:01	6.0	40°18′	126°24′	West of Cape Mendocino	6.0	6	—	—	—
1941/07/01	07:50	5.9	34°22′	119°35′	Carpenteria	5.9	5.9	—	5.5, 6.0	(6.0)
1941/09/14	16:43	5.8	37°34′	118°44′	Tom's Place	5.8, 6.0	5.8	—	5.6	
1941/09/14	18:39	6.0	37°34′	118°44′	Tom's Place	6.0	6.0	—	5.6	(5.5)
1941/10/03	16:13	6.4	40°24′	124°48′	West of Cape Mendocino	6.4	6.4	—	—	—
1942/10/21	16:22	6.5	33° 3′	116° 5′	Fish Creek Mountains	6.5	6½	—	6.0, 6.3	6.6
1942/12/03	09:44	5.9	39°42′	119°18′	North of Wadsworth, Nev.	5.5	5.9	—	—	—
1945/05/19	15:07	6.2	40°24′	126°54′	West of Cape Mendocino	6.0	6.2	—	—	—
1945/09/28	22:24	6.0	41°54′	126°42′	West of Crescent City	6.0	6.0	—	—	—
1946/03/15	13:49	6.3	35°44′	118° 3′	Walker Pass	6.3	6¼	—	6.1	6.0
1947/04/10	15:58	6.4	34°59′	116°33′	Manix	6.2	6.4	—	6.3, 6.4	6.6
1948/12/04	23:43	6.5	33°56′	116°23′	Desert Hot Springs	6.5	6.5±	—	6.2, 6.5	6.0
1948/12/29	12:53	6.0	39°33′	120° 5′	Verdi, Nev.	6.0	6.0	—	5.7	—
1949/03/24	20:56	6.2	41°18′	126°	West of Eureka	5.9	6.2	—	—	—
1949/05/02	11:25	5.9	34° 1′	115°41′	Pinto Mountain	5.9	5.9	—	—	—
1951/10/08	04:10	6	40°15′	124°30′	West of Cape Mendocino	5.8	6	—	—	—
1951/12/26	00:46	5.9	32°48′	118°18′	San Clemente Island	5.9	5.9	—	—	—
1952/07/21	11:52	7.7	35° 0′	119° 1′	Kern County earthquake	7.2	7.7	7.8	7.0	7.5, 7.3
1952/07/21	12:05	6.4	35° 0′	119° 0′	Kern County	6.4	—	—	—	—
1952/07/23	00:38	6.1	35°22′	118°35′	Kern County	6.1	—	—	—	5.7
1952/07/29	07:03	6.1	35°23′	118°51′	Bakersfield	6.1	—	—	—	6.3
1952/11/22	07:46	6.0	35°44′	121°12′	Bryson	6.0	6±	—	—	—
1954/01/12	23:33	5.9	35° 0′	119° 1′	West of Wheeler Ridge	5.9	—	—	—	5.7
1954/03/19	09:54	6.2	33°17′	116°11′	Arroyo Salada	6.2, 6.2	—	—	6.2	6.4
1954/07/06	11:13	6.6	39°25′	118°32′	Rainbow Mountain, Nev.	6.8	6.6	6.3	—	6.2
1954/07/06	22:07	6.4	39°18′	118°30′	Rainbow Mountain, Nev.	6.0	6.4	—	—	6.1
1954/08/24	05:51	6.8	39°35′	118°27′	Stillwater, Nev.	6.8	6.8	6.9	—	6.6
1954/08/31	22:20	6.3	39°30′	118°30′	Stillwater, Nev.	5.8	6.3	—	—	5.8
1954/10/24	09:44	6.0	31°30′	116°	East of Santo Tomas, B.C.	6.0	—	—	—	6.0
1954/11/12	12:26	6.3	31°30′	116°	East of Santo Tomas, B.C.	6.3	—	—	—	6.3
1954/11/25	11:16	6.5	40°16′	125°38′	West of Cape Mendocino	6.1	6.5	7.2	—	—
1954/12/16	11:07	7.1	39°19′	118°12′	Fairview Peak, Nev.	7.2	7.1	—	—	7.2
1954/12/16	11:11	6.8	39°30′	118° 0′	Dixie Valley, Nev.	7.1	6.8	—	—	7.0
1954/12/21	19:56	6.6	40°56′	123°47′	East of Arcata	6.5	6.6	—	—	—
1956/02/09	14:32	6.8	31°45′	115°55′	San Miguel, B.C.	6.8	—	—	6.3	6.5

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TABLE 6.1.—*Major California and Nevada earthquakes, 1979–1989*—Continued

Date and origin time (GMT)		M	Lat N. and Long W.		Locality	M_L	M_{G-R}	M_S	M_I	M
1956/02/09	15:24	6.1	31°45′	115°55′	San Miguel, B.C.	6.1	—	—	—	6.0
1956/02/14	18:33	6.3	31°30′	115°30′	San Miguel, B.C.	6.3	—	—	—	6.2
1956/02/15	01:20	6.4	31°30′	115°30′	San Miguel, B.C.	6.4	—	—	—	6.2
1956/10/11	16:48	6.0	40°40′	125°46′	West of Cape Mendocino	6.0	—	—	—	—
1956/12/13	13:15	6.0	31°	115°	Western shore, Gulf of California	6.0	—	—	—	—
1959/03/23	07:10	6.3	39°36′	118° 1′	Dixie Valley, Nev.	6.3	—	—	—	—
1959/06/23	14:35	6.1	39° 5′	118°49′	Schurz, Nev.	6.1	—	—	—	—
1960/08/09	07:39	6.2	40°19′	127° 4′	West of Cape Mendocino	6.2	—	—	—	—
1966/06/28	04:26	6.0	36° 0′	120°30′	Parkfield	5.5, 5.6, 5.7	—	6.0	5.7	6.1
1966/08/07	17:36	6.3	31°48′	114°30′	Gulf of California	6.3	—	—	—	6.3
1966/09/12	16:41	6.0	39°25′	120° 9′	Truckee	6.0	—	—	—	5.9
1968/04/09	02:28	6.5	33°11′	116° 8′	Borrego Mountain	6.4, 6.3, 6.8	—	6.8	6.3	6.5
1968/06/26	01:42	5.4	40°14′	124°16′	Punta Gorda	5.9	—	5.4	—	—
1971/02/09	14:00	6.5	34°25′	118°24′	San Fernando	6.4, 5.8	—	6.5, 6.5	6.5	6.7
1973/02/21	14:45	5.2	34° 4′	119° 2′	Point Mugu	5.9, 5.6	—	5.2	—	5.3
1979/08/06	17:05	5.7	37° 7′	121°31′	Coyote Lake	5.8	—	5.7	5.6	5.7
1979/10/15	23:16	6.5	32°36′	115°18′	Imperial Valley	6.6, 6.5, 6.4	—	6.9, 6.7	6.0	6.4 to 6.6
1980/01/24	19:00	5.8	37°50′	121°47′	Livermore	5.8	—	5.9	—	5.8
1980/05/25	16:33	6.1	37°36′	118°50′	Mammoth Lakes	6.1, 6.4, 6.2	—	6.1	—	6.2
1980/05/25	16:49	5.9	37°39′	118°54′	Mammoth Lakes	6.0,5.9	—	—	—	—
1980/05/25	19:44	5.8	37°33′	118°49′	Mammoth Lakes	6.1, 6.6, 6.4	—	5.8	—	5.9
1980/05/27	14:50	6.0	37°29′	118°48′	Mammoth Lakes	6.2, 6.4, 5.8	—	6.0	—	5.9
1980/06/09	03:28	6.4	32°12′	115° 5′	Victoria, B.C.	6.1, 6.1	—	6.4	—	6.4
1980/11/08	10:27	7.2	41° 7′	124°40′	West of Eureka	6.9	—	7.2	—	7.4
1981/04/26	12:09	6.0	33° 8′	115°39′	Westmorland	5.6	—	6.0	—	5.9
1981/09/04	15:50	5.9	33°40′	119° 7′	North of Santa Barbara Island	5.3	—	5.9	—	5.9
1981/09/30	11:53	5.8	37°35′	118°52′	Mammoth Lakes	5.9, 6.0, 5.9	—	5.8	—	5.7
1983/05/02	23:42	6.5	36°14′	120°19′	Coalinga	6.7, 6.1, 6.1	—	6.5	—	6.4, 6.5
1983/07/22	02:39	5.7	36°14′	120°25′	Coalinga	6.0, 5.6	—	5.7	—	5.7, 6.0
1984/04/24	21:15	6.1	37°19′	121°39′	Morgan Hill	6.2	—	6.1	—	6.2, 6.5
1984/09/10	03:14	6.7	40°23′	127° 9′	Mendocino Fracture Zone	6.6	—	6.7	—	6.7
1984/11/23	18:08	5.7	37°27′	118°36′	Round Valley	6.1, 6.2	—	5.7	—	5.8
1985/08/04	12:01	5.9	36° 8′	120°10′	North Kettleman Hills	5.6	—	5.9	—	6.1, 6.1
1986/07/08	09:20	6.0	34° 0′	116°36′	North Palm Springs	5.9	—	6.0	—	6.2
1986/07/20	14:29	5.6	37°34′	118°26′	Chalfant Valley	5.9, 5.9	—	5.6	—	5.8
1986/07/21	14:42	6.2	37°32′	118°26′	Chalfant Valley	6.5, 6.0	—	6.2	—	6.3, 6.4
1986/07/31	07:22	5.2	37°28′	118°22′	Chalfant Valley	5.8, 5.9	—	5.2	—	5.5
1987/10/01	14:42	5.8	34° 3′	118° 5′	Whittier Narrows	5.9	—	5.8	—	6.1
1987/11/24	01:53	6.2	33° 4′	115°47′	Elmore Ranch fault	5.8	—	6.2	—	5.9
1987/11/24	13:16	6.6	33° 1′	115°51′	Superstition Hills	6.0	—	6.6	—	6.5
1989/10/18	00:04	7.1	37° 2′	121°53′	Loma Prieta	7.0	—	7.1	—	7.0

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earthquakes have been documented, some on the same fault strand, and the entire zone of plate-boundary deformation is exceptionally broad. Major changes in fault strike also play a role in redistributing plate-boundary deformation and diffusing it over a wider zone. Compressional bends introduce uplift, crustal thickening, and subsidiary reverse faulting, such as in the Transverse Ranges of southern California. Extensional bends are characterized by subsidence, basin filling, and, possibly, volcanism, as occurs in the Imperial Valley. Extensional and compressional features are more localized at the smaller-scale discontinuities and changes in fault strike that occur throughout the San Andreas system.

Crustal movements observed at the surface reflect deformation processes occurring at depth in the lithosphere. Both laboratory rock-mechanics experiments and studies of exhumed fault zones define the nature of these processes, which, in turn, constrain the classes of large-scale faulting models consistent with surface measurements. In the cool and brittle seismically active parts of the crust, elastic processes are dominant, the frictional strength of active faults increases linearly with depth, and faulting is controlled by Coulomb failure. The transition from brittle seismic behavior to ductile aseismic deformation occurs in the midcrust. Although it is generally agreed that this transition occurs as a result of increasing temperature, its precise mechanism is uncertain. If deformation in the midcrust is concentrated within a narrow vertical shear zone lying beneath the seismically active fault plane, then the brittle/ductile transition may reflect either the increasing importance of ductile or cataclastic flow at depth (Sibson, 1982) or a thermally controlled transition from unstable to stable frictional sliding (Brace and Byerlee, 1966; Tse and Rice, 1986). However, if ductile deformation is broadly distributed in the midcrust, then the cyclic buildup and relief of stresses in the brittle seismogenic crust is controlled by the stress transfer between the elastic lithosphere and ductile "asthenosphere" and the flow properties of the latter.

Both the steady, aseismic movements within the San Andreas plate-boundary zone and the coseismic strain release in large earthquakes are well within the range of detectability of repeated geodetic-survey measurements. The purpose of this chapter is to summarize the salient features of these observations, demonstrating the constraints they place on the amount of present-day plate motion occurring across the San Andreas plate-boundary zone and showing how measurements shed light on the mechanics of the cycle of strain accumulation and release. The emphasis is necessarily on movements close to the main strands of the San Andreas fault system, where observations are most numerous, although some networks extend as far as 100 km from the major faults. The measurements include triangulation, repeated observations of the angular separation of permanent survey markers, for which useful data date back to about 1850, when gold was first discovered in California; trilateration, repeated line-length measurements made by laser ranging since about 1970; and local measurements of aseismic fault slip made periodically or recorded continuously over apertures of about 10 to 100 m since about 1960.

OBSERVATIONS OF CRUSTAL DEFORMATION

The focus here is on the spatial and temporal patterns of interearthquake horizontal crustal movements in California that owe their origins to relative motion between the Pacific and North American plates, movements that supply the strain energy which is stored in crustal rocks and ultimately released in large shallow-focus earthquakes. Observations of purely coseismic crustal deformation are not explicitly considered in this chapter; such movements are now well-understood consequences of slip on approximately the upper 10 to 15 km of vertical strike-slip faults. These models and their predicted deformation patterns are discussed within the context of the entire earthquake deformation cycle in the next section. Readers interested in the coseismic movements observed for specific San Andreas earthquakes are referred to the reports by Lawson (1908) and Thatcher (1975) (1906 San Francisco earthquake), Zhang and others (1988) (1940 El Centro earthquake), and Segall and Harris (1987) (1966 Parkfield earthquake).

Vertical crustal movements can locally be substantial, at least when averaged over recent geologic time (see Yeats, 1977; Lajoie, 1986). Deformation from reverse-faulting earthquakes has also been well documented in several events (for example, 1952 Kern County earthquake by Stein and Thatcher, 1981; 1971 San Fernando earthquake by Castle and others, 1975; 1983 Coalinga earthquake by Stein, 1983). Nonetheless, vertical movements are second-order features along most of the San Andreas fault system, and so they are not considered further in this chapter.

Furthermore, in this chapter there is no review of measurement techniques, methods of analyzing and reducing data, or the mathematical and computational tools used in modeling deformation processes. Interested readers are referred to the reports by Bomford (1980) and Savage and Prescott (1973) for descriptions of horizontal-deformation-surveying methods and their precision, to those by Prescott (1976, 1981), Thatcher (1979), and Segall and Harris (1987) for discussions of data-analysis methods, and to the references cited below in the section entitled "Mechanics of Deformation" for details of the mathematical techniques used in model formulation.

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Contemporary crustal movements in California are concentrated within a plate-boundary deformation zone that is typically 50 to 200 km wide, centered approximately on the San Andreas fault. Observations of coseismic, postseismic, and interseismic movements define the earthquake deformation cycle and constrain models of strain accumulation and release for strike-slip plate boundaries.

7. PRESENT-DAY CRUSTAL MOVEMENTS AND THE MECHANICS OF CYCLIC DEFORMATION

By WAYNE THATCHER

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INTRODUCTION

Crustal movements measured in California today sample deformation processes that have continued through at least the past 5 Ma of Pliocene, Pleistocene, and Holocene time. During this interval, several hundred kilometers of right-lateral offset has accumulated across the San Andreas fault system, and many thousands of great earthquakes similar to the historical events of 1857 and 1906 have undoubtedly occurred. The observed deformation results from relative right-lateral translation of the Pacific and North American plates far from the main plate-boundary faults, which are either freely slipping and without major seismic activity, or are in locked frictional contact and slip episodically in repeated great earthquakes. Aseismic fault slip (creep), as occurs across the San Andreas fault in central California (fig. 7.1), causes no crustal deformation beyond a growing offset across the fault, although this offset may be distributed across a zone as broad as a few tens or hundreds of meters. Where the plate-boundary fault is alternately locked aseismically in its upper 10 km or so and abruptly slipping in great earthquakes, deformation extends several tens of kilometers into the plate interiors. Between large events, elastic strains build up in this zone and are episodically released every few hundred years. Subsequent postearthquake recovery processes redistribute the strains aseismically for years to decades after a major shock, and this deformation gradually merges into the steady accumulation of elastic-strain energy that persists until the frictional strength of the fault is again exceeded. This sequence of interearthquake strain accumulation, coseismic strain release, and postseismic readjustment is thus a recurring process, here referred to inclusively as the earthquake deformation cycle.

Several fault-zone features result in measurable deformation spread over an extremely broad plate-boundary zone. This deformation occurs where the San Andreas fault system comprises several subparallel splays, as in both the San Francisco Bay region and southern California. There, both aseismic slip and major strike-slip

◀ FIGURE 7.1.—A wall and sidewalk in Hollister, Calif., are bent and offset by creep on the Calaveras fault. A slip rate of 5 to 6 mm/yr characterizes much of the Calaveras fault. View eastward along north side of Sixth Street. Photograph by R.E. Wallace, U.S. Geological Survey.

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Horizontal interearthquake deformation is summarized below in rates of both displacement and shear strain. For both of these parameters, the components parallel to major active faults are the most significant and best illustrate the dominant pattern of present-day tectonic movements, and so in this chapter these components are commonly shown exclusively. For example, although three independent tensor components are needed to completely characterize the horizontal-deformation field, in California the only significantly nonzero strain-rate component is commonly the shear strain parallel to the local trend of faults in the San Andreas system. Here, I consider only the component of maximum horizontal shear-strain rate, which, within observational uncertainty, almost invariably parallels the San Andreas fault or one of its major strands.

SHEAR STRAIN ON THE SAN ANDREAS FAULT SYSTEM

Rates of contemporary shear strain are displayed in several complementary ways in figures 7.2 through 7.4; details of each rate determination are summarized in table 7.1. Although only the magnitude of the maximum shear-strain rate is shown in each figure, the orientation of the maximum-horizontal-contraction axis is listed in table 7.1. Note that for each of the strain rates shown in figures 7.2 through 7.4, aseismic fault slip contributes only negligibly, if at all, to the measured deformation. Further details on each strain field determination can be found in the references cited in table 7.1.

Shear-strain rates peak at 0.4 to 0.6 μrad/yr (fig. 7.2) across the currently locked northern and southern sections of the San Andreas fault. Significant but slightly lower strain rates of 0.3 to 0.4 μrad/yr are observed across right-lateral strike-slip faults in the northern California Coast Ranges (north of lat 38° N.) east of the San Andreas fault, as well as across the San Jacinto fault in southern California. Shear-strain rates resolvably greater than zero are observed as far as about 80 km from the San Andreas fault itself.

In addition, significant deformation is occurring across active faults in east-central California. In the White Mountains, along the southern California-Nevada State line, small but resolvable strain rates (0.06±0.02 μrad/yr) have been measured, and the orientation of the strain field indicates crustal extension perpendicular to north-south-striking normal faults in the area. Somewhat higher deformation rates are observed farther south, where right-lateral strain is occurring parallel to the Owens Valley fault, site of the $M \simeq 8$ earthquake of 1872 (see chap. 6).

Shear-strain rate is plotted as a function of perpendicular distance from the San Andreas fault in figure 7.3. Deformation rates peak at the fault and decrease to half their maximums at a distance of about 30 km from the fault. Most of the deformation is encompassed within a zone about 100 km wide centered on the fault ("San Andreas boundary deformation zone"), as discussed below. However, the reader may confirm that this total lies in the range of about 30–40 mm/yr by drawing a smooth curve through the data plotted in figure 7.3 and integrating this curve (that is, measuring and summing the total area underneath the curve) from –60 to +60 km.

Maximum shear-strain rates at the San Andreas fault tend to be higher across the 1906 earthquake rupture in northern California (approx 0.6 μrad/yr) than in southern California (0.4 μrad/yr), although the Carrizo Plain data violate this generalization. Rather high deformation rates are also observed 20 to 60 km east of the San Andreas fault in the northern California Coast Ranges.

Shear-strain rates at various locations on the two currently locked sections of the San Andreas fault are plotted versus time since the most recent great earthquake at each locality in figure 7.4. Most of these data are derived from triangulation measurements, many of which were first made in the late 19th or early 20th century. Thus, these determinations are much less precise than those listed in table 7.1 and plotted in figures 7.2 and 7.3, most of which are from the post-1970 period. Nonetheless, it is clear from figure 7.4 that deformation rates on the fault are much higher in the years to tens of years immediately after a great earthquake than they are later. Although it may be questionable to lump values from northern and southern California together on a single plot, the temporal decline in shear-strain rate shown in figure 7.4 depends only on about the first 70 years of data plotted, all of which come from the 1906 rupture on the northern section of the San Andreas fault.

ASEISMIC SLIP, INTEGRATED DISPLACEMENT RATES, AND PACIFIC-NORTH AMERICAN PLATE MOTION

Rates of surface aseismic slip (fault creep) at representative points on the San Andreas fault system are listed in table 7.2 and plotted in figure 7.5. All fault segments displaying measurable aseismic slip are represented, but the detailed distribution along each segment is not shown; interested readers are referred to the references cited in table 7.2 for more details. Figure 7.5 also displays the rates of relative right-lateral displacement integrated across geodetic networks of 50- to 140-km aperture that span the San Andreas and related faults in seven areas of California, for several of which the detailed displacement-rate pattern is shown in figures 7.6 and 7.7.

With the notable exception of the central, creeping section of the San Andreas fault, aseismic slip at the surface represents only a very small proportion of the

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total right-lateral displacement across the San Andreas fault system. On the 160-km-long central section of the San Andreas fault, maximum fault-creep rates average 30 mm/yr, close to the geodetically derived displacement rate of 33±1 mm/yr obtained over a 60-km aperture that spans the fault and the California Coast Ranges to the southwest. These data are the strongest evidence that no significant strain is accumulating in the crustal blocks adjacent to the fault in this region, and so all the relative plate motion taken up by the San Andreas system is here being accommodated by rigid-block translation across the fault. Just north of this segment, on the southern section of the Calaveras fault, a significant amount of right-lateral slip at a rate of about 13 mm/yr, occurs as fault creep. Elsewhere in California, however, measured aseismic-slip rates range from 2 to 6 mm/yr, and creep

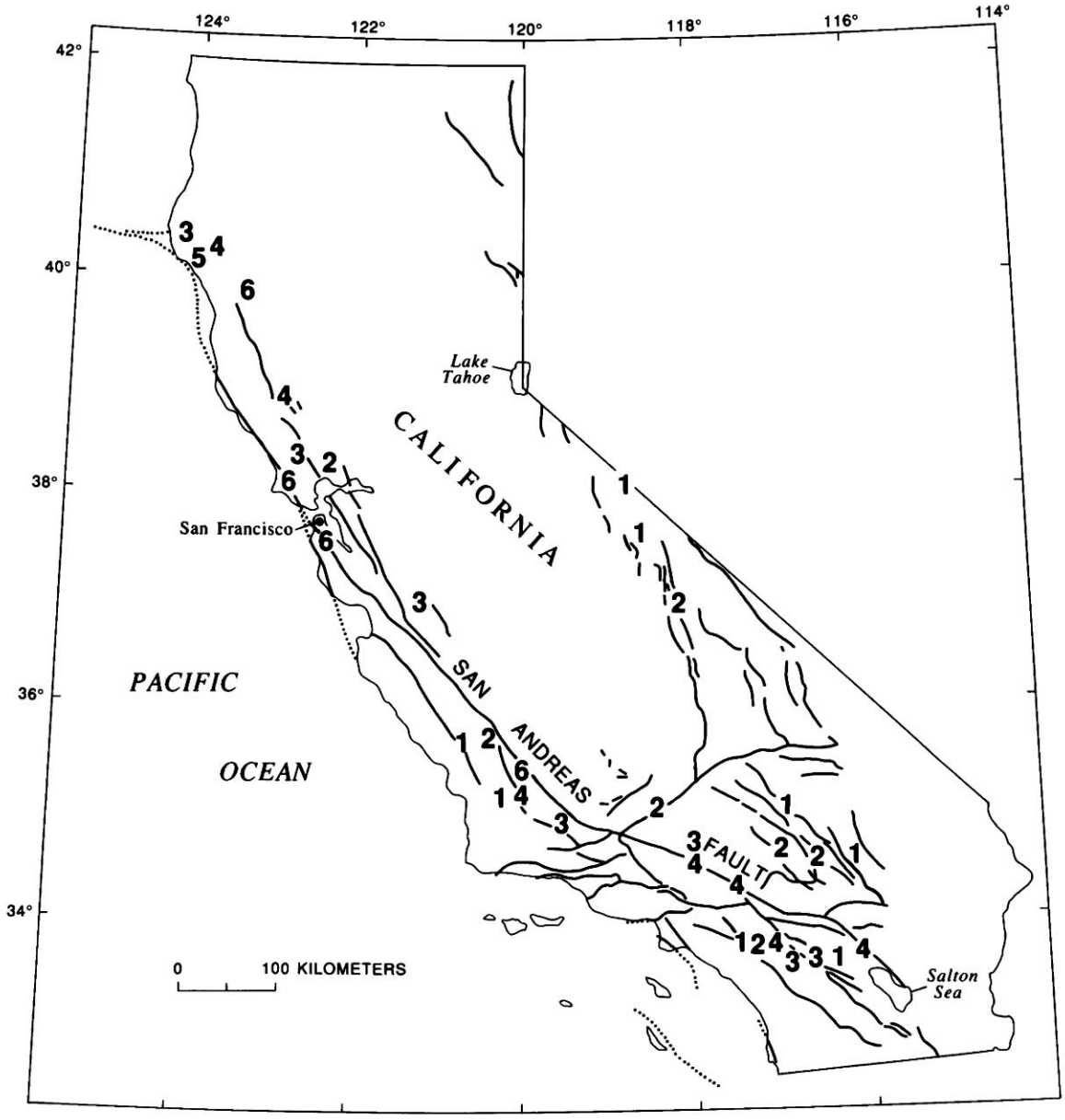

FIGURE 7.2.—Shear-strain rates (in 10^{-7} rad/yr) and major active Quaternary faults of California; faults dotted where concealed. See table 7.1 for details.

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commonly occurs only on restricted segments of otherwise-locked faults (for example, the Garlock and San Jacinto faults).

The integrated right-lateral displacement rates shown in figure 7.5 firmly constrain the proportion of Pacific-North American relative plate motion accommodated across the San Andreas fault system in California. In northern, central, and southern California, maximum rates range from 33 to 37 mm/yr. Global reconstructions of the motions of the major tectonic plates over the past 3 Ma, as well as analyses of magnetic-anomaly lineations at the mouth of the Gulf of California, point to a relative Pacific-North American plate-motion rate of 49±3 mm/yr (DeMets and others, 1987). The San Andreas fault system thus accounts for 70 to 80 percent of the relative plate motion, although the San Andreas fault itself does not everywhere take up all of this motion, and deformation is typically distributed across a boundary zone about 100 km wide.

Precisely how much additional relative plate motion is accommodated across other faults in California is uncertain, although the amount is probably very little. According to Minster and Jordan (1987), very long baseline interferometric (VLBI) surveying results indicate that oblique extension of the Basin and Range province, directly east of California, is occurring at a rate of 10±2 mm/yr with an orientation of N. 56° ±10° W. Depending on the exact rate and orientation of this extension, as well as on the precise direction of relative Pacific-North American plate motion, the residual "missing" plate motion being accommodated in California on faults other than those of the San Andreas system ranges from negligibly small to possibly as much as 10 mm/yr. Thus, although the geodetic coverage in California is far from complete (see figs. 7.2, 7.5), all or most of the zone of significant plate-boundary deformation apparently has been encompassed.

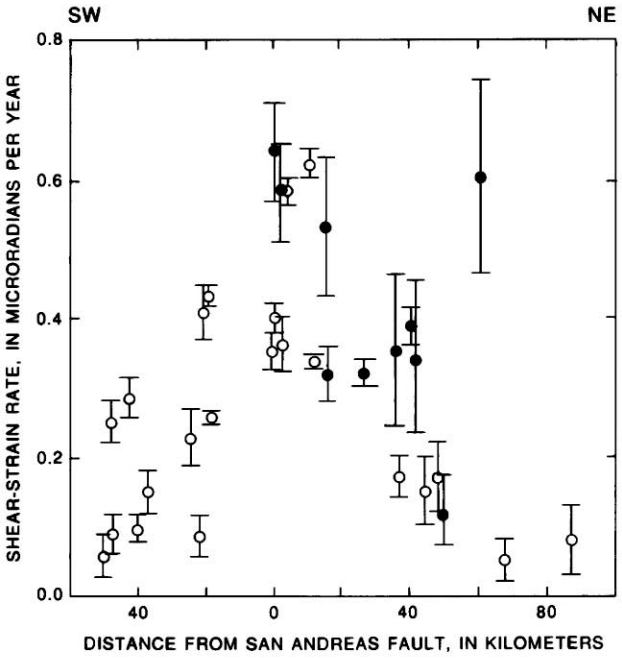

FIGURE 7.3.—Shear-strain rate versus perpendicular distance from the San Andreas fault. Dot, determination from northern California; circle, determination from southern California. 1-σ error bars shown for reference.

DETAILED DISPLACEMENT-RATE PATTERNS

Considerable detail on the distribution of deformation in the San Andreas boundary zone is provided by the rather complete geodetic coverage available in the San Francisco Bay region and southern California. In the method used to reduce these data, geodetic-line-length changes are used to determine station-displacement rates relative to a point at the center of gravity of the network. Fault-normal displacements are permitted by this method, but their values are minimized in the inversion

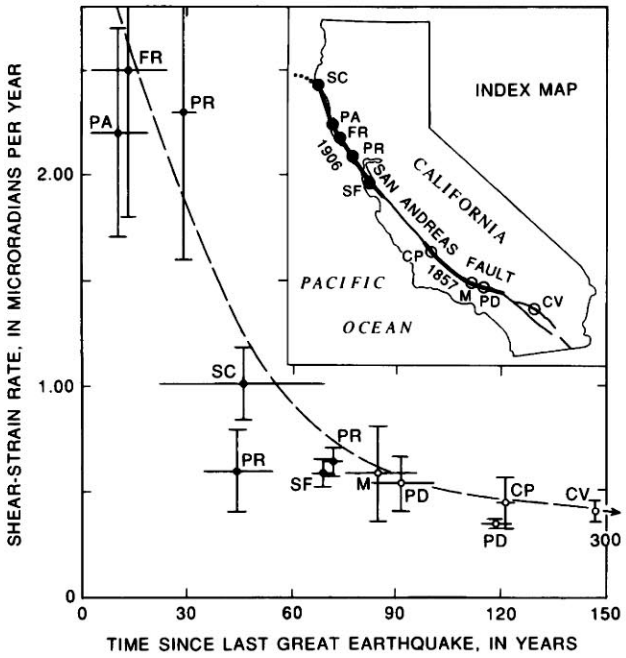

FIGURE 7.4.—Shear-strain rate versus time since last great earthquake (years 1906 and 1857 in inset; heavy line indicates extent of fault rupture) on the San Andreas fault. CP, Carrizo Plain; CV, Coachella Valley; FR, Fort Ross; M, Mojave; PA, Point Arena; PD, Palmdale; PR, Point Reyes; SC, Shelter Cove; SF, San Francisco. Locations of data points are keyed to index map. For each data point, vertical bar is 1 σ, and horizontal line indicates time interval between surveys. Data points are plotted at middle of intervals. Dots, determinations from northern California; circles, determinations from southern California; dashed curve, approximate fit to data (Thatcher, 1983).

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TABLE 7.1.—*Shear-strain rates in California*

[Maximum compression measured from north, with clockwise direction positive]

Area	Location		Rate (ppm/yr)	Maximum compression direction* (°)	Interval	Reference
	Lat N.	Long W.				
Mendocino	40.1°	124.0°	0.53±0.10	3±4	1981–84	Breen and others (1987).
	40.1°	123.7°	.35±0.11	11±6	--	
	40.2°	124.1°	.34±0.11	21±9		
Round Valley	39.9°	123.3°	.60±0.14	-11±5	1942–64	Prescott (1985).
Point Reyes	38.1°	122.8°	.64±0.07	2±2	1972–82	Prescott and Yu (1986).
Santa Rosa (Rodgers Creek fault).	38.4°	122.8°	.32±0.02	12±2	--	--
The Geysers (Maacama fault).	38.8°	122.9°	.39±0.03	11±3	--	--
Napa (West Napa fault)	38.3°	122.3°	.17±0.05	20±9	--	--
San Francisco peninsula	38.5°	122.4°	.58±0.07	-2±9	1970–80	Prescott and others (1981).
White Mountains	37.9°	118.6°	.06±0.02	-13±12	1972–79	Savage and Lisowski (1984).
	37.5°	118.5°	.06±0.02	-8±14		
Owens Valley	36.9°	118.1°	.16±0.06	28±12	1974–79	Savage and Lisowski (1980).
Hollister (E. of Calaveras fault).	36.9°	121.3°	.32±0.04	-16±3	1971–78	Savage and others (1979).
San Luis network:						
Central	35.5°	120.4°	.23±0.04	-23±3	1977–83	N.E. King (unpub. data, 1988).
West	35.4°	120.7°	.09±0.03	-18±10	--	--
Carrizo network:						
A	35.4°	119.8°	.62±0.02	--	1977–83	N.E. King (unpub. data, 1983).
B	35.3°	119.8°	.58±0.02	--	--	--
C	35.1°	119.9°	.43±0.02	--	--	--
D	35.1°	120.2°	.10±0.02	--	--	--
Tehachapi network:						
Garlock fault	34.9°	118.5°	.17±.03	4±3	1973–83	King and Savage (1984).
San Andreas fault	34.6°	118.0°	.34±.01	-17±1	--	--
Cajon network	34.3°	117.5°	.36±.04	-16±2	1974–84	Savage and others (1986).
Los Padres network	34.8°	119.5°	.26±.01	-1±1	--	
Barstow	35.0°	116.9°	.08±.05	24±17	1979–84	King (1985).
Palmdale	34.4°	118.2°	.35±.03	-19±4	1971–80	Savage and others (1981).
Mojave network:						
W1	34.6°	117.0°	.17±.05	4±11	1934–82	Sauber and others (1986).
W3	34.4°	116.6°	.15±.05	5±8	--	--
Eastern	34.5°	116.1°	.05±.03	--	--	--
Anza network:						
A	33.8°	117.4°	.06±.03	--	1973-81	King and Savage (1983).
B	33.8°	117.1°	.15±.03	30±13	--	--
C	33.8°	117.0°	.41±.04	21±5	--	--
D	33.5°	116.8°	.25±.03	30±8	--	--
E	33.5°	116.7°	.29±.03	1±5	--	--
F	33.6°	116.4°	.09±.03	--	--	--
G	33.7°	116.1°	.40±.02	8±2	--	--

process (see Prescott, 1981). Gross departures from this constraint would be revealed by notable disagreements between observed and predicted line-length changes, but no such discrepancies were found for the results presented here. Because the fault-normal displacement rates are small and show no consistent trends, they are not plotted on the profiles presented here.

Displacement rates in the San Francisco Bay region are plotted in figure 7.6. The distribution of deformation varies considerably across the San Andreas boundary zone from north to south of the San Francisco Bay. In the north bay, the integrated right-lateral-displacement rate across the network of 27±3 mm/yr (fig. 7.6*B*) indicates that not all of the boundary zone has been captured within its 110-km aperture. Within about 5 km of the San Andreas fault, rapid change in the gradient of deformation rate indicates that interearthquake strain is concentrated close to the fault. Outside this near-fault region, deformation southwest of the fault appears to be negligible. Northeast of the fault, however, the persistence of significant movements right to the edge of the profile suggests that the 5- to 10-mm/yr deficit in boundary-zone deformation across this profile is being accommodated to the east of the Green Valley fault. Across the central and south bay (fig. 7.6*C*), movements are more evenly distributed through the network, and the integrated

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TABLE 7.2.—*Representative aseismic-slip rates on faults of the San Andreas system*

Fault	Site	Lat N.	Long W.	Rate (mm/yr)	Reference
Hayward	Hayward network	37.6°	122.1°	6	Prescott and Lisowski (1983).
Northern section of the Calaveras.	Camp Parks	37.7°	121.9°	3	Do.
Southern section of the Calaveras.	San Felipe	37.0°	121.5°	13	Lisowski and Prescott (1981).
San Andreas	Cienega Winery	36.7°	121.5°	13	Schulz and others (1982).
Do	Eade Ranch	36.4°	121.0°	30	Buford and Harsh (1980).
Do	Parkfield (Durham Ranch)	35.9°	120.4°	13	Do.
Garlock	Cameron	35.1°	118.3°	4	Louie and others (1985).
San Andreas	Indio Hills	33.7°	116.2°	2	Do.
San Jacinto (Coyote Creek strand).	Bailey's Well	33.0°	116.0°	5	Do.
Imperial	Interstate Highway 80	32.8°	115.5°	5	Do.

displacement rate of 37±3 mm/yr across the south bay suggests that the entire boundary zone has been spanned. Closer examination of the profile, however, reveals several zones of locally high deformation gradient, one across the San Andreas fault, where it resembles that observed near the fault in the north bay. In addition, rapid changes in the profile across the Hayward and Calaveras faults reflect aseismic slip at rates of 3 to 6 mm/yr on these faults (see fig. 7.5).

In southern California (fig. 7.7), deformation across the San Andreas boundary zone notably broadens from the Salton Sea, in the south, northwestward to the Big Bend region of the San Andreas fault north of Los Angeles (see fig. 7.5). At the south end of the Salton Sea, all of the boundary-zone deformation, 35±1 mm/yr, occurs within an area about 50 km wide (profile S, fig. 7.7*C*) that rapidly broadens to more than 100 km wide north and west of the Salton Sea (profile N, fig. 7.7*C*) and, possibly, broader still by about 50 km farther northwest (fig. 7.7*B*). North and west of Los Angeles, networks of 100-km aperture capture only 18±2 mm/yr of the total right-lateral-displacement rate (fig. 7.5). The profiles in figures 7.7*B* and 7.7*C* also show that in contrast with the northern section of the San Andreas fault, deformation gradients across the fault are smoother, and deformation is not so closely concentrated near the fault.

MECHANICS OF DEFORMATION

The observations described in the previous section point to a range of mechanical behavior for the faults comprised by the San Andreas system, from freely sliding with only minor accompanying seismicity, to completely locked from the surface to seismogenic depths except for abrupt slip during infrequent great earthquakes.

On the 160-km-long central section of the San Andreas fault, virtually all fault slip occurs aseismically. Slip rates measured at or near the fault are close to the average rate for the entire San Andreas boundary zone (fig. 7.5), no strain is detectable in the crustal blocks adjacent to the fault, and historical earthquakes of $M \geq 5\frac{1}{2}$ have not occurred. Abundant minor seismicity (see fig. 4.10) contributes only negligibly to the slip budget, and except for a few small patches of fault surface that are in frictional contact between these small earthquakes, the first-order steady-state model for this segment involves rigid translation of adjacent fault blocks across the freely sliding plane of the San Andreas.

A transitional behavior applies to those fault segments where steady-state fault creep is observed at the surface but historical or prehistoric earthquakes of $M \geq 6$ have been documented. Examples include the Parkfield and Coachella Valley segments of the San Andreas fault, the Hayward fault, and the Imperial fault. On these segments, during the interseismic phase of the earthquake cycle, the fault is inferred to be freely slipping in its upper few kilometers, in locked frictional contact at seismogenic depths (approx 3–10 km), and once again freely slipping at greater depths (fig. 7.8*A*). The result of this slip distribution is interseismic creep at the surface fault trace and elastic-strain accumulation in the adjacent blocks (figs. 7.8*B*, 7.8*C*).

THICK- AND THIN-LITHOSPHERE MODELS

The most extreme features of locked fault behavior are currently observed on the two San Andreas fault segments where great earthquakes have occurred in historical time, in 1857 and 1906 (see fig. 5.11 for locations and coseismic-slip distributions). On these segments, no aseismic slip is observed at the Earth's surface, the two faces of the fault are in locked frictional contact to depths

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of 10 to 15 km, and interearthquake slip is either extremely small or absent. At greater depths, the mechanics of fault movement is uncertain, but two models bound the range of expected behavior (fig. 7.9). In the first, the thick-lithosphere model, the depth D of coseismic faulting is much less than the thickness H of elastically strong lithosphere. Interearthquake deformation then predominantly results from episodic or steady aseismic slip on the downward extension of the seismogenic fault zone, and any effects of the underlying weak asthenosphere can be safely neglected. In the second, the thin-lithosphere model (fig. 7.9), coseismic faulting depth is comparable to elastic-plate thickness. In this model, transient postseismic and steady interseismic flow in the

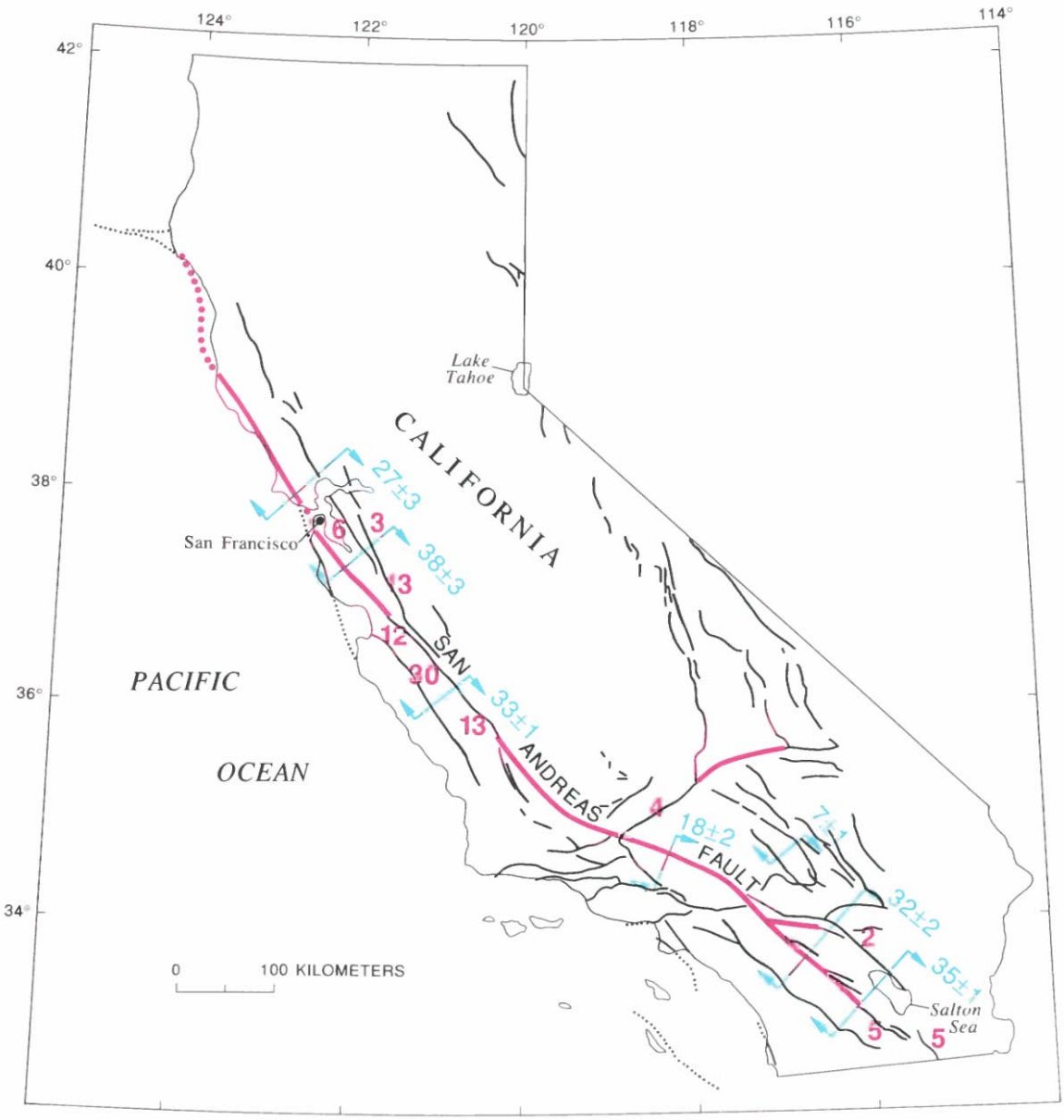

FIGURE 7.5.—Sketch map of California, showing rates (red numbers) of aseismic slip (fault creep) and relative right-lateral-displacement rates (blue numbers) near arrows, which indicate direction of relative movement along major active strands of the San Andreas fault system. Values in millimeters per year. Locked (no surface slip) segment of major fault, red line; other Quaternary fault, black line; faults dotted where concealed. See table 7.2 for details.

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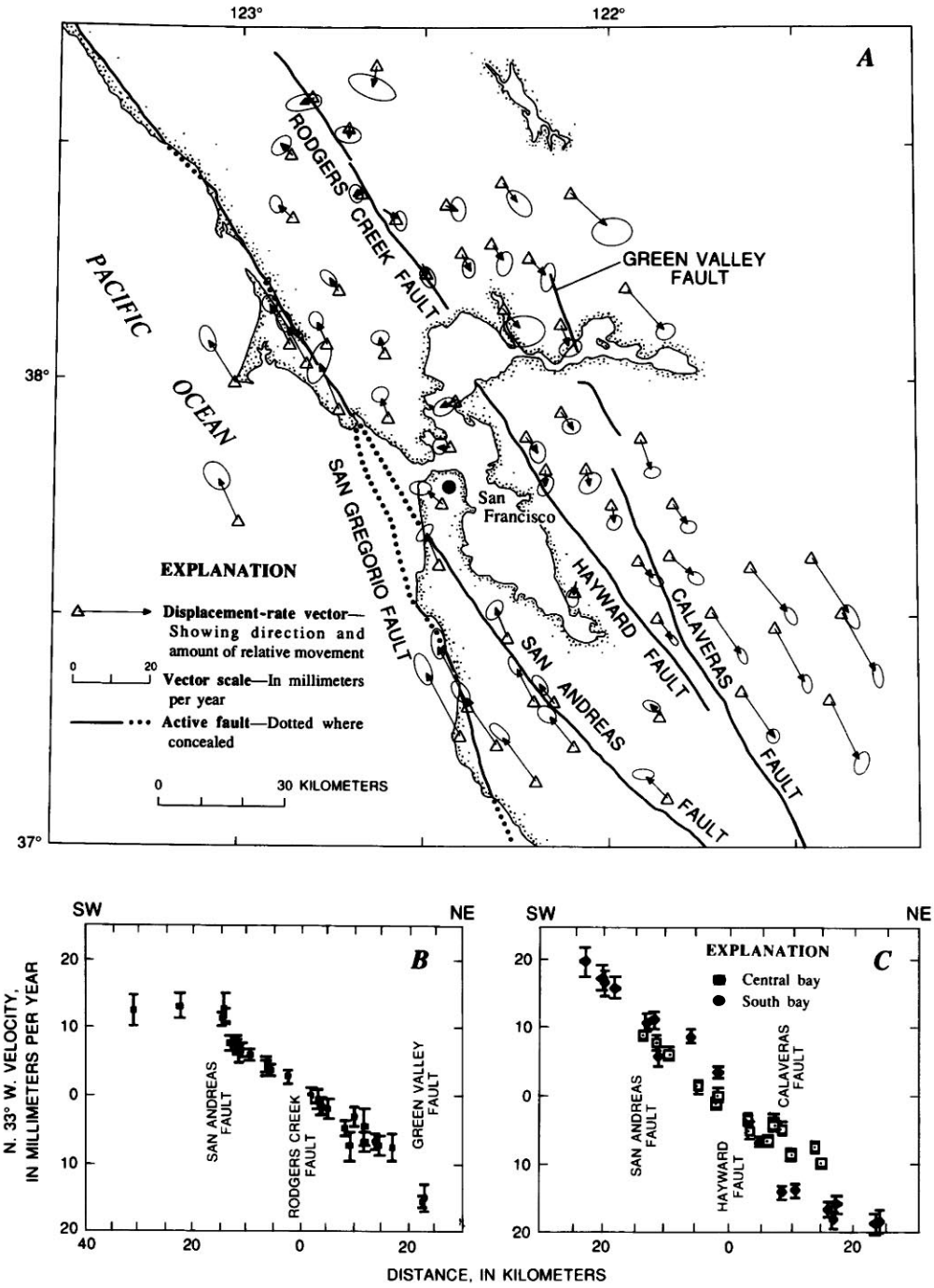

FIGURE 7.6.—Displacement rates across the San Francisco Bay region. *A*, Relative right-lateral displacement rates determined from repeated geodetic surveys made during 1971–87. Error ellipses show 95-percent-confidence limits for each determination (Prescott and others, 1987). *B*, Relative station velocities parallel to approximate trend of the San Andreas fault (N. 33° W.) plotted against distance perpendicular to this trend for north bay. 1-σ bars are indicated. Perpendicular velocity component is negligible and omitted here. *C*, Same as figure 7.6*B* for central and south bay.

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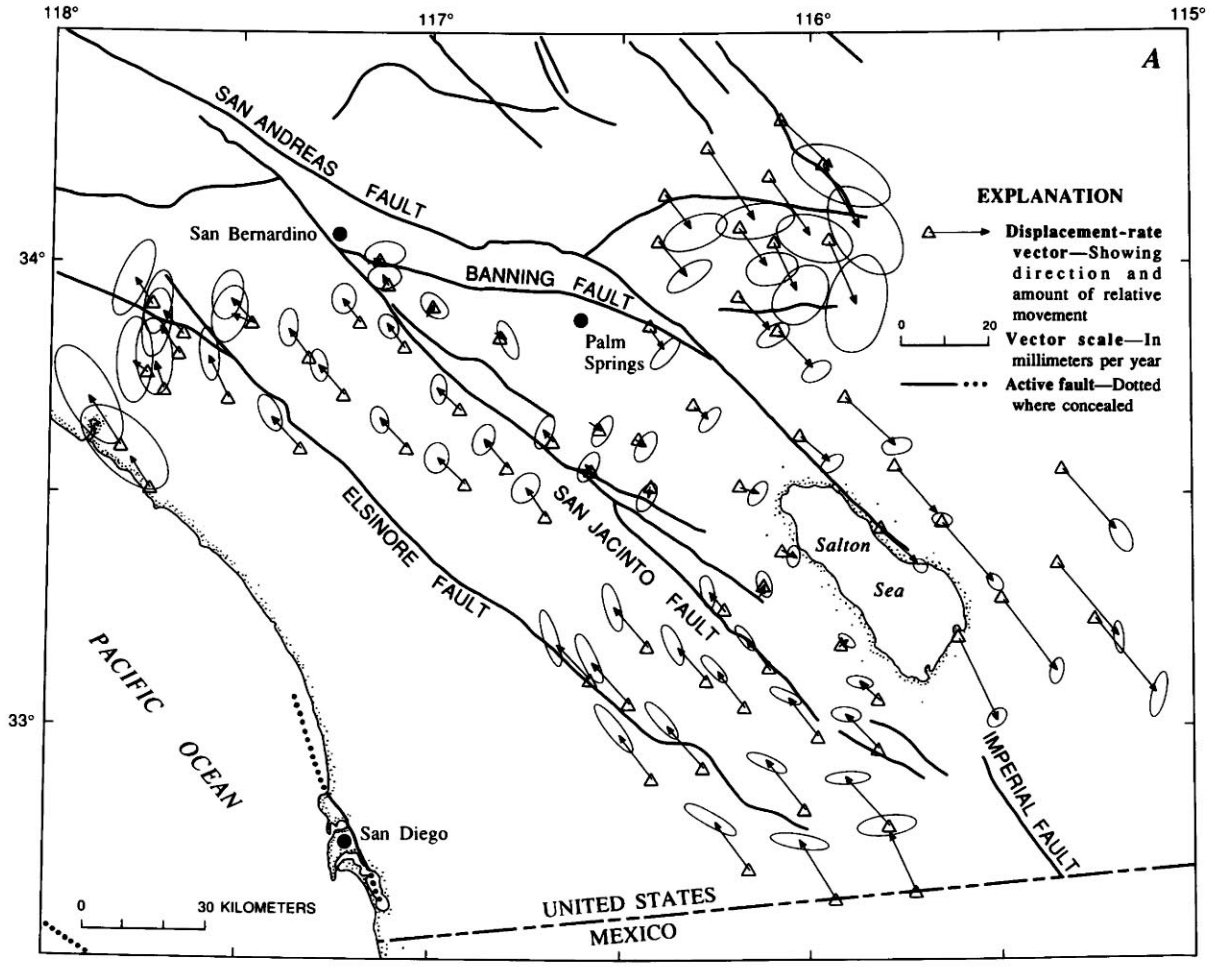

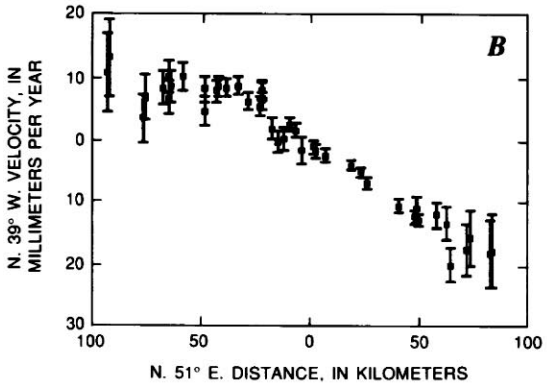

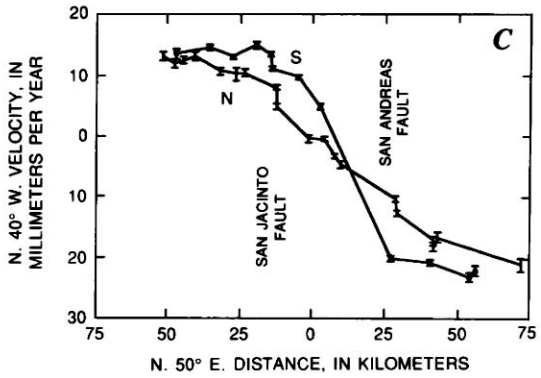

FIGURE 7.7.—Displacement rates in southern California. *A*, Relative right-lateral displacement rates determined from repeated geodetic-survey measurements during 1973–87. Error ellipses show 95-percent-confidence limits for each determination (Prescott and others, 1987). *B*, Relative station velocities parallel to approximate trend of the San Andreas fault (N. 39° W.) plotted against distance perpendicular to this trend, for stations in northern part of map in figure 7.7*A*. 1-σ error bars are indicated. Perpendicular velocity component is negligible and is not plotted here. *C*, Same as figure 7.7*B* for stations largely to north (N) and south (S) of the Salton Sea.

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asthenosphere provide the dominant mechanism for interearthquake strain accumulation.

Note that in the context of these two models, the terms "lithosphere" and "asthenosphere" are linked to mechanical properties of the Earth's crust and upper mantle: The lithosphere is the strong elastic layer near the Earth's surface, and the asthenosphere is the region of ductile flow that lies beneath. Their boundary may thus lie well above the thermal boundary layer that separates the moving plates from the convecting mantle. If so, then at least the upper part of the "asthenosphere" forms part of the tectonic plate and moves with it.

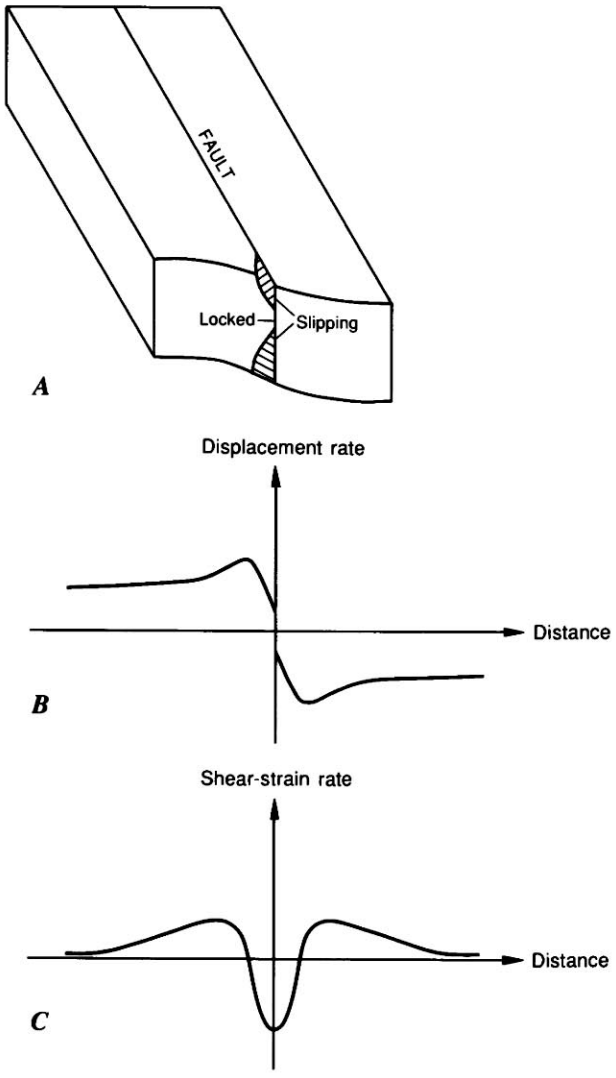

FIGURE 7.8.—Elastic-half-space model showing fault creep at surface, locked (nonslipping) fault at depth, and freely sliding zone at great depth (*A*). Displacement rate (*B*) and strain rate (*C*) are plotted against distance from fault.

Thus considered, the boundary between "lithosphere" and "asthenosphere" defines the zone of decoupling between surface tectonic processes and those that occur in the ductile region beneath. The location of this boundary is thus of central importance to the broad-scale tectonics of the San Andreas fault, the nature of the earthquake-generation process and its thermomechanical implications (see chap. 9), and the relation between shallow structural features and those inferred at depth (see chap. 8). I explore below the influence of this boundary location on cyclic earthquake-related deformation at the currently locked transform fault zones in the San Andreas, illustrating the contrasting mechanical behavior of the thick- and thin-lithosphere models.

All of the models considered here are two dimensional, and so neither slip nor mechanical properties vary along fault strike. Each model consists of only a single planar, vertical strike-slip fault. However, because the medium properties are linear elastic and (or) viscoelastic, the effects of multistranded fault zones can be obtained by simply superposing the deformation due to slip on individual fault segments. Furthermore, all of the two-dimensional models discussed here have also been considered in three dimensions, and so complexities arising from changes in fault strike, variations in slip along strike, and the finite extent of faulting can be incorporated straightforwardly as necessary. Similarly, except for the transition from elastic lithosphere to viscoelastic asthenosphere, depth variations in material properties are not considered, although, again, solutions have been obtained for faulting in plane-layered elastic

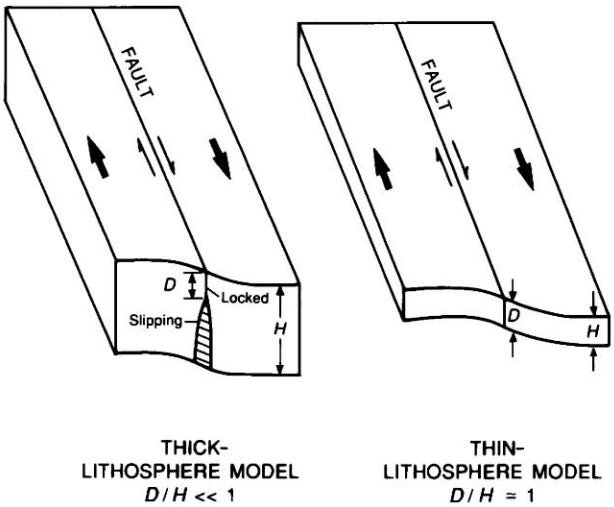

FIGURE 7.9.—Thick- and thin-lithosphere models. *D*, depth of coseismic faulting; *H*, thickness of elastically strong lithosphere. Small arrows along fault and larger arrows indicate direction of relative movement of fault and tectonic plates, respectively.

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and viscoelastic media. Although fault end effects and changes in slip and geometry along fault strike can be locally important, these effects, as well as those due to depth-varying material properties, are generally second order relative to the deformation features described here. More important are the effects of the several subparallel strands that compose much of the San Andreas fault system along its two currently locked sections. In these sections, the interseismic deformation due to each major fault strand contributes significantly to the observed displacement pattern, and as a rule the effects of faults lying off the San Andreas proper cannot be safely ignored in matching models to data across the entire San Andreas boundary zone.

The simplest form of the thick lithosphere model, first proposed by Savage and Burford (1970), is illustrated in figure 7.10. In this idealized model, interearthquake strains accumulate uniformly throughout the deformation cycle and have precisely the same spatial pattern as coseismic strains, except that the sense of movement is reversed. The cycle consists of coseismic slip Δu extending from the surface to depth D and steady interearthquake aseismic slip at a constant rate $\dot{u}$ ($=\Delta u/T$, where T is the earthquake recurrence interval) beginning at $z=D$ and extending to great depth. For this model of interearthquake deformation, simple expressions relate surface-displacement rates $\dot{u}_x(y)$ and shear-strain rates $\dot{e}_{xy}(y)$ to the fault parameters $\dot{u}$ and D and the distance y from the fault trace:

$$\frac{du_x(y)}{dt} = \dot{u}_x(y) = \frac{\dot{u}}{\pi}\tan^{-1}\left(\frac{y}{D}\right)$$

and

$$\dot{e}_{xy}(y) = \frac{d}{dy}\left[\dot{u}_x(y)\right] = \frac{\dot{u}}{\pi D}\left[\frac{1}{1+\left(\frac{y}{D}\right)^2}\right]$$

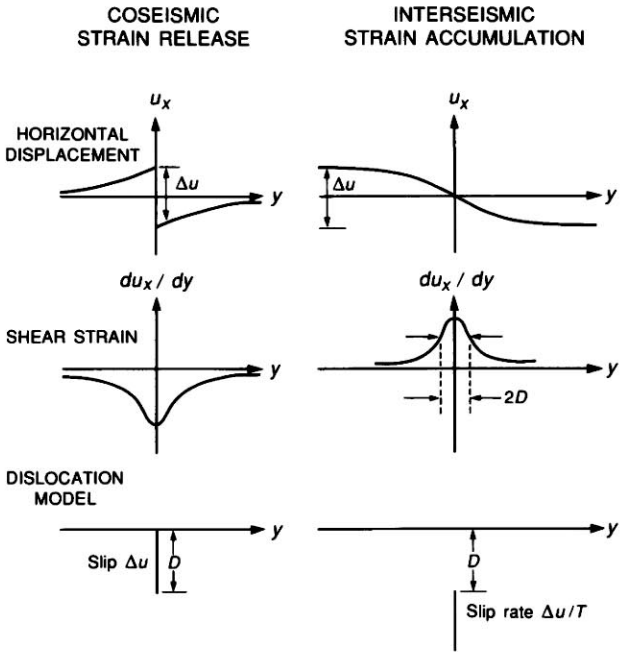

FIGURE 7.10.—Elastic-half-space model for earthquake cycle. Δu, coseismic slip; D, depth of coseismic slip; T, earthquake recurrence interval; u_x, horizontal displacement parallel to fault; du_x/dy, shear-strain component parallel to fault; y, distance from fault.

A principal utility of this model is the ease with which approximate values of displacement and strain rate can be computed, commonly as a preliminary step to more detailed computations that employ complex models which nonetheless show many of the same general features. For example, using typical San Andreas values of $\Delta u=4$ m, $T=200$ yr, and $D=15$ km, then $\dot{u}=20$ mm/yr, and the engineering shear-strain rate (twice the tensor strain rate $\dot{e}_{xy}$) at the fault trace ($y=0$) is about 0.8 μrad/yr, a value close to some of the peak strain rates plotted in figures 7.2 and 7.3. Furthermore, the bell-shaped distribution of secular strain across the model fault (middle right, fig. 7.10) generally accords with observations (fig. 7.3), and the width of the profile is a direct measure of the fault-locking depth D. (Note, however, that the observations summarized in figure 7.3 include strain rates determined from multistranded segments of the San Andreas fault system, and so they are not directly comparable to the model calculations for a single fault strand illustrated in fig. 7.10.) Recalling the observations discussed in the section above entitled "Observations of Crustal Deformation," the wider zone of secular strain across the southern section of the San Andreas can be rationalized if the depth of seismic slip and, thus, the locking depth of the fault are simply greater in southern than in northern California. As it stands, this model has no transient effects and so is too simple to explain the postearthquake strain changes plotted in figure 7.4. However, introducing a rather straightforward modification remedies this defect while accounting for the observed difference in strain-rate profiles between northern and southern California. Surprisingly, these same features are, for different reasons, natural consequences of the thin-lithosphere model.

The two models are illustrated in figure 7.11. In the thick-lithosphere model, postseismic effects are introduced by specifying transient postearthquake slip on a segment of the fault immediately beneath the coseismic rupture. Its time history is constrained by an exponentially decreasing slip rate (time constant α), and its magnitude by the requirement that the cumulative slip sum to the coseismic offset Δu by the end of the cycle. In the thin-lithosphere model, the transient deformation

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results from flow in the asthenosphere due to stress relaxation after seismic faulting in the lithosphere. Its time scale is controlled by the asthenosphere-relaxation time $\tau=2\eta/\mu$, when η is the effective viscosity of the asthenosphere and μ is the average shear modulus of lithosphere and asthenosphere, here taken to be equal. In both models, the transient motions are superimposed on a steady component of deformation that is due to relative plate motion.

Detailed computations show that the two models produce surface deformations that with suitable choices of model parameters are observationally indistinguishable (see Thatcher, 1983). Here, the discussion is restricted to qualitative features, as summarized in figure 7.12. Near the fault, shear-strain rates monotonically decrease over time and gradually approach a constant (fig. 7.12*B*), while the deformation profile broadens and strains diffuse into the interiors of the adjacent plates as the cycle progresses (fig. 7.12*A*). It is easy to match the observed temporal decline in strain rate with either model; the particular parameter combinations are themselves not unique, and a range of choices can provide equally good agreement. All satisfactory thin-lithosphere models, however, require an elastic plate only 10 to 15 km thick, the maximum depth of coseismic slip in the 1906 earthquake (Thatcher, 1975). Both models predict a broadening of the zone of deformation that depends on the time interval since the latest great earthquake, and so the greater width of the strain-rate profile in southern California can be accounted for. For example, data from the northern, locked section of the San Andreas fault may correspond to times t_1 to t_3 in figure 7.12, whereas those from the southern section may correspond to times t_4 and t_5.

More complex models that combine features of both the thick- and thin-lithosphere models are also consistent with available data (for example, Li and Rice, 1987). Furthermore, coseismic and interearthquake fault slip undoubtedly vary as a function of depth, rather than abruptly terminating at some specified fault depth. Although this gradationality of the slip distribution modifies the detailed patterns of surface strain and displacement from those illustrated in figure 7.10, for example, the same qualitative features are preserved, and it will be difficult to distinguish between differing slip-depth distributions on the basis of surface-deformation measurements alone.

In summary, at transform plate boundaries, available data are consistent with both thick- and thin-lithosphere models but do not strongly constrain either. The most geophysically interesting feature of both models is the predicted postearthquake diffusion-like spread of strain from the plate-bounding fault into the interiors of the adjacent plates. Postearthquake surveys, however, are sufficiently infrequent and areal coverage sufficiently limited that these effects, if they indeed occur, have not been directly observed. Details of the temporal decline in deformation rate near the fault are also absent.

STRESS-SLIP-CONSTITUTIVE-LAW FAULT MODELS

A completely different class of large-scale-faulting models are now being developed to more realistically incorporate the fault-failure process into the earthquake deformation cycle (for example, Stuart, 1979; Tse and Rice, 1986). Instead of specifying slip on the plate-bounding fault, these models extrapolate from laboratory

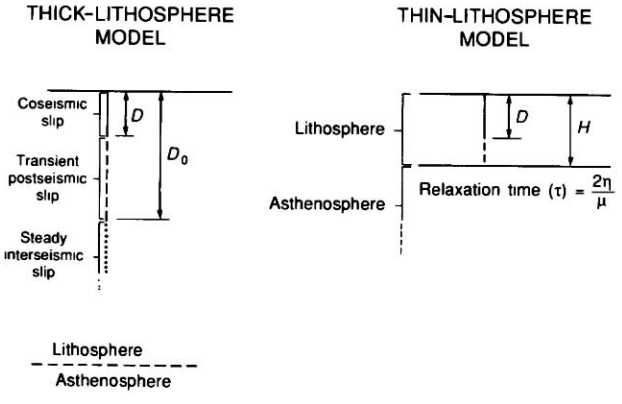

FIGURE 7.11.—Specific features of thick- and thin-lithosphere models. D, depth of coseismic slip; D_0, depth to bottom of zone of transient postseismic slip; H, thickness of elastically strong lithosphere; η, effective viscosity of asthenosphere; μ, average shear modulus of lithosphere and asthenosphere.

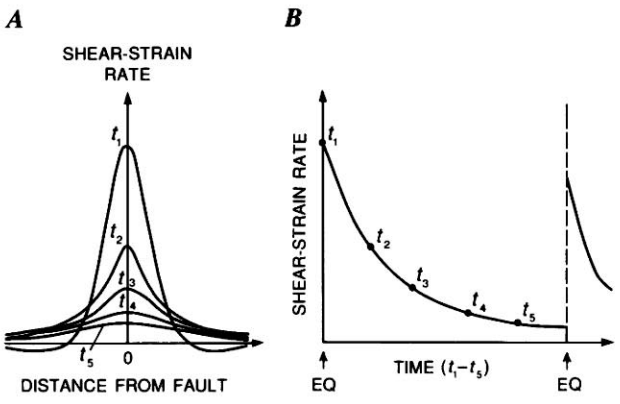

FIGURE 7.12.—Complete earthquake-cycle model predictions for thick- and thin-lithosphere models. *A*, Shear-strain rate versus distance from fault and its temporal evolution through deformation cycle. *B*, Shear-strain rate on fault versus time for one complete cycle. EQ, earthquake.

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observations of the time-dependent frictional properties of rocks (for example, Dieterich, 1979; Tullis, 1988) to assign slip-stress-constitutive laws to the fault surface. As remotely applied stresses increase, each segment of the fault slips at a rate that depends on both the previous slip history and the current applied stress, and so the cycle of elastic-strain accumulation and release can be simulated. By specifying the depth dependence of fault frictional properties, a slip behavior nearly identical to that of the thick-lithosphere model (fig. 7.11*A*) follows naturally. A sample calculation of this type (Tse and Rice, 1986) illustrates the method and shows typical results (fig. 7.13). After a large coseismic slip event in approximately the upper 10 km of the model fault, transient postseismic slip occurs on both the coseismic fault plane and its downdip extension. As slip rates decline to near zero on the shallow segments of the fault, interseismic slip at greater depths approaches nearly steady-state values. Finally, near the end of the cycle, the constitutive model predicts an increase in slip rate on the shallow coseismic fault segment before the next large slip instability ("earthquake").

Although the appropriateness of this extrapolation of laboratory results to large-scale faulting is a matter of current debate and the scaling of laboratory parameters to the field is uncertain, Tse and Rice's calculations clearly demonstrate that the principal observed features of the earthquake deformation cycle on the San Andreas fault can be reproduced by such models. Ongoing laboratory studies should refine and modify the stress-slip-constitutive laws, and geodetic and continuous strain-monitoring observations of preearthquake and postearthquake crustal deformation can test the applicability of these postulates to large-scale faulting processes.

SUMMARY

Contemporary crustal movements in California are concentrated within a plate-boundary-deformation zone that is typically 50 to 200 km wide, approximately centered on the San Andreas fault. Integrated right-lateral displacement rates across this zone range from 33 to 37 mm/ yr, representing about 75 percent of the Pacific-North American relative plate motion. Most or all of the rest may be taken up east of the San Andreas fault system in the Basin and Range province. Although aseismic fault slip (creep) is a locally important component of this relative plate motion, most of the geodetically measured deformation represents elastic strain on the crustal blocks adjacent to faults of the San Andreas system. Rates of secular (interseismic) shear strain are a maximum on the two currently locked segments of the San Andreas fault, sites of the great 1857 and 1906

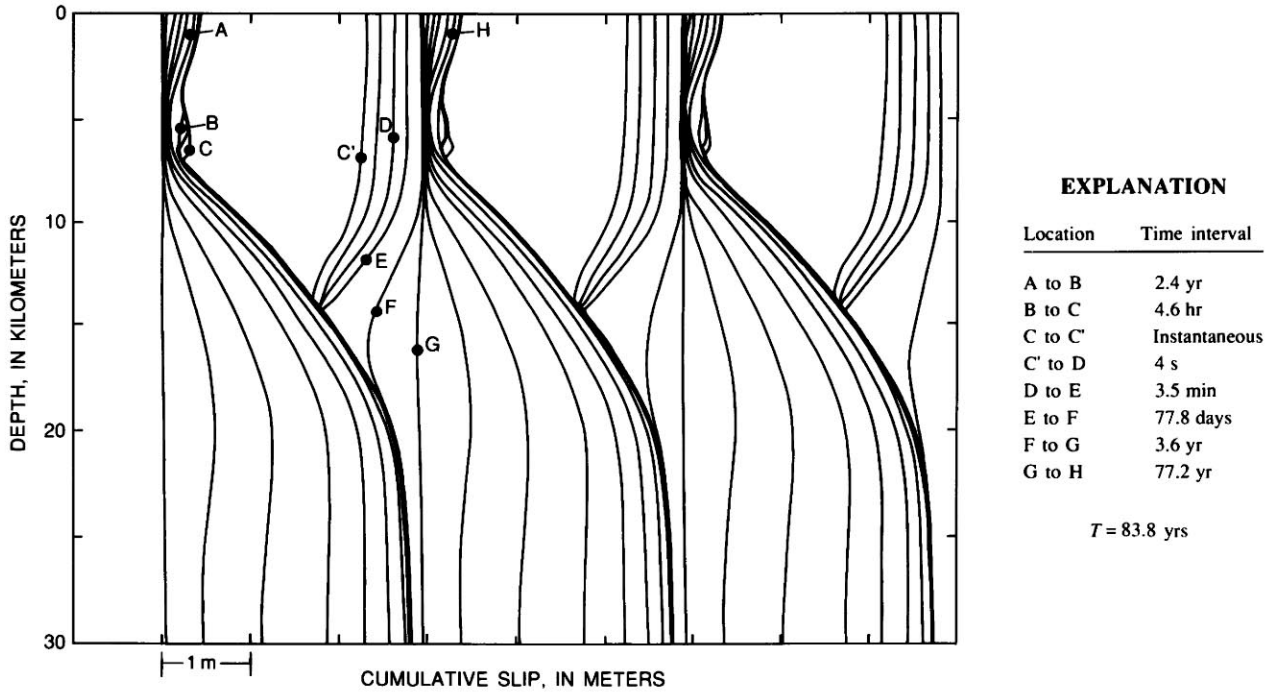

FIGURE 7.13.—Cumulative slip versus depth for selected time intervals through deformation cycle in quasi-static fault-instability model modified from Tse and Rice (1986). *T*, recurrence interval.

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earthquakes. Values range from 0.4 to 0.6 parts per million per year (ppm/yr) at the fault to 0.1 ppm/yr 30 to 80 km from it. Deformation occurring at the times of large strike-slip earthquakes (coseismic strain) is concentrated within a few tens of kilometers of the surface fault rupture, indicating that earthquake fault slip is largely confined to the upper 10 to 15 km of the crust. After major events, postseismic shear strain occurs at transiently high rates (more than 2 ppm/yr) that decay to background interseismic rates over a time scale of years to tens of years.

Observations of coseismic, postseismic, and interseismic movements define the earthquake deformation cycle and constrain models of strain accumulation and release for strike-slip plate boundaries. Observations are fitted equally well by two contrasting models. In the first model, the depth of coseismic faulting is much less than the thickness of the elastically strong lithosphere, and postseismic and interseismic deformation result from transient and steady aseismic slip on the downward extension of the earthquake fault plane. At the other extreme, if earthquake slippage extends through most or all of the elastic lithosphere, interearthquake deformation is due to transient or steady flow in the underlying weak substrate ("asthenosphere").

FUTURE DIRECTIONS FOR RESEARCH

Although the broad outlines of current movement across the San Andreas boundary zone are now known and the main features of the cyclic deformation expected from great strike-slip earthquakes have been delineated, many issues still remain to be explored. Although all of the relative Pacific-North American plate motion occurring across California may have been measured geodetically, this determination is not yet definitive, and as much as 10 mm/yr of motion may be accommodated east or west of the approximately 100-km-wide zone defined by current measurements. Furthermore, the thickness of the elastically strong crust is uncertain by at least a factor of 3, and so major alternative models of the earthquake deformation cycle cannot be distinguished (fig. 7.9). Because surface-deformation observations cannot themselves resolve this ambiguity, other data, possibly gravity-field observations and lithospheric-deflection models (for example, McNutt, 1980), are needed.

Few details exist on the preseismic and postseismic movements related to large plate-boundary earthquakes. Whether detectably anomalous crustal movements precede large earthquakes is uncertain. Theoretical models and fragmentary observations suggest that precursory slip may occur on or beneath the eventual coseismic rupture plane. However, except for the observation that premonitory deformations must be small relative to coseismic movements (for example, Johnston and others, 1987), precursory slip is otherwise unconstrained. Existing data are sufficient to demonstrate that postseismic movements, at least those from great earthquakes, are large—commonly, 10 to 30 percent of the coseismic deformation (Thatcher, 1984)—but the time scale and spatial distribution of these motions are not well determined at strike-slip plate boundaries. Laboratory experiments on lower-crustal rock types suggest that their ductile behavior is not approximated well by linear viscoelasticity, as assumed in the thin-lithosphere model, but postseismic observations are not yet sufficiently detailed to confirm this expectation.

Furthermore, vertical crustal movements in California are not well understood. Though not dominant in California's largely strike-slip-faulting environment, vertical movements can nonetheless be locally important in such regions as the Los Angeles and Ventura Basins, the Transverse Ranges of southern California, and the Cape Mendocino area of northern California. Current and future work that integrates geologic and geodetic information in these regions should begin to shed light on long-term, secular vertical-movement patterns and their origins.

Within complex, multistranded fault zones and, possibly, in simpler regions, permanent inelastic deformation of upper-crustal rocks may contribute significantly to the current movement pattern. For example, at subduction boundaries, geologic and geodetic observations indicate a substantial imbalance between cumulative interearthquake strain and coseismic strain release, commonly reflected in long-term uplift or subsidence of coastal and inland regions. However, at such predominantly transcurrent boundaries as the San Andreas, the observable effects of inelastic strain are more subtle. The thermal consequences of such deformation may be the most direct evidence for inelastic strain (see chap. 9). However, for California at least, the available data are either contradictory or ambiguous, and the extent to which measured interearthquake movements release elastically stored strain is currently unresolved.

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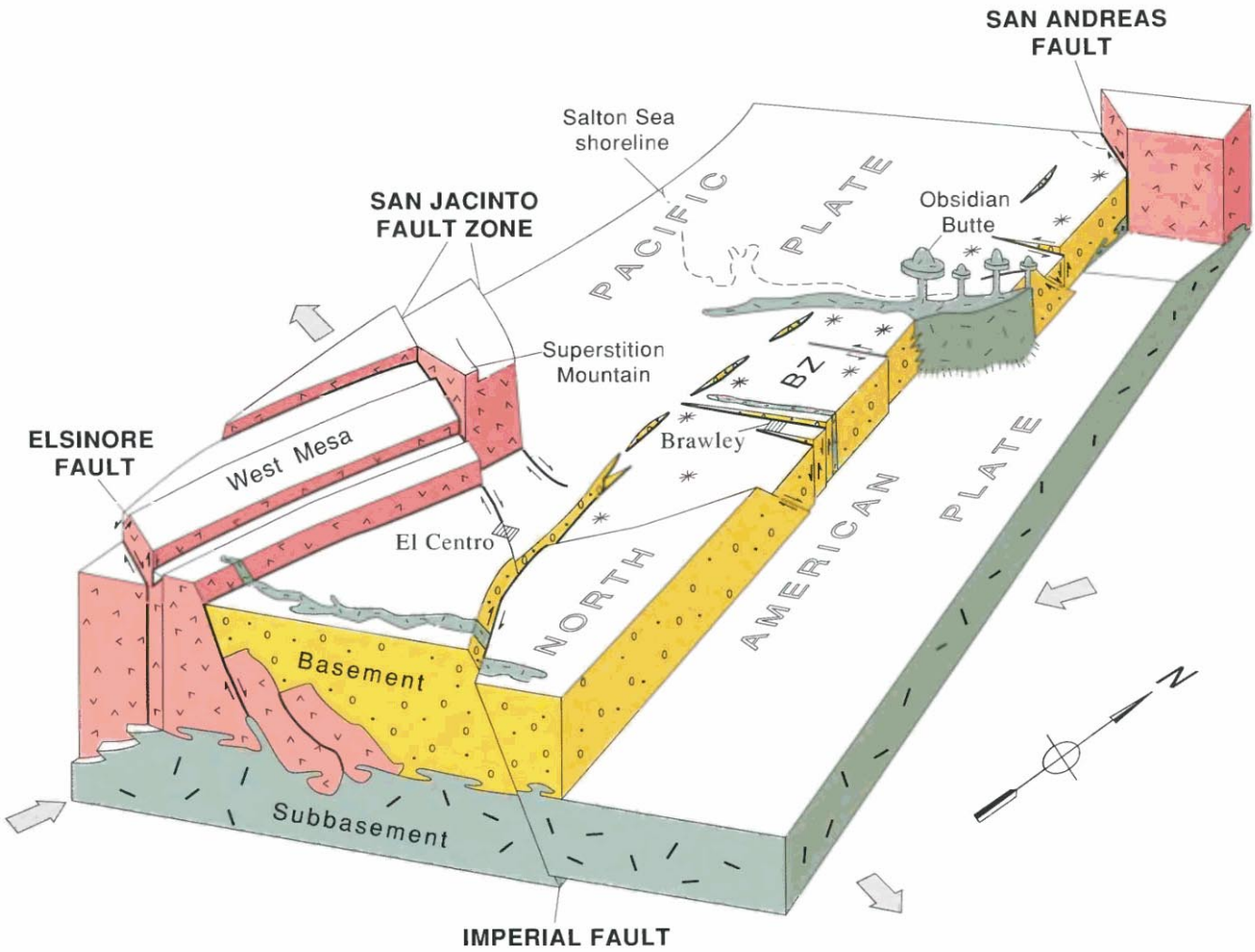
EXPLANATION

- Pre-late Miocene crystalline basement
- Late Miocene and younger metasedimentary basement
- Subbasement (basaltic intrusions)
- Inferred intrusions or fractures underlying geothermal areas
- ✳ BZ — Brawley seismic zone
- Fault— Arrows indicate direction of relative movement
- Principal stress direction



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The crust of much of California was formed at an Andean-type continental margin during the Mesozoic and early Cenozoic, and was modified by large strike-slip offsets along the San Andreas fault system during the late Cenozoic. Decoupling within the crust, as implied by present upper-crustal tectonic wedging in central California, and decoupling between the crust and mantle, as implied by "subduction" of lithospheric mantle in southern California, indicates that the San Andreas fault system must change with depth in its location and (or) style of deformation.

8. LITHOSPHERIC STRUCTURE AND TECTONICS FROM SEISMIC-REFRACTION AND OTHER DATA

By GARY S. FUIS and WALTER D. MOONEY

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INTRODUCTION

Studies of the crustal and upper-mantle structure of California along the San Andreas fault system have been underway for more than half a century, beginning with the early studies by Byerly and Wilson (1935) and Byerly (1946) in northern California and by Gutenberg (1943) in southern California. Crustal profiling along and

◀ FIGURE 8.1.—Schematic block diagram of Imperial Valley region of the Salton Trough, with unmetamorphosed sedimentary rocks removed and seismic basement cut away along line approximately parallel to the Brawley seismic zone (BZ; see fig. 8.7). Seismic basement consists of rocks with *P*-wave velocities of 5.5 to 6.5 km/s. In this region, there are two types of seismic basement: one type, on flanks of the Salton Trough, consists of pre-late Miocene igneous and metamorphic rocks; other type, in central part of trough, consists of late Miocene and younger metasedimentary rocks (similar in age and provenance to sedimentary rocks stripped off in this diagram). Pacific and North American plates are separating across the Brawley seismic zone, an inferred onshore spreading center of the East Pacific Rise. North and south of the Brawley seismic zone, these two plates are separated from each other by transform faults, the San Andreas and Imperial faults, respectively. As the plates pull apart, subsidence occurs within the Brawley seismic zone, sediment is deposited to fill rift from above, and mafic intrusions (basalt, diabase, and gabbro) enter rift from below, metamorphosing sedimentary rocks below a certain depth (generally approx 5 km in central part of rift). This process is repeated until central part of rift consists entirely of young crust. Geographic locations projected downward onto seismic basement for reference.

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near the San Andreas fault was first accomplished in the early 1960's by Eaton (1963), Healy (1963), and Roller and Healy (1963). Research accelerated after the 1966 M=6.0 Parkfield, Calif., earthquake to include both detailed crustal profiling and installation of dense seismic networks for the study of earthquakes (see chap. 5; Eaton and others, 1970). Since 1970, a wide variety of seismologic methods have been used to investigate crustal and upper-mantle structure in the vicinity of the San Andreas fault system. In this chapter, we summarize the main features of this structure and relate the structure to broad-scale tectonic processes.

Seismologic studies of crustal and upper-mantle structure in California make use of three primary data sources: (1) traveltimes of local earthquakes as measured by permanent and temporary seismic arrays, (2) seismic-refraction and reflection profiles, and (3) teleseismic delay times measured by seismic arrays. Traveltimes of local earthquakes, in addition to containing the information needed to locate earthquakes, contain a wealth of information regarding the seismic-velocity structure of the crust and upper mantle. Velocity structure can be determined from these traveltimes by iteratively adjusting an initial velocity model and associated hypocentral parameters, using inversion methods (for example, Crosson, 1976; Eberhart-Phillips and Oppenheimer, 1984). The resolution of velocity structure from local earthquake data is a function of the interstation spacing of the network and the abundance and distribution of seismicity.

Seismic refraction and reflection profiles together form a complementary set of seismic measurements. Seismic-refraction profiles provide the highest resolution of seismic P-wave velocities in the crust and upper mantle. The seismic-refraction method, however, generally does not provide the sharpest picture of lithologic interfaces, from which geologic structure is inferred; such a picture is better provided by seismic-reflection profiling.

Teleseismic delay-time studies offer the most effective means of determining the structure of the subcrustal lithosphere. The method is based on interpreting relative arrival times of compressional waves throughout a seismic array in terms of velocity variations at depth beneath the array. The Earth structure in the volume beneath the array generally is described by a series of blocks, and velocity deviations are derived for each block from the observed delay times (Aki and others, 1977; Thurber and Aki, 1987). The California seismic array is ideally suited for such investigations because of its large areal extent and the length of time it has been in operation (see chap. 5).

The primary product of the seismologic methods described above is a model of the seismic P-wave-velocity distribution in the crust and upper mantle. However, the interpretation of seismic P-wave velocities in terms of rock type is highly nonunique because laboratory velocity data indicate that numerous rock types can have similar velocities (for example, Birch, 1960). This interpretation is further complicated by the fact that, in rocks at pressures of less than 2 kbars (depths above 8 km), seismic velocities are strongly affected by the presence of cracks (on all scales) and porosity. In addition, rock velocities are affected by temperature and the presence of water. Thus, the interpretation of P-wave velocities in terms of rock types must involve other data sets, including laboratory velocity measurements on rocks at different pressures, temperatures, and water saturations, surface geologic data, well data, and other geophysical data, including gravity and magnetic data. Fortunately, abundant laboratory velocity data (for example, Stewart and Peselnick, 1977; Lin and Wang, 1980), geologic data (see chaps. 1, 3), and geophysical data (see chap. 9) are available for California, making the lithosphere of this region one of the best studied in the world.

In this chapter, we summarize the lithospheric structure and tectonics along the San Andreas fault system of California (fig. 8.2) with maps of crustal thickness and upper-mantle seismic-velocity anomalies, and with crustal cross sections for central and southern California. Structure changes more rapidly parallel to the San Andreas fault in southern California than in central California, and so we supplement the cross section for southern California with a map showing crustal-block motions and a diagram illustrating the different motion of the lithospheric mantle below. Seismic and other data currently are still not dense enough to construct a cross section along the San Andreas fault system itself.

Construction of the crustal cross section for central California led us to a new interpretation of upper-crustal tectonic wedging, the mechanism whereby the Franciscan assemblage was emplaced in the Coast Ranges during the late Mesozoic(?) and Cenozoic. This interpretation extends that of Wentworth and others (1984) to include a two-part history whereby the observed structures atop the wedge, which include both extensional and compressional faults, were created. We further speculate that similar tectonic wedging occurred in southern California from the Mojave Desert to the Chocolate Mountains to emplace the Rand schist and the Pelona-Orocopia schist of Haxel and Dillon (1978) into rocks east of the San Andreas fault.

CRUSTAL-THICKNESS MAP OF CALIFORNIA

A contour map of crustal thicknesses in California (fig. 8.3*A*) provides an overview of the geophysical setting of the San Andreas fault system. The seismic and gravity

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data used in compiling this map (fig. 8.3*B*) were discussed by Mooney and Weaver (1989).

Crustal thickness along the San Andreas fault increases from 16–24 km in northern California to 28–32 km in southern California. Thus, the crust along the San Andreas fault system is everywhere thinner than the 36-km average for the conterminous United States (Braile and others, 1989), and in northern California it is

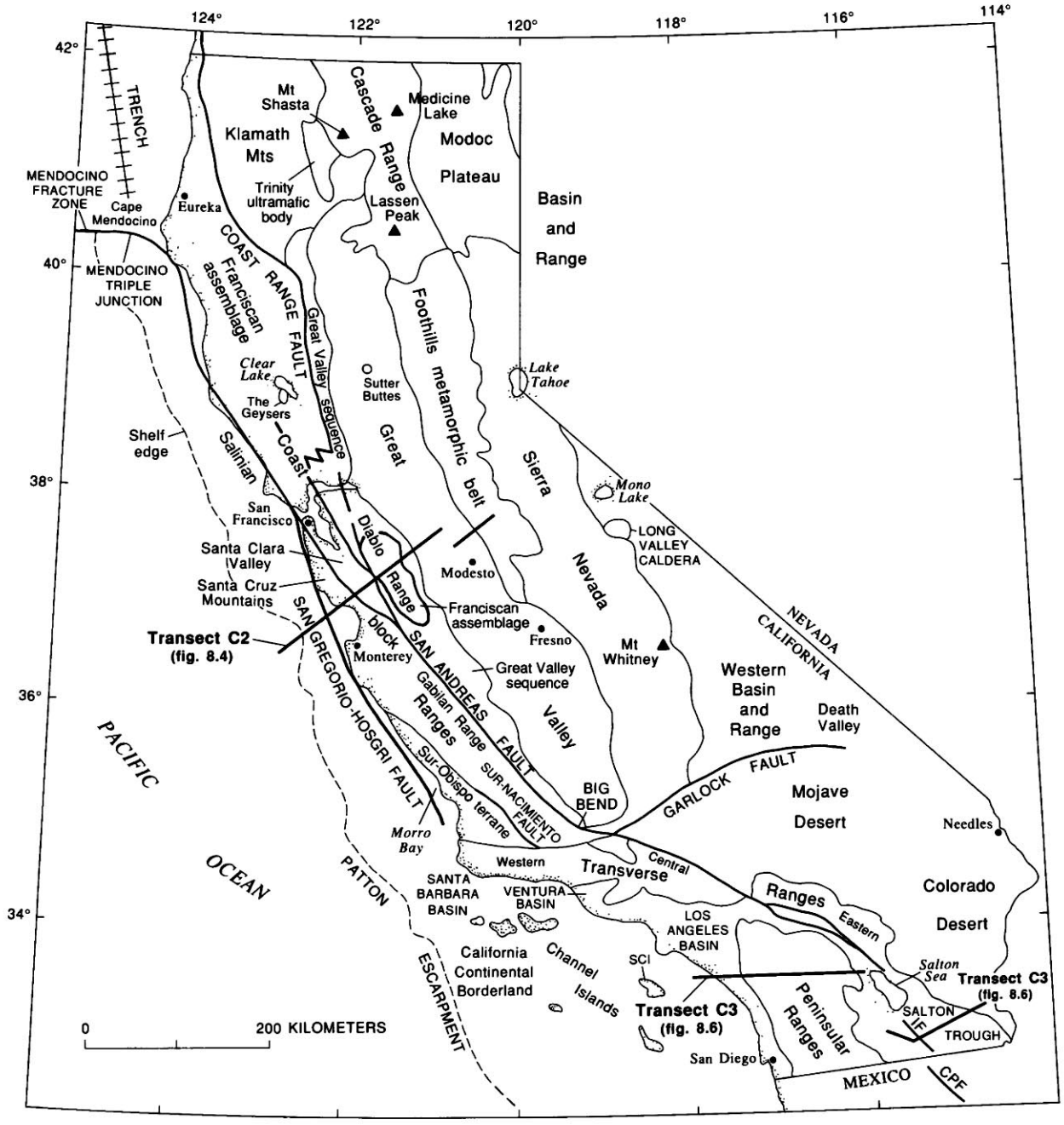

FIGURE 8.2.—California, showing place names, geologic provinces, selected geologic units, and locations of crustal transects shown in figures 8.4 and 8.6. The San Andreas fault extends from the Salton Trough to triple junction at Cape Mendocino. CPF, Cerro Prieto fault; IF, Imperial fault; SCI, Santa Catalina Island. Fault with crosslining is trench, offshore northern California.

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substantially thinner than this average. To a first-order approximation, crustal thickness resembles the topography (see Jachens and Griscom, 1983, fig. 13).

Cape Mendocino in northern California marks the change from the strike-slip regime of the San Andreas fault to the subduction regime of the Cascade Range. North of Cape Mendocino, the crust thickens eastward from about 16 km at the coast to about 38 km in the southern Cascade Range (fig. 8.3*A*). Near the coast, this thickness includes both the North American plate and the subducting Gorda plate. Estimates of crustal thickness in the northern Coast Ranges at Cape Mendocino lack

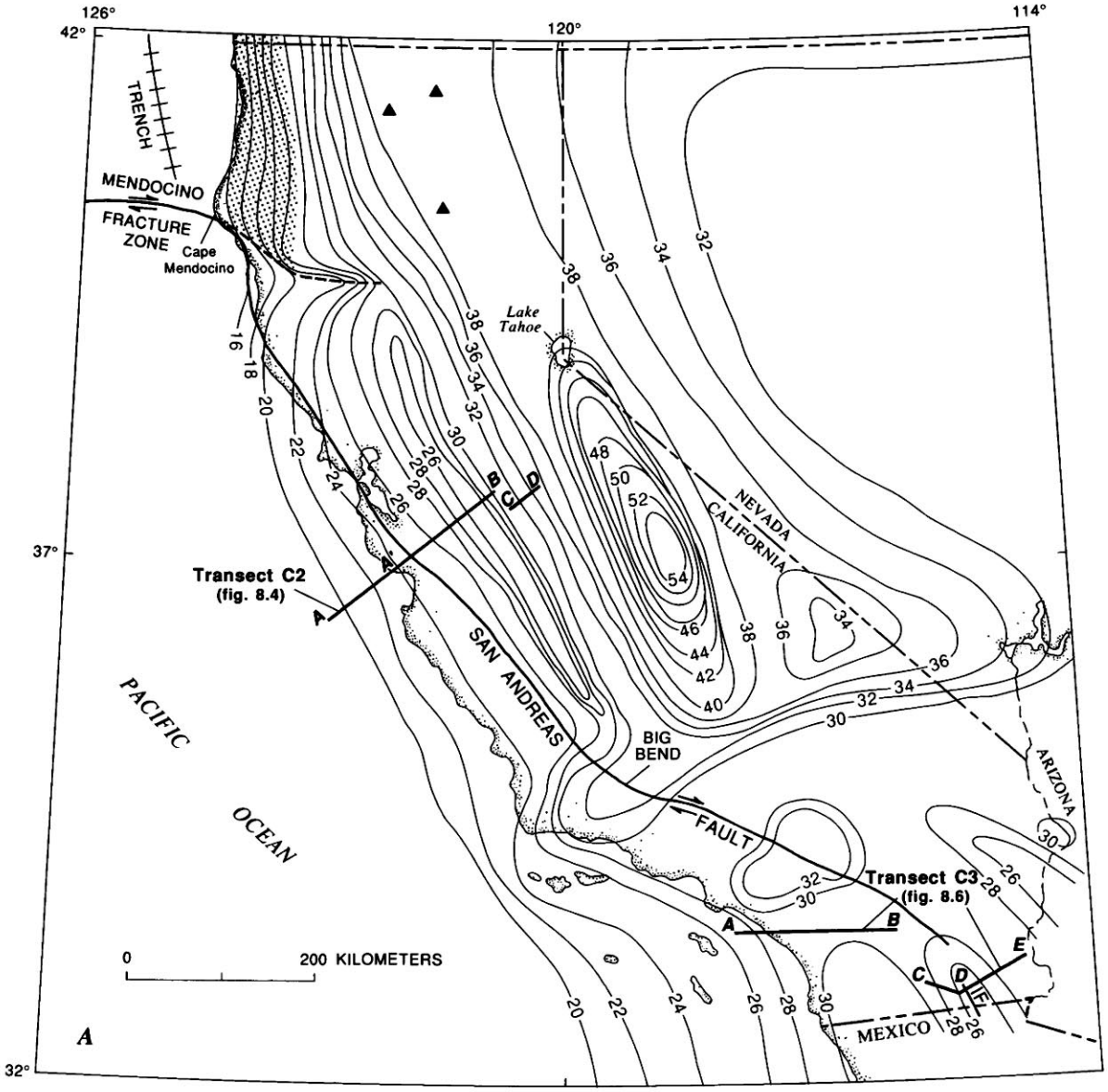

FIGURE 8.3.—Crustal thickness (*A*) for California and adjacent regions, modified from Mooney and Weaver (1989), with data sources (*B*). Contour interval, 2 km. Northeast of the San Andreas fault in central California, thin crust (within enclosed 28-km contour) corresponds to Mesozoic/early Cenozoic forearc basin (Great Valley; see fig. 8.2 for place names), and thick crust (within enclosed 40-km contour) corresponds to magmatic arc of same age (Sierra Nevada). Southwest of the San Andreas fault in central California, this Andean-marginal sequence is repeated but shortened; crust is relatively thin there. In southern California, crustal thickness is relatively uniform (about 30 km), despite considerable tectonic activity throughout most of geologic time,

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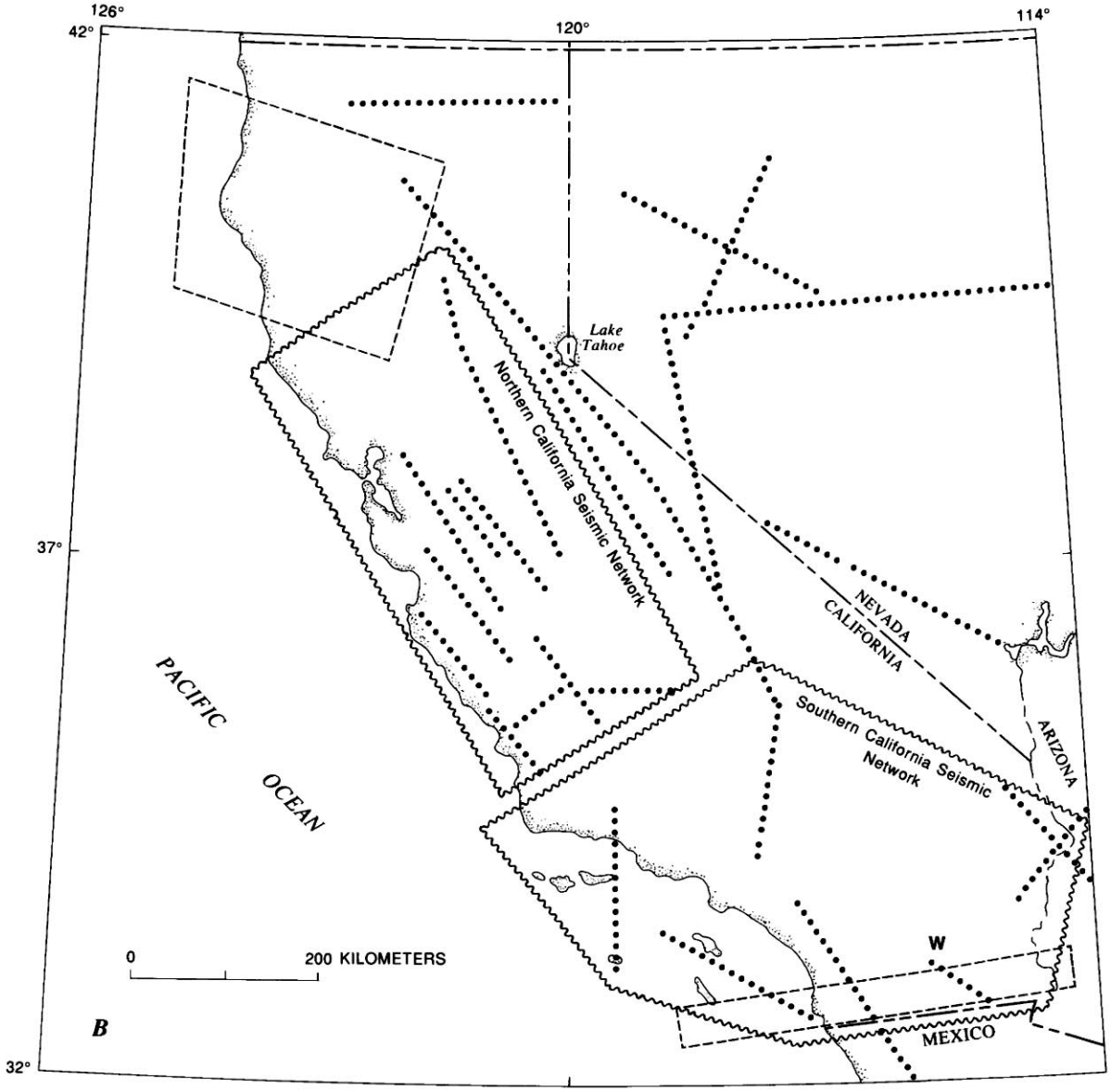
seismic refraction or reflection control, but detailed gravity models, heat-flow observations, and teleseismic data indicate an abrupt decrease in both crustal and lithospheric thickness southward of the landward projection of the Mendocino Fracture Zone (see chaps. 9, 10; Zandt and Furlong, 1982; Jachens and Griscom, 1983).

In central California, the crust thickens eastward from about 25 km near the coast to as much as 55 km in the



including present subduction of lithospheric mantle (see below). Estimated error in figure 8.3*A* is 10 percent, or 1 to 1½ contour intervals. Heavy lines, faults—dashed where the Mendocino Fracture Zone extends onshore (and beneath North American plate); arrows indicate direction of relative movement; crosslined along trench, offshore northern California. Triangles, volcanoes of Cascade Range continental arc. Dot pattern, area of contours on Gorda-plate Moho. IF, Imperial fault. Data sources in 8.3*B* include seismic-refraction profiles (dotted lines), earthquake networks (wavy outlines), and gravity (dashed outlines). "W" associated with seismic-refraction profile in the Salton Trough indicates that only wide-angle reflections are available to constrain Moho depth.

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Sierra Nevada, but this general landward thickening is interrupted by thin crust (25 km) beneath the Great Valley (fig. 8.3*A*; compare Oppenheimer and Eaton, 1984). The crust of central California represents a Mesozoic and early Cenozoic Andean-type continental margin (see chap. 3; Hamilton, 1969) that has been modified by late Cenozoic strike-slip faulting along the San Andreas fault system and by uplift of the Sierra Nevada. Andean features include a subduction complex (eastern Coast Ranges), a forearc basin (Great Valley), and a magmatic arc (Sierra Nevada). Cenozoic strike-slip faulting along the San Andreas fault system has moved a shortened Andean-marginal sequence outboard of this sequence. Southwest of the San Andreas fault, the batholithic Salinian block (western Coast Ranges) is juxtaposed, across other right/oblique-slip faults of the San Andreas fault system, against an inactive accretionary prism, or subduction complex (western Coast Ranges and offshore California).

In southern California, the crust thickens eastward from about 20 km at the western margin of the California Continental Borderland to about 32 km in the eastern Transverse Ranges (fig. 8.3*A*). Over most of onshore southern California, crustal thickness is 30±2 km. Considering the complex tectonic history of this region, including the present subduction of lithospheric mantle (see below), this uniformity in crustal thickness is remarkable.

CENTRAL CALIFORNIA

Crustal structure in central California is grossly two dimensional, as can be readily inferred from the crustal-thickness map (fig. 8.3*A*). There are five blocks or provinces with subparallel fault boundaries: an accretionary prism, which is partly off shore; the Salinian block, which underlies the western Coast Ranges, including the Santa Cruz Mountains and Gabilan Range; a complex block between the San Andreas and Calaveras faults, underlying the Santa Clara Valley; the Diablo block, beneath the Diablo Range; and the Great Valley/Sierran block (fig. 8.2). To illustrate the crustal structure of central California, we have modified and reinterpreted the part of Centennial Continent-Ocean Transect C2 (Saleeby, 1986) that extends from offshore California at Monterey Bay to the Sierran foothills near Modesto (figs. 8.2, 8.4). Seismic control, which is exceptionally good along this transect, has been augmented since Saleeby's (1986) study primarily by analysis of seismic-refraction profiles in the Great Valley (fig. 8.4*A*). The reader is referred to Hill (1978) for an earlier treatment of deep structure along approximately this same transect.

TRANSECT C2

OFFSHORE REGION

The offshore region of transect C2 is underlain by an inactive, early Tertiary accretionary prism overlapped by uppermost Oligocene to Holocene sedimentary rocks (see Saleeby, 1986). The San Simeon terrane, consisting of Late Cretaceous Franciscan rocks (disrupted marine sedimentary rocks; see chap. 3), is imbricated in this prism along with poorly known, lower Tertiary sedimentary rocks. The prism is underlain by oceanic crust with an inferred age of about 26 to 20 Ma (Atwater and Menard, 1970; Atwater, 1989). The accretionary prism is juxtaposed against granitic rocks of the Salinian block across the (inactive) Nacimiento fault, which is overlapped by upper Tertiary sedimentary rocks. This fault, in turn, is offset by the (active) right/oblique-slip San Gregorio-Hosgri fault. The Moho is 10 km below sea level near the west end of the transect (Shor and others, 1971) and deepens to 24- to 26-km depth beneath the Gabilan Range and Santa Cruz Mountains (Walter and Mooney, 1982).

We follow D.S. McCulloch (in Saleeby, 1986) in showing steep northeastward dips on both the Nacimiento and San Gregorio-Hosgri faults (fig. 8.4*A*) that are based on marine reflection data. Focal mechanisms for earthquakes on the San Gregorio-Hosgri fault at this latitude indicate nearly pure strike slip on vertical planes; however, farther south, they indicate chiefly reverse faulting on northeast- or southwest-dipping planes (see chap. 5).

SALINIAN BLOCK

The area between the Nacimiento and San Andreas faults is underlain by a batholithic terrane that has been transported northwestward by the San Andreas (and other?) fault(s) by amounts estimated to range from 550 km (see Ross, 1978) to 2,500 km (Champion and others, 1984). Plutonic rocks include tonalite, granodiorite, and quartz monzonite of mostly Late Cretaceous age (Ross, 1978; Mattinson, 1982). Metamorphic pendants and screens include mostly quartz-rich clastic rocks of amphibolite facies. Ross and McCulloch (1979) postulated that these upper-crustal plutonic and metamorphic rocks are not rooted to the lower crust but are in fault contact with a buried terrane, possibly consisting of Franciscan rocks.

The velocity structure derived by Walter and Mooney (1982) from Stewart's (1968) seismic-refraction measurements in the Gabilan Range and Santa Cruz Mountains can be subdivided into four separate crustal layers with velocities of 2.1–4.6 km/s (layer 1), 5.3–5.6 km/s (layer 2),

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EXPLANATION FOR FIGURES 8.4*A* AND 8.6*A*

3.6/4.6 **P-wave velocity in kilometers per second at top/base of layer**—Velocities in parentheses are projected

P-wave velocity boundary—Heavy tick where profile perpendicular to page; light line where profile in plane of page; short dashed where change in gradient only; long dashed in figure 8.4*A* for model of Dean Whitman and others (unpub. data, 1985). Boundaries are determined by refraction profiling except for offshore central California (fig. 8.4*A*) where they are determined by reflection profiling

? **Reflector from reflection profiling**—Queried where uncertain

Density and magnetic boundary

? **Inferred region in which midcrustal and Moho discontinuities may exist**—Queried where uncertain

LVZ **Possible low-velocity zone**

Fault

EXPLANATION FOR FIGURES 8.4*B* AND 8.6*B*

LITHOLOGIC SYMBOLS FOR TECTONIC ENVIRONMENT

Oceanic

Sedimentary rocks
- **Basin floor and trench turbidites**
- **Pelagic sedimentary rocks**

Igneous and metamorphic rocks
- **Seamounts**
- **Ophiolite, or top of ophiolite where undivided mafic crust is shown below**
- **Serpentine**

Magmatic arc

Sedimentary rocks
- **Forearc rocks**
- **Intra-arc rocks**

Volcanic rocks
- **Rocks of mixed and (or) intermediate composition**

Plutonic rocks
- **Granite and quartz monzonite**
- **Granodiorite and tonalite**
- **Gabbro**

Continental and continental rift

Sedimentary rocks
- **Nonmarine clastic rocks**—Circles, conglomerate; circles and dots, conglomerate and sandstone; darker color, metamorphosed
- **Marine clastic rocks**—Strike-and-dip symbol, carbonate bearing

Volcanic rocks
- **Rocks of mixed felsic to mafic composition**

Metamorphic rocks
- **Middle crust**—Inferred to be gneiss and schist developed at 10- to 20-km depth at greenschist to amphibolite facies
- **Lower crust**—Inferred to be gneiss developed below 20-km depth at amphibolite to granulite facies

Mafic crust, undivided—Denser pattern; higher velocity

Mantle—Closely spaced ticks, top of lithospheric mantle; widely spaced ticks, top of asthenospheric mantle or lithospheric mantle with partial melt

OTHER SYMBOLS

Melange—Symbols enclosed by zigzag lines indicate block type

α β γ **Metamorphic facies**—Amphibolite, blueschist (± eclogite), greenschist

Shear zone

Lithologic contact

A T **Normal or strike-slip fault**—Sense of motion shown: arrows indicate direction of relative movement; A, away from observer; T, toward observer

Mesozoic thrust fault—Sawteeth on upper plate

Mesozoic or Cenozoic thrust fault—Teeth on upper plate; arrow indicates inferred motion of upper plate; dotted where inferred to have formerly existed

Cenozoic thrust fault—Teeth on upper plate; arrow indicates inferred motion of upper plate

Mesozoic or Cenozoic detachment fault—Ticks on upper plate

Cenozoic detachment fault—Ticks on upper plate

In figure 8.6, Chocolate Mountains: Mesozoic or Cenozoic thrust or detachment fault ("Chocolate Mountains thrust fault"; see text)

NOTE: Lithologic contacts and faults—Long dashed where not constrained by figures 8.4*A* and 8.6*A* or by earthquakes of chapter 5; short dashed where gradational (lithologic contact only) or projected above surface; queried where existence uncertain

? **Top of brittle-ductile transition zone inferred from earthquakes (see text)**—Queried where uncertain

Explanation for figures 8.4 and 8.6.

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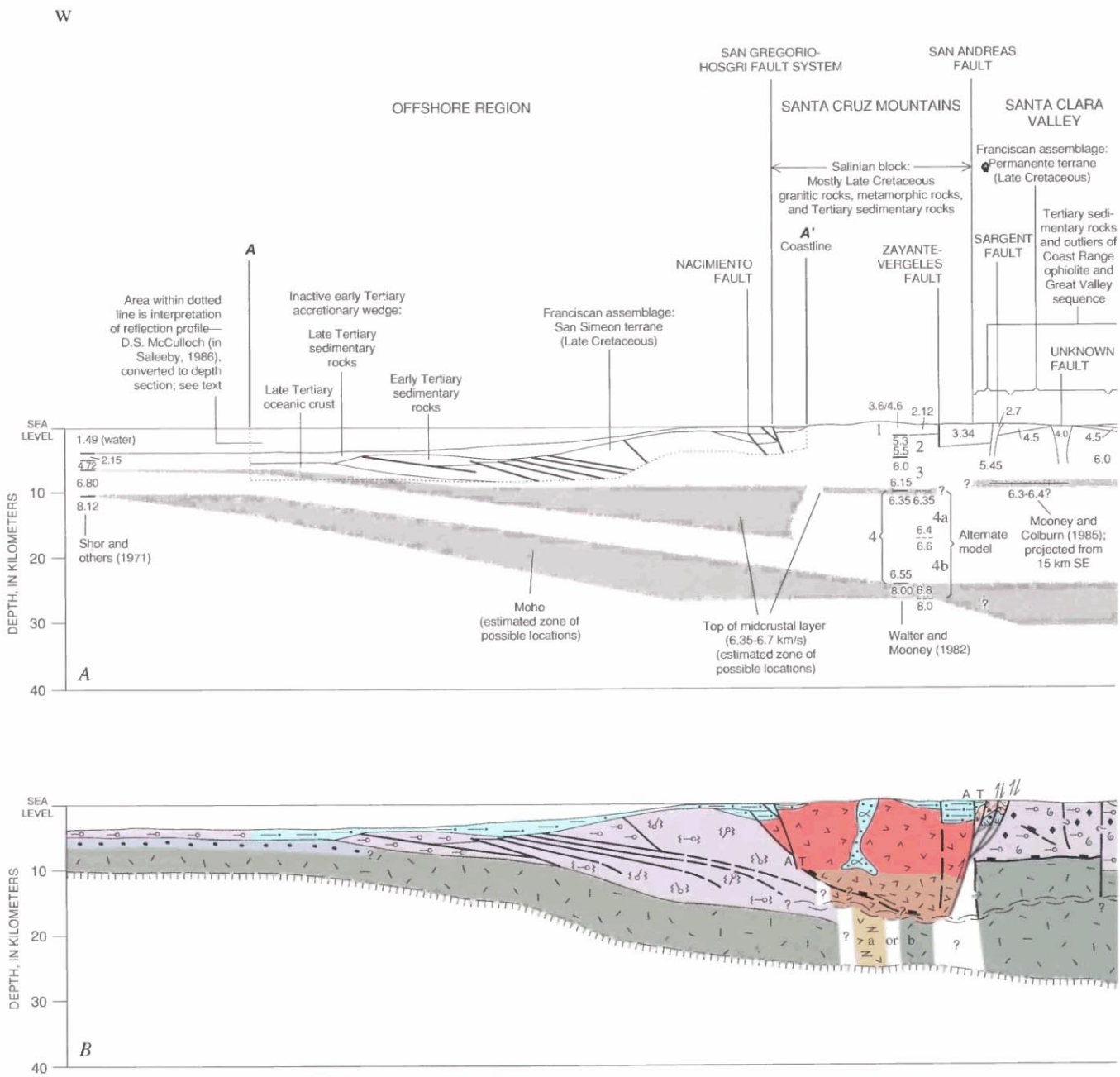

FIGURE 8.4.—Crustal structure of central California. *A*, Surface geology, depth-converted seismic-reflection data, and models of seismic-refraction, gravity, and magnetic data along western part of Centennial Continent-Ocean Transect C2 (see Saleeby, 1986). *B*, Reinterpretation of Transect C2. Major features in figure 8.4*B* include, from west to east, (1) offshore, inactive, early Tertiary accretionary wedge; (2) batholithic Salinian block of the Santa Cruz Mountains, positioned between the active oblique-slip San Gregorio-Hosgri and San Andreas faults; (3) Franciscan terranes of the Santa Clara Valley and Diablo Range, interpreted to compose a tectonic wedge; (4) Mesozoic and Cenozoic sedimentary rocks of the Great Valley; and (5) rocks of the Sierran foothills, including Jurassic and older volcanic, plutonic, and related sedimentary rocks accumulated or emplaced in an island-arc setting and Cretaceous plutonic rocks. Tectonic wedge in feature 3 is interpreted to have moved during the late Mesozoic(?) and Cenozoic, possibly in several episodes, largely along contact between Mesozoic crystalline rocks and overlying Mesozoic sedimentary rocks. In the eastern Great Valley, these sedimentary rocks are still rooted to (or depositionally overlie) this basement. Movement of

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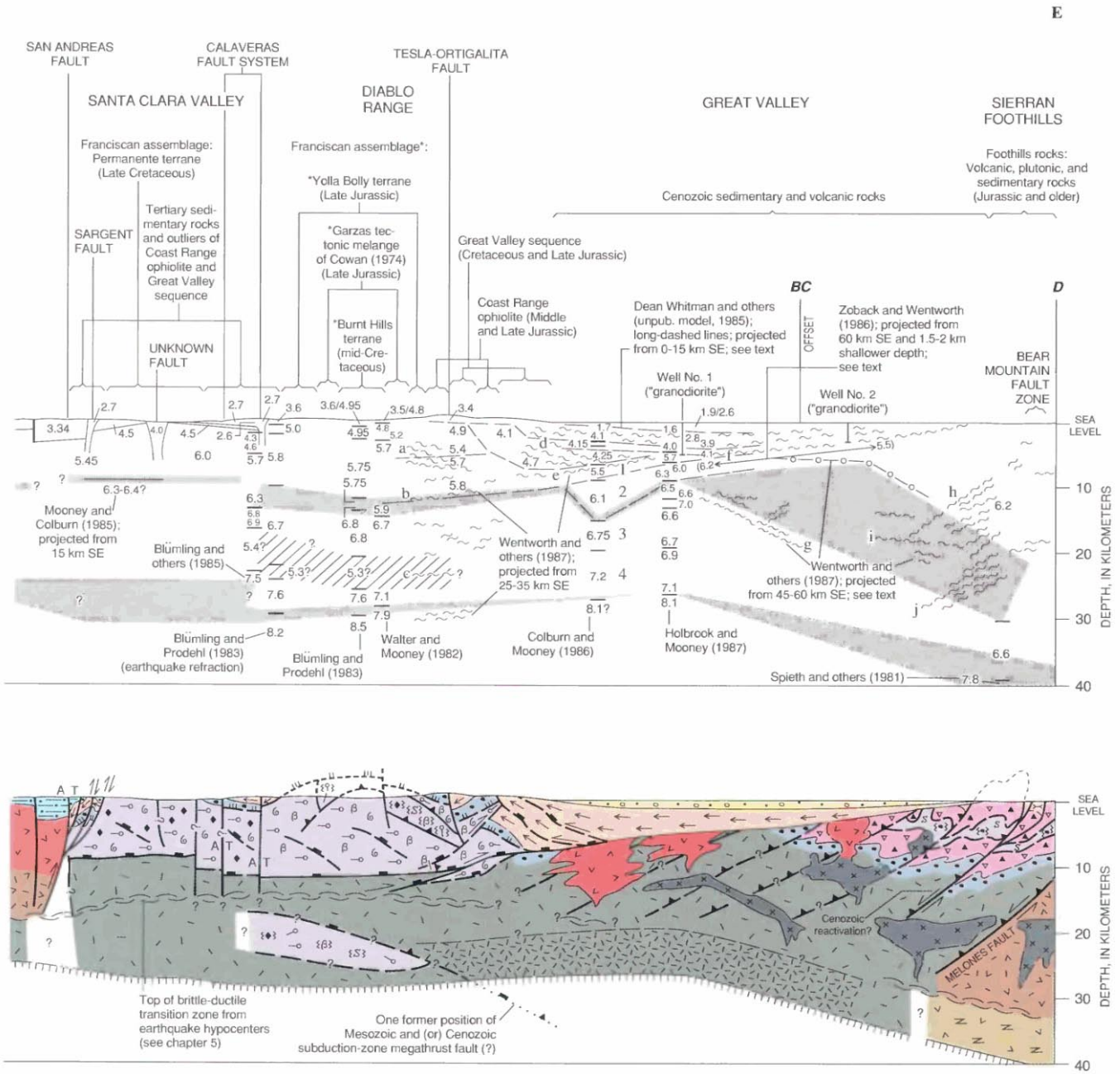

wedge during present San Andreas transform-faulting regime may be along one or more thrust faults that merge with postulated decollement in brittle-ductile transition zone in the crust. This reinterpretation differs from Saleeby's (1986) in eliminating inferred east-dipping subduction zone or thrust fault beneath the western Great Valley. Off shore, interpretation of unmigrated reflection section by D.S. McCulloch (in Saleeby, 1986) has been converted to depth section, using assumed velocities for each inferred geologic unit. In the Santa Cruz Mountains, velocity model consisting of layers 1 through 4 is shown (fig. 8.4*A*; see fig. 8.5*A*), along with alternative model in which layer 4 is subdivided into layers 4a and 4b. First model gives rise to interpretation a, and alternative model to interpretation b (fig. 8.4*B*). a–j, reflectors in the eastern Diablo Range, Great Valley, and Sierran foothills; 1–4, seismic-velocity layers in the Great Valley (fig. 8.4*A*) discussed in text. See figures 8.2 and 8.3 for location of Transect C2. No vertical exaggeration.

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6.0–6.15 km/s (layer 3), and 6.35–6.55 km/s (layer 4). Layer 4, middle and lower crust, can alternatively be modeled as two layers of velocities 6.3 km/s (layer 4a) and 6.6–6.8 km/s (layer 4b). These layer velocities can be correlated to rock type using surface geologic data and laboratory velocity data. Layer 1 corresponds to outcrops of Cenozoic sedimentary rocks along the transect. Basement outcrops along or near the transect include abundant quartz monzonite (Ross, 1972). Lin and Wang (1980) studied the velocity behavior of a sample of quartz monzonite from this region as a function of pressure and temperature, and constructed a velocity-depth curve for this rock appropriate for the Coast Ranges. On their curve (fig. 8.5*A*), the rock is slightly faster than layers 2 and 3 and slower than layer 4. Walter and Mooney (1982) interpreted layers 2 and 3 as granitic rocks similar to this quartz monzonite. The somewhat lower velocity of these two layers in comparison with the laboratory sample may be interpreted to result from (1) megascopic fractures in the Earth, not present in the laboratory sample; (2) a slightly lower content of mafic minerals (which have high seismic velocity) in the granitic rocks beneath the transect in comparison with the laboratory sample; or (3) both. Layer 4 is intermediate in velocity between the quartz monzonite sample and gabbro samples (hornblende gabbro and olivine gabbro) from the Coast Ranges. Walter and Mooney (1982) interpreted this layer to correspond to gneiss of intermediate composition, on the basis of a comparison of layer 4 with other laboratory data. In an alternative model, however, where middle and lower crust are separated as layers 4a and 4b, layer 4b may be reasonably interpreted as gabbro (fig. 8.5*A*).

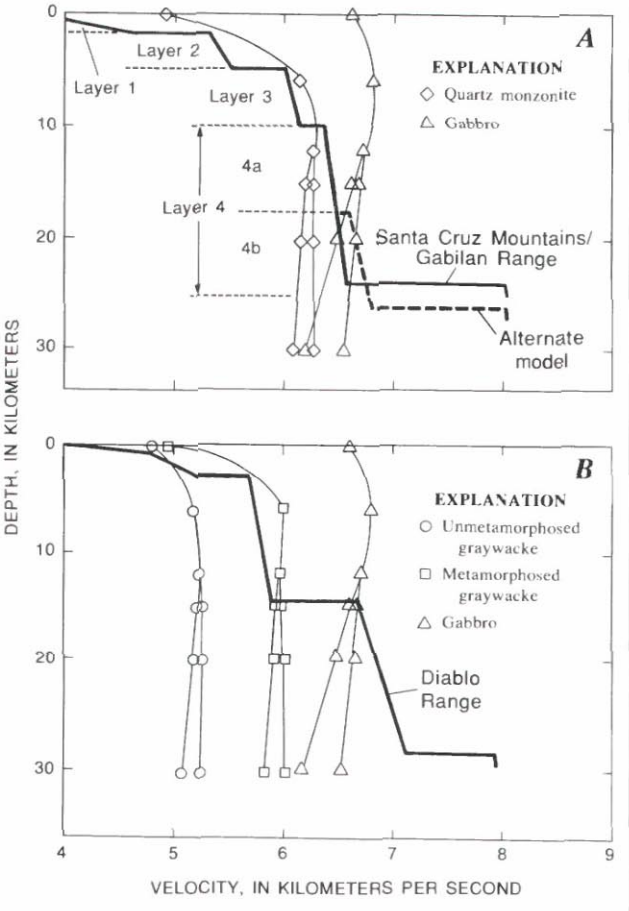

FIGURE 8.5.—Velocity-depth curves. *A*, Santa Cruz Mountains and Gabilan Range (Salinian block). *B*, Diablo Range. Heavy curves from seismic results (Walter and Mooney, 1982); light curves from laboratory velocity measurements and heat-flow modeling (two different geotherms assumed below about 10-km depth; Lin and Wang, 1980). See text for discussion of layers shown in figure 8.5*A*.

Alternative interpretations of these several crustal layers are also possible, given the fact that different rock types may have similar velocities. Stewart and Peselnick (1977) and Lin and Wang (1980) studied the velocity behavior of Franciscan rocks, also common in the Coast Ranges (Jennings and Strand, 1958). Two lithologic components of the Franciscan assemblage, unmetamorphosed and metamorphosed graywacke, produce velocity-depth curves (fig. 8.5*B*) that bracket those for most other components of the Franciscan assemblage (including basalt). On the basis of velocity data alone, layers 2 and 3 might be interpreted as Franciscan rocks, but surface geologic data lead us to reject this interpretation. On the basis of velocity data alone, however, layer 4 is most likely not Franciscan rocks. Thus, if the middle and lower crust of the Salinian block represents a different terrane from the upper crust, as postulated by Ross and McCulloch (1979), that terrane is most likely not Franciscan assemblage.

In our cross section (fig. 8.4*B*), we show alternative interpretations of layer 4, given the alternative velocity models discussed above. In one interpretation (a, fig. 8.4*B*), layer 4 is entirely gneiss of intermediate composition. In a second interpretation (b, fig. 8.4*B*), layer 4a is intermediate gneiss, and layer 4b is gabbro. In interpretation a, no buried terranes are present; in interpretation b, the lower-crustal gabbro may be a buried terrane (oceanic crust) or magmatically underplated gabbro.

SANTA CLARA VALLEY—SAN ANDREAS TO CALAVERAS FAULTS

In the Santa Clara Valley, between the San Andreas and Calaveras faults, Franciscan assemblage (Permanente terrane; Blake and others, 1982) is overlain by outliers of Late Jurassic Coast Range ophiolite and Upper Cretaceous Great Valley sequence (McLaughlin

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and others, 1988a). The Franciscan assemblage includes melange, volcanogenic sandstone, pillow basalt, serpentine, chert, and limestone. The Franciscan sedimentary rocks were deposited in equatorial waters and presumably transported thousands(?) of kilometers northward before accretion to the North American Continent (Blake and others, 1982).

Along transect C2, the San Andreas fault juxtaposes a thick section of Tertiary marine sedimentary rocks on the southwest against slivers of Coast Range ophiolite, Great Valley sequence, and other Tertiary marine rocks on the northeast that have been imbricated along the southwest-dipping Sargent fault and related thrust faults (McLaughlin and others, 1988a). Presumably, the granitic rocks of the Salinian block and Franciscan assemblage are juxtaposed at depth. In contrast, similar rocks are juxtaposed on either side of the Calaveras fault, including Coast Range ophiolite, Great Valley sequence, and, at depth, presumably the Franciscan assemblage.

Aftershocks of the M=7.1 Loma Prieta earthquake of 1989 indicate a steep southwestward dip (approx 70°) on the San Andreas/Sargent fault zone, and the main shock produced subequal components of strike- and reverse-slip motion (Plafker and Galloway, 1989). Relatively low elevations in this region, however, indicated that the motion along this fault zone in the past has been chiefly strike slip, and seismicity before the Loma Prieta earthquake (Olsen and Lindh, 1985; Olsen, 1986) indicates a complex fault zone that may include both vertical and southwest-dipping fault strands (see fig. 8.4*B*).

Although a steep (80°–85°) eastward dip on the Calaveras fault is indicated by earthquakes (see cross sec. *D–D'*, fig. 5.7*B*; Reasenberg and Ellsworth, 1982; Oppenheimer and others, 1988), such an attitude is not resolvably different from a vertical dip (shown in fig. 8.4*B*), given errors in earthquake locations.

A seismic-refraction profile across the Santa Cruz Mountains and Santa Clara Valley reveals a heterogeneous upper crust (Mooney and Colburn, 1985). Layer offsets and velocity changes are visible in the model for this profile at the Zayante-Vergeles, Sargent, and Calaveras faults but, surprisingly, not at the San Andreas fault. An additional discontinuity is visible at an inferred buried fault in the central Santa Clara Valley (fig. 8.4*A*). Vertical zones of low velocity, 1 to 2 km wide, extending to a depth of as much as 3 to 5 km, are visible at a few of these faults (Mayer-Rosa, 1973; Blümling and others, 1985; Mooney and Colburn, 1985). The surficial layer (2.1–4.5 km/s) corresponds to different rocks in different places (fig. 8.4*B*). The "basement" layer has a velocity (5.4–6.0 km/s) appropriate for either granitic or Franciscan rocks at shallow crustal levels (Mooney and Colburn, 1985; see discussion above and fig. 8.5); presumably, it represents Franciscan rocks except west of the San Andreas fault. The higher-velocity basement (6.0 km/s) in the eastern Santa Clara Valley may represent metamorphosed Franciscan rocks. A strong reflector is visible at 8- to 9-km depth beneath the Santa Clara Valley, but the seismic velocity below it is unknown. By analogy with the strong midcrustal reflector in the Diablo Range (see below), we infer this reflector to be the top of accreted island-arc and (or) oceanic crust.

Moho depth beneath the Santa Clara Valley is not known accurately enough to resolve whether the Moho steps downward to the east at the San Andreas and Calaveras faults or dips smoothly eastward between control points in the Santa Cruz Mountains/Gabilan Range (24- to 26-km depth) and the Diablo Range (29- to 30-km depth). McEvilly and Clymer (1975) conducted a seismic-reflection survey across the San Andreas fault south of its junction with the Calaveras and found a crustal thickness of 24 km with no change in thickness across the fault. Peake and Healy (1977), however, indicated a change in crustal thickness at the fault in this area.

DIABLO RANGE

The Diablo Range, the east-central Coast Ranges between the Calaveras fault and the Great Valley, is underlain chiefly by Franciscan assemblage. These rocks constitute at least three thrust sheets or nappes that are folded into an antiform (fig. 8.4; Blake, 1981; Saleeby, 1986). The youngest thrust sheet, the Burnt Hills terrane (Blake and others, 1982; Saleeby, 1986), consists of mid-Cretaceous blueschist-facies graywacke, arkose, conglomerate, argillite, and chert, approximately equivalent in age and provenance to mid-Cretaceous forearc sedimentary rocks of the Great Valley sequence. The Burnt Hills terrane is exposed in the core of the antiform. The oldest thrust sheets are the Upper Jurassic (informal) Garzas tectonic melange (Cowan, 1974) and the Yolla Bolly terrane (Blake and others, 1982). The Garzas tectonic melange consists of mafic blueschist-amphibolite, greenstone, serpentinized peridotite, and metagraywacke; it contains fragments of Upper Jurassic rocks (Coleman and Lanphere, 1971; Suppe and Armstrong, 1972) similar to those accreted in the Sierran foothills during the Nevadan orogeny (see below). The Yolla Bolly terrane lithologically resembles the Burnt Hills terrane, although there are some important differences. Both the Garzas tectonic melange and Yolla Bolly terrane crop out on the flanks of the antiform. The Coast Range ophiolite and Great Valley sequence lie above the Franciscan rocks on the low-angle Coast Range fault, which is complexly offset by the steeply dipping Cenozoic Tesla-Ortigalita fault on the northeast flank of the Diablo Range (fig. 8.4). (We follow Jayko and others, 1987, in referring to the

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"Coast Range thrust fault" as simply the "Coast Range fault"—see below.)

The velocity structure of the Diablo Range derived by Walter and Mooney (1982) from seismic-refraction data collected by Stewart (1968) includes, beneath a 3.5- to 5.3-km/s near-surface layer, a 5.7- to 5.9-km/s layer beginning at 3-km depth, a 6.7- to 7.1-km/s layer beginning at 15-km depth, and the Moho at 29-km depth (fig. 8.4*A*). Importantly, a strong reflection is observed from the layer boundary at 15 km, indicating a strong velocity contrast between upper and lower crust. Blümling and Prodehl (1983) reanalyzed the same data and derived a similar velocity structure, except that they interpreted more phases in the data and added a lower-crustal low-velocity layer (5.3? km/s), with its base at about 26-km depth.

Seismic-reflection data have been collected in the eastern Diablo Range (Zoback and Wentworth, 1986) and compiled with other seismic data (Wentworth and others, 1987). These reflection data include a band of strong reflectors in the upper crust that dips shallowly east (reflectors a, fig. 8.4*A*), a weak reflector in the middle crust that dips shallowly west (reflector b), and a weak reflector at about 30-km depth (reflector c). The shallowly west-dipping reflector b, appears to link the top of the Great Valley basement with the top of the 6.7- to 7.1-km/s layer (Wentworth and Zoback, 1989).

Between 3- and 15-km depth, seismic velocities in the Diablo Range are well bracketed by velocity-depth curves predicted for end-member rocks of the Franciscan assemblage (fig. 8.5*B*; Steward and Peselnick, 1977; Lin and Wang, 1980). Within this depth range, the observed velocities also are slightly lower than those predicted for most granitic rocks (see fig. 8.5*A*). Between 15- and 20-km depth, the observed velocities agree well with those predicted for gabbro (fig. 8.5*B*; Lin and Wang, 1980) or, possibly, high-grade metamorphic rocks (Birch, 1960; Christensen and Fountain, 1975).

The 6.7- to 7.1-km/s layer in the Diablo Range may represent the middle and lower crust of an island arc or several imbricated island arcs. If so, this layer might include mixed intermediate and mafic plutonic rocks, including compositions from granodiorite to gabbro, as well as metamorphic rocks (see description of the Coast Range ophiolite by Evarts, 1977). Its relatively high velocity indicates that rocks of mafic composition must dominate or that the rocks are of amphibolite to granulite facies. This "island arc" interpretation is consistent with linking this layer to rocks beneath the Great Valley and thence to rocks of the Sierran foothills, which represent the middle and upper crust of island arc(s) (Saleeby, 1986). The 6.7- to 7.1-km/s layer, however, may also represent middle and lower oceanic crust, or diabase and gabbro, similar to the lowest layer of oceanic crust at the west end of transect C2 (fig. 8.4*A*). The 6.7- to 7.1-km/s layer is too thick, however, to represent a single layer of oceanic crust. It consists of either several slices of tectonically underplated oceanic crust or of oceanic crust that has been augmented by mafic intrusions after underplating. If the low-velocity zone of Blümling and Prodehl (1983) is present, the 6.7- to 7.1-km/s layer may include oceanic sedimentary rocks tectonically underplated along with the oceanic crust.

We show a fault contact between the Franciscan assemblage and the 6.7- to 7.1- km/s layer in the Diablo Range to reflect the eastward transport of a wedge of Franciscan rocks (fig. 8.4*B*), similar to that discussed by Wentworth and others (1984). This interpretation departs from that of Saleeby (1986), who linked the shallowly east-dipping reflectors in the eastern Diablo Range (a, fig. 8.4*A*) with a hypothetical subduction zone or thrust fault beneath the Great Valley and Sierran foothills (see section below entitled "Discussion—Tectonic Wedging").

GREAT VALLEY AND SIERRAN FOOTHILLS

Rocks of the Great Valley are known from exposures in an upturned section on the east side of the Diablo Range and from wells. The upturned section rests structurally above the Franciscan assemblage on the low-angle Coast Range fault, although in many places this relation is obscured by younger high-angle faults. This upturned section includes, from oldest to youngest, Middle and Late Jurassic Coast Range ophiolite and a related tuffaceous unit; Upper Jurassic and Cretaceous Great Valley sequence, which is chiefly forearc flysch; lower Cenozoic postarc marine and terrestrial sedimentary rocks; and upper Cenozoic continental-arc sedimentary rocks (Maddock, 1964; Evarts, 1977; Bartow and others, 1985).

At the latitude of transect C2, the Coast Range ophiolite is interpreted to be a (rifted) island-arc assemblage because it contains abundant silicic volcanic and intrusive rocks (Bailey and Blake, 1974; Evarts, 1977; Hopson and others, 1981; McLaughlin and others, 1988b). Its contact with the overlying sedimentary rocks, though faulted in most places, is believed to be fundamentally depositional (Bailey and others, 1970); on transect C2 it is demonstrably depositional (Evarts, 1977).

The Great Valley sequence and younger rocks exposed in the upturned section in the eastern Diablo Range appear to be nearly twice as thick as the section of sedimentary rocks penetrated in wells farther east in the Great Valley (fig. 8.4). Some of this apparent westward thickening results from the stratigraphic addition of older rocks to the basal part of the section in the west; some may be caused by imbrication along thrust faults (Wentworth and others, 1984). Similar apparent thickening

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west of the synclinal axis of the Great Valley has been documented in other localities as well. In the southern Great Valley, Wentworth and others (1984) indicated an apparent doubling of thickness west of the axis, and in the northern Great Valley, an apparent trebling of thickness.

Most of the basement rocks that have been penetrated by wells in the Great Valley have been identified as granitic rocks (Saleeby, 1986). Rocks exposed in the Sierran foothills, east of the Great Valley, may be related to basement rocks beneath the Great Valley, but they are not so dense or magnetic (see below; fig. 8.4*A*).

Deep structure along transect C2 in the Great Valley has been elaborated in some detail by Colburn and Mooney (1986), Holbrook and Mooney (1987), and Dean Whitman and others (unpub. data, 1985) from seismic-refraction data, and by Wentworth and others (1987) primarily from seismic-reflection data. Seismic velocities in the sedimentary section range from 1.6 to 4.1 km/s where these velocities can be clearly ascribed to sedimentary rocks, such as near well No. 1 (fig. 8.4*A*). In the eastern Diablo Range, velocities as high as 4.7 km/s may also be due to sedimentary rocks (fig. 8.4*A*). East of the synclinal axis in the Great Valley, reflections within the sedimentary section are subparallel to the top of basement, which is marked by the disappearance of reflections (f, fig. 8.4*A*). West of the synclinal axis, these reflections (d, fig. 8.4*A*) diverge slightly from the inferred top of basement (e, fig. 8.4*A*).

Beneath the sedimentary rocks of the Great Valley are several layers of increasing seismic velocity: a 5.5- to 5.7-km/s layer, 1.5 to 2 km thick (layer 1), a 6.0- to 6.3-km/s layer, 2.5 to 6 km thick (layer 2); a 6.6- to 6.75-km/s layer, 4 to 7 km thick (layer 3); and a 6.9- to 7.2-km/s layer, about 7 km thick (layer 4) (fig. 8.4*A*). In addition, there is a thin, laterally discontinuous 7.0-km/s layer embedded in the top of layer 3. Well No. 1 indicates that layer 1 is granitic rocks. Farther west, however, this layer may be interpretable either as granitic rocks or as Franciscan assemblage, which have similar velocities at this depth (fig. 8.5). In the original data of Colburn and Mooney (1986) and Holbrook and Mooney (1987), there is no perceptible reflection from an interface between layers 1 and 2 (as there is, for example, between layer 1 and the overlying sedimentary rocks), and so these two layers may, in fact, grade into one another. Layer 2 could then also be granitic rocks, and layers 1 and 2 together would constitute a velocity-depth section similar, for example, to upper crust of the batholithic Salinian block (figs. 8.4*A*, 8.5). Layers 3 and 4 (6.6–7.2 km/s), which are analogous to the lower-crustal layer in the Diablo Range (6.7–7.1 km/s), may represent the middle and lower crust of accreted island arc(s) and (or) oceanic crust. The Moho is well documented at about 27-km depth. Deep reflection data beneath the Great Valley (Wentworth and others, 1987) indicate a conspicuous east-dipping band of reflections (g, fig. 8.4*A*) and less conspicuous subhorizontal and west-dipping reflectors.

Rocks of the Sierran foothills consist of Lower to Upper Jurassic mafic to felsic volcanic and plutonic rocks and related sedimentary rocks (argillite, chert, and flysch) that were accumulated or emplaced in an island-arc setting (Clark, 1964; Schweickert and Cowan, 1975; Saleeby, 1982; Schweickert and Bogen, 1983). The basement and metamorphic wallrocks for the intrusive rocks are tectonically disrupted and polymetamorphosed Paleozoic ophiolitic rocks (approx 300 Ma; Saleeby, 1982).

The island arc(s) in which the Jurassic rocks of the Sierran foothills were formed collapsed against the margin of the North American Continent during the Late Jurassic Nevadan orogeny (Jones and others, 1976). How this collapse occurred is problematic. Steeply east-dipping faults and upright antiforms are seen in the Sierran foothills, but a study by Moores and Day (1984) of surface relations 300 km north of transect C2 indicates obduction of the arc(s) on west-dipping thrust faults. These rocks were intruded during the Early Cretaceous by mafic to intermediate plutons belonging to the western phase of Sierra Nevada plutonism (Evernden and Kistler, 1970).

The deep structure of the Sierran foothills is known from the reconnaissance seismic-refraction experiment of Spieth and others (1981), the reflection profiling of Zoback and Wentworth (1986), and the compilation of reflection, refraction, and potential-field results by Wentworth and others (1987). The refraction data can be modeled with a 6.2-km/s basement from near the surface to about 30-km depth, a 6.6-km/s lower crust, and a Moho at 39-km depth. Other models are possible, however, and the Moho may be as shallow as 30 km (Spieth and others, 1981). We have projected the seismic-reflection results and gravity/magnetic boundary of Wentworth and others (1987) from 45 to 60 km southward onto transect C2. Two conspicuous west-dipping sets of reflections are visible, as well as a few subhorizontal reflectors. The gravity/magnetic boundary, however, has a moderate eastward dip.

Our projection of the results of Wentworth and others (1987) is uncertain not only because of the distances involved but also because their profile terminates on the east in an area that is anomalous both geologically and geophysically. In this area, batholithic rocks (trondhjemite) engulf most accreted rocks of the Sierran foothills (Jennings, 1977) and are associated with a gravity low (Oliver and others, 1980). Our projection, however, may be defensible as follows. (1) The batholithic rocks responsible for the gravity low probably do not extend below 10-km depth (R.C. Jachens, oral commun., 1988); most of the reflectors that we have projected are largely below

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that depth. (2) The modeled gravity/magnetic boundary is approximately similar in shape throughout the length of the Great Valley (Andrew Griscom, oral commun., 1988); in our projection, we have attempted to correct for the difference in azimuth between transect C2 and the profile of Wentworth and others (1987) by assuming a strike parallel to the Great Valley.

Given the geologic and seismic constraints discussed above, we have interpreted the cross section through the Great Valley and Sierran foothills (fig. 8.4*B*), using some of the ideas of Wentworth and others (1984, 1987) for the configuration of an inferred tectonic wedge of Franciscan rocks, and some of the ideas of Saleeby (1986) for structure within crystalline rocks. The uppermost part of our cross section (to approx 2-km depth) on the east flank of the Diablo Range (fig. 8.4*A*) was supplied by R.C. Evarts (written commun., 1989). Below this area, we have added a hypothetical west-dipping thrust fault to bring the Great Valley sequence beneath the easternmost block of the Coast Range ophiolite and to grossly satisfy the velocity constraints of Dean Whitman and others (unpub. data, 1985; fig. 8.4*A*). East of the Coast Range ophiolite, we postulate thrust faults that largely follow bedding planes in the upturned section of the Great Valley sequence, similar to those postulated by Wentworth and others (1984) for the northern Great Valley. These "backthrust" faults are required for emplacement of the wedge and help explain the thickening of the Great Valley sequence in the western limb of the syncline (see section below entitled "Discussion—Tectonic Wedging"). From the easternmost backthrust fault in the Great Valley to the San Andreas fault, we have modeled the discontinuity between variably reflective rocks of lower velocity (Franciscan assemblage, Coast Range ophiolite, and Great Valley sequence; 1.7–5.8 km/s) and poorly reflective rocks of higher velocity (mafic rocks of the Diablo Range and crystalline basement of the Great Valley; 5.5–6.8 km/s) as the floor thrust fault of the wedge. Wentworth (1987) presented a similar interpretation.

The details of composition and structure in the crystalline rocks beneath the Great Valley and Sierran foothills are speculative. Saleeby (1986) interpreted these rocks to consist fundamentally of slabs or nappes of island-arc and oceanic rocks obducted along west-dipping Nevadan thrust faults intruded by chiefly Early Cretaceous Sierran granitic plutons. We have adopted this basic scheme and added some details, interpreting layers 1 and 2 in the basement beneath the Great Valley (5.5–6.3 km/s; see above) as post-Nevadan felsic plutonic rocks, although, as noted above, the western part of layer 1 (5.5 km/s) may be Franciscan assemblage. We interpret the east-dipping gravity/magnetic boundary of Wentworth and others (1987) as the average top of mafic crust (pre-Nevadan gabbro, diabase, or basalt) in the inferred obducted sequence. Alternatively, this boundary may be the average top of mafic, magnetic intrusions in the crust (post-Nevadan gabbro) or the average base of felsic, nonmagnetic intrusions (post-Nevadan granitic rocks). At the location where this boundary was actually modeled, it may be the average base of a large trondhjemite intrusion. We associate the east-dipping reflections beneath the central Great Valley (g, fig. 8.4*A*) with the thin, discontinuous 7.0-km/s layer of Holbrook and Mooney (1987), although the depth correspondence is imperfect, and we interpret this feature as a gabbroic dike. Alternatively, these east-dipping reflections may represent an east-dipping fault zone. Following Saleeby (1986), we correlate the upper and lower west-dipping bands of reflections in the eastern Great Valley and Sierran foothills (h, j, fig. 8.4*A*) with the Bear Mountain and Melones fault zones, which may represent Cenozoic reactivations of inferred west-dipping Nevadan thrust faults.

DISCUSSION—TECTONIC WEDGING

GEOLOGIC HISTORY

Wentworth and others (1984) interpreted the juxtaposition of Franciscan assemblage and a coeval section consisting of Coast Range ophiolite and Great Valley sequence as having occurred during landward movement of the Franciscan assemblage as a tectonic wedge. They reinterpreted the "Coast Range thrust fault" of Bailey and others (1970), a subduction megathrust between the Coast Range ophiolite and the Franciscan assemblage, as the roof thrust of the wedge. More recently, the thrust nature of the "Coast Range thrust fault" has been reevaluated. Jayko and others (1987), testing an hypothesis by Platt (1986), produced abundant evidence that the contact between Franciscan assemblage and Coast Range ophiolite is a detachment surface along which the upper plate was extended during uplift of the Franciscan assemblage. Their evidence is the consistent attenuation, as opposed to repetition, of geologic section across this discontinuity and associated faults above it. They proposed the term "Coast Range fault" for this discontinuity, which we adopt here. Evidence of attenuation is present even on transect C2, in that the two outcrops of the Coast Range ophiolite in the eastern Diablo Range (fig. 8.4*A*) represent an abridged section of ophiolite: The western outcrop is partially serpentinized ultramafic rock of the basal part of an ophiolite, whereas the eastern outcrop is the sill complex and volcanic flows of the upper part of an ophiolite. These two parts of the ophiolite are now juxtaposed across the crooked, steeply dipping Tesla-Ortigalita fault. Although this fault now offsets the

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Coast Range fault, it may represent reactivation of a normal fault that originally soled into the Coast Range fault (compare Raymond, 1973).

The extensional nature of the Coast Range fault poses several problems for emplacement of the Franciscan assemblage as a tectonic wedge. Where is the roof thrust fault of the wedge? How did the Franciscan assemblage reach its current position with an extended overlying section of the Coast Range ophiolite and Great Valley sequence? Was the Franciscan assemblage uplifted from beneath the western Great Valley? The apparent continuity between the Great Valley basement and the 6.7- to 7.1-km/s layer in the Diablo Range indicates a negative answer to the last question.

These problems can be solved if the extensional event was separated in time and space from the compressional event, or tectonic wedging. Jayko and others (1987) reviewed the published evidence regarding the geologic history of extensional faulting. In one place, the Coast Range fault and associated faults are overlapped by sedimentary rocks of Oligocene and younger age, and in another place by sedimentary rocks of Paleocene and younger age. The occurrence of detritus derived from the Franciscan assemblage in Paleocene and Eocene strata of the Coast Ranges (Dickinson, 1966; Berkland, 1973) indicates that the lower plate was exposed by the early Tertiary. Jayko and others (1987) inferred that uplift of the Franciscan assemblage and associated extensional faulting in the upper plate occurred during the Late Cretaceous and (or) early Tertiary.

The history of compressional tectonics in the Coast Ranges is sparse and varies from place to place. In the northern Coast Ranges, thrust faulting and folding began during the early Tertiary (Blake and others, 1987; M. C. Blake, Jr., oral commun., 1989), and compressional deformation is continuing today in rocks of the northern Great Valley (Harwood and Helley, 1987). In the southern Coast Ranges, at least four Cenozoic deformations or uplifts, indicated by unconformities or eastward-migrating depocenters, have ages of late Paleocene, late Eocene to early Miocene, late Miocene, and late Pliocene (Namson and Davis, 1988; Namson and others, 1990; Rentschler and Bloch, 1988). Modern thrust faulting and folding still is occurring, as indicated by the 1983 Coalinga earthquake (see chap. 5; Eaton, 1990).

Landward movement of the Franciscan assemblage as a wedge may have even begun in the Mesozoic. In the northern Coast Ranges, several northwest-striking faults (Paskenta, Elder Creek, and Cold Fork faults) offset rocks structurally above the Franciscan assemblage (but not the Franciscan assemblage itself) and represent major discontinuities in the depositional environment of the Great Valley sequence (Jones and Irwin, 1971). These faults, which have displacements of tens of kilometers to as much as 100 km, are interpreted to have moved primarily during the Cretaceous (Jones and Irwin, 1971), although the latest limit on the time of movement is about 3.4 Ma (Hardwood and Helley, 1987; M.C. Blake, Jr., oral commun., 1989). Wentworth and others (1984) and Jayko and others (1987) interpreted these faults as tear faults in the plate structurally above a wedge of Franciscan assemblage.

In light of the above data and interpretations, we postulate (1) that uplift of the Franciscan assemblage and extension of the upper plate, consisting of Coast Range ophiolite and Great Valley sequence, occurred during the Cretaceous (or, at the latest, during the early Tertiary, if Cretaceous movement on the Paskenta-Cold Fork fault system is not linked to landward wedge transport) well west of the present Diablo Range; and (2) that a tectonic wedge of Franciscan assemblage was subsequently driven landward, with the extended upper plate riding passively atop it. This wedge is interpreted to have moved along a floor thrust fault aligned with the contact between the Great Valley sequence and its crystalline basement. To the west of the present Diablo Range, where movement initiated, the basement was an outboard part of the Coast Range ophiolite. Beneath the Great Valley, where the movement is presently occurring, the basement is similar to the Coast Range ophiolite but contains numerous younger plutons. A roof thrust fault apparently developed only near the east tip of the wedge (fig. 8.4*B*); presumably, erosion kept pace with uplift near the tip. Differential vertical or horizontal movements of the wedge may have produced tear faults, such as the Paskenta, Elder Creek, and Cold Fork faults, and may have reactivated extensional faults to produce complex faults, such as the Tesla-Ortigalita fault.

PAST AND PRESENT TECTONIC REGIMES

The Mendocino triple junction has moved northward through offshore central California during approximately the past 20 Ma, and subduction of the Farallon plate (or its derivative) was replaced by transform motion of the Pacific plate past North America (see chap. 3; Atwater, 1970, 1989). If tectonic wedging occurred during the late Mesozoic and Cenozoic, in association with all of the episodes of tear faulting or compression outlined above, then clearly it was driven during both subduction and transform regimes. At present, it is being driven by a transform regime. At least two additional arguments can be made that wedge motion—indeed, probably a major fraction of wedge motion—occurred during the subduction regime. The first argument is simply based on geometry: The east boundary of the Coast Ranges, inferred to coincide approximately with the buried tip of the wedge, largely parallels Mesozoic structures in the

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Sierran foothills and the Great Valley rather than the late Cenozoic San Andreas fault (Wentworth and Zoback, 1989; C.M. Wentworth, oral commun., 1990). The second argument, developed below, is based on the total apparent displacement of the wedge.

If the inferred tectonic wedge of Franciscan assemblage extends to the San Andreas fault, as we have shown (fig. 8.4*B*), then a minimum shortening of about 70 km has occurred along faults at the top and bottom of the wedge in the Diablo Range. Likewise, in the northern Coast Ranges, the inferred tear faults in the plate above the wedge have a total displacement—and, thus, shortening—of many tens of kilometers (Wentworth and others, 1984), possibly as much as 100 km (Jones and Irwin, 1971).

Although a transform regime has replaced a subduction regime in central California over approximately the past 20 Ma, plate-margin compression, necessary to drive the wedge, has persisted for only approximately the past 5 Ma (Page and Engebretson, 1984). At about 5.5–4.5 Ma, transform motion was also transferred from offshore faults to the modern San Andreas fault system (see chap. 3; Atwater, 1989; Humphreys and Weldon, in press). Present plate-margin compression is understandable from (1) the slight misalignment of the direction of relative plate motion (N. 35° W.; Minster and Jordan, 1978) and the strike of the San Andreas fault (N. 40° W.), and (2) the opening of the Basin and Range province. Crouch and others (1984) calculated from these two effects a rate of shortening across the Coast Ranges that, integrated over the past 5.5 Ma, predicted a total shortening of 28 to 72 km. Most of this shortening could be accounted for in small fault displacements and folds distributed throughout the Coast Ranges (Crouch and others, 1984). Thus, the minimum shortening of 70 to 100 km represented by the tectonic wedge, as discussed above, would appear to equal or exceed the maximum shortening calculated for the transform regime, a result suggesting that some, if not most, of the wedge motion occurred during the subduction regime.

Shear coupling between the subducting plate and overlying accretionary prism (Franciscan assemblage) could conceivably drive the wedge during the subduction regime. Such a mechanism has been postulated for southern Alaska by Fuis and Plafker (in press). To drive the wedge during a transform regime appears to require a less obvious mechanism, such as plate-margin compression combined with differing deformation in the upper and lower crust. Such a mechanism is developed below.

Sibson (1982) pointed out, on the basis of strength considerations, that ductile flow could be expected in the middle crust, below the maximum depth of earthquake hypocenters. Several workers (Crouch and others, 1984; Namson and Davis, 1988; Eaton and Rymer, in press) have postulated a decollement near the base of the seismicity in the Coast Ranges (avg 15-km depth; see chap. 5; Wesson and others, 1973) into which thrust and oblique-slip faults on both sides of the Coast Ranges sole. They envision differential movement between upper and lower crust caused by differing alignment of the transform faults in these two layers, or by shortening of the lower crust by ductile thickening.

We have incorporated the idea of a Coast Range-wide detachment in our cross section (fig. 8.4*B*). In the Diablo Range, we show a young thrust fault at the base of the inferred tectonic wedge soling into the brittle-ductile transition zone, which in this area is, coincidentally, near the interface between Franciscan rocks and mafic crust. Although we also indicate soling of the San Gregorio-Hosgri fault into such a zone and underthrusting of the Salinian block by the early Tertiary accretionary prism, focal mechanisms in this region indicate pure strike slip on the San Gregorio-Hosgri fault (see chap. 5) and argue against this interpretation. Such an interpretation of a Coast Ranges-wide midcrustal detachment requires that the deformational style and (or) location of the San Andreas fault system change from the upper to the lower crust.

If we have correctly inferred the geologic history of wedge movement, it is remarkable that such movement has apparently occurred in two quite different tectonic regimes, a subduction regime and a transform regime.

SOUTHERN CALIFORNIA

The crustal structure of southern California is complicated by the Big Bend in the San Andreas fault, situated between the Coast Ranges and Transverse Ranges, and by onshore spreading centers of the East Pacific Rise, situated in the Salton Trough (figs. 8.2, 8.3). The Big Bend is thought to result from westward movement of the Sierra Nevada relative to the Mojave Desert, along the Garlock fault (Hill and Dibblee, 1953). The San Andreas fault crosses the Transverse Ranges, between the Big Bend and Salton Trough, at an angle oblique to relative plate motion, while somehow remaining a largely vertical, strike-slip fault.

The onshore spreading centers in the Salton Trough are situated at echelon offsets between the San Andreas, Imperial, and Cerro Prieto faults (see fig. 3.8; Lomnitz and others, 1970). These three faults are interpreted as transform faults; the San Andreas links the northernmost spreading center in the Salton Trough with the Mendocino triple junction. A progressive decrease in spreading rate northward along the East Pacific Rise is inferred to give rise to movement on the San Jacinto, Elsinore, San Miguel/Newport-Inglewood, and other faults in southern

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California and Mexico (Lomnitz and others, 1970; Elders and others, 1972).

First, we discuss a transect across southern California, Centennial Continental-Ocean Transect C3 (Howell and others, 1985). Second, because of the three-dimensionality of the geology and tectonics in southern California, we include a discussion of block motions, largely from Weldon and Humphreys (1986).

TRANSECT C3

We modify and reinterpret the section of Centennial Continent-Ocean Transect C3 (Howell and others, 1985) that extends from Santa Catalina Island to the Colorado Desert (fig. 8.2). This section of the transect crosses four blocks or provinces, the California Continental Borderland (hereafter referred to simply as the "borderland"), Peninsular Ranges, Salton Trough, and Chocolate Mountains (fig. 8.6). The transect crosses the Newport-Inglewood, Elsinore, San Jacinto, and Imperial strike-slip faults. Constraints for the transect include surface geology, isotopic studies, seismic-refraction profiling (which is sparse, except in the Salton Trough), tomographic studies, and potential-field studies.

BORDERLAND

The borderland is broken up by right-slip faults into several northwest-trending blocks. Our cross section (fig. 8.6) begins on the easternmost block, the "Catalina terrane" (Howell and others, 1985), bounded on the east by the Newport-Inglewood fault. The Catalina terrane is underlain, beneath patches of Tertiary volcanic rocks, by Franciscan assemblage, on the basis of outcrops on Santa Catalina Island (Platt, 1975, 1976; Jones and others, 1976) and submarine dredge and core samples (Vedder and others, 1974). The block west of the Catalina terrane, the "San Nicholas terrane" (Howell and others, 1985), is inferred to be underlain, beneath Cenozoic marine sedimentary rocks, by rocks similar to the Great Valley sequence and Coast Range ophiolite of central California, possibly in fault contact with Franciscan assemblage at depth (Vedder and others, 1974).

A reversed seismic-refraction profile just west of Santa Catalina Island indicates *P*-wave velocities of 5.8 km/s to 6-km depth and of 6.7 km/s to the Moho at about 24-km depth (fig. 8.6*A*, Shor and Raitt, 1958). This velocity-depth section is similar to that for the Diablo Range of central California (see above), where Franciscan rocks are equated with the 5.8-km/s interval, and middle and lower crust of island arc(s) and (or) oceanic crust are equated with the 6.7-km/s interval. In this region, there is no clear evidence of landward movement of the Franciscan assemblage as a tectonic wedge, although such evidence may surface during future investigations. As in the Diablo Range, the lower crust must have been brought to its present 18-km thickness by (1) imbrication of slices of island-arc crust, (2) tectonic underplating of several thicknesses of oceanic crust, and (or) (3) magmatic underplating. Subduction continued beneath the borderland until sometime between 30 and 20 Ma (see Atwater, 1970), depending on the latitude to which the borderland is palinspastically restored.

PENINSULAR RANGES

The Peninsular Ranges are underlain in the west by supracrustal rocks, including, from top to bottom, Cenozoic marine sedimentary rocks, Cretaceous forearc sedimentary rocks, Lower(?) Cretaceous and Upper Jurassic andesite (Santiago Peak Volcanics), and Middle Jurassic flysch (Bedford Canyon Formation) that was disrupted and overturned before the Late Jurassic (Larsen, 1948; Jennings, 1977; Criscione and others, 1978). These rocks are intruded by Early Cretaceous plutons of the Peninsular Ranges batholith that include chiefly tonalite and gabbro and show no special age trends (static magmatic arc; Silver and others, 1979). About 80 km east of the coastline, both prebatholithic and batholithic rocks change (fig. 8.6*A*): To the east, the prebatholithic rocks are dominantly metamorphosed clastic rocks of amphibolite grade, and the batholithic rocks are chiefly tonalite and granodiorite whose ages decrease progressively eastward (from 105 to 80–90 Ma; migrating magmatic arc; Silver and others, 1979). Major-element chemistry and oxygen isotopes indicate that deep crustal rocks in the west half of the batholith are dominantly primitive and tholeiitic but, in the east, more aluminous and oxidized (fig. 8.6*A*). Older crust that was once at the Earth's surface is inferred at depth in the east (Silver and others, 1979).

Seismic constraints for the deep structure of the Peninsular Ranges are sparse. Using blasts at the Corona Quarry in the northernmost Peninsular Ranges, Gutenberg (1951) and Shor (1954) obtained an unreversed refraction profile, extending southward to the United States-Mexican border, along with a reflection record at the blast site. Interpretation of these data by Shor and Raitt (1958) indicated velocities of 5.9 km/s to 8-km depth, 6.8 km/s to 26-km depth (with a possible low-velocity zone in this interval), and 7.0 km/s to the Moho at 30- to 32-km depth (fig. 8.6*A*). In contrast, a study by Nava and Brune (1982) using a blast at the same quarry, reversed by an earthquake in Baja, Mexico, indicated a Moho depth of 42 km. Hearn and Clayton (1986a, b) used as many as 600,000 arrivals from local earthquakes in southern California to map the velocity of the crust and upper mantle, using tomography. Their map indicates

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that the west half of the Peninsular Ranges has a higher average upper-crustal velocity and a lower average mantle velocity in comparison with the east half. Their map of P_n delays for the Peninsular Ranges suggests no crustal root and an average crustal thickness of nearly 30 km. Gravity modeling of the Peninsular Ranges (Fuis and others, 1984) and isostatic calculations also indicate a maximum crustal thickness of 30 to 33 km. In our cross section (fig. 8.6*B*), we adopt a maximum crustal thickness of 33 km.

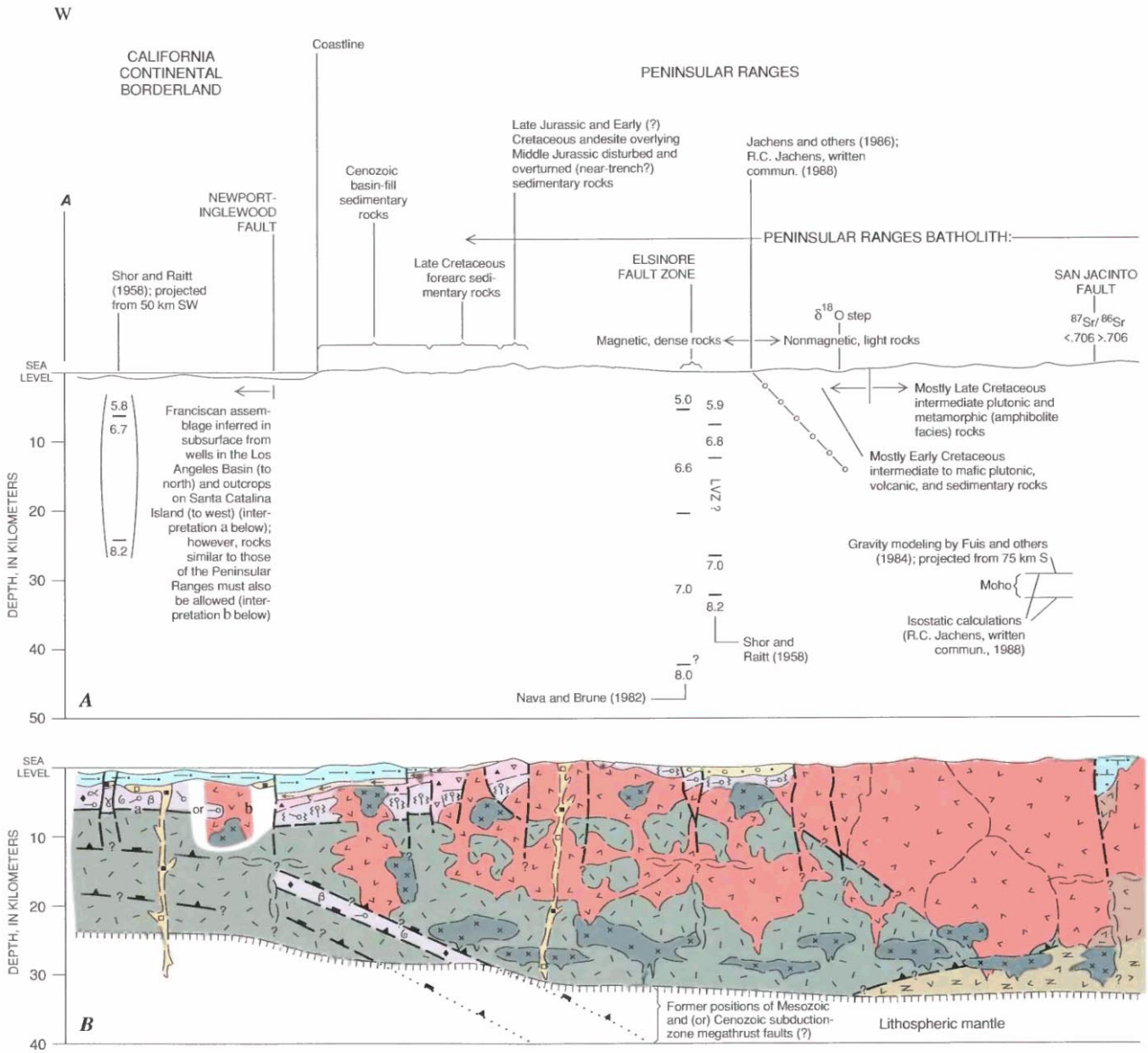

FIGURE 8.6.—Crustal structure of southern California. *A*, Surface geology, isotope data, and models of seismic-refraction, gravity, and magnetic data for part of Centennial Continent-Ocean Transect C3 (see Howell and others, 1985). *B*, Reinterpretation of Transect C3. Major features in figure 8.6*B* include, from west to east, (1) Franciscan assemblage overlying mafic crust in the borderland; (2) Peninsular Ranges batholithic block, consisting of west half inferred to be underlain at depth by mafic (island arc or oceanic) crust and east half inferred to be underlain at depth by intermediate continental Precambrian(?) rocks; (3) late Cenozoic rift, the Salton Trough, whose central part is inferred to be underlain by entirely new crust that includes, from top to bottom, sedimentary rocks, thermally metamorphosed sedimentary rocks, and gabbro generated at onshore

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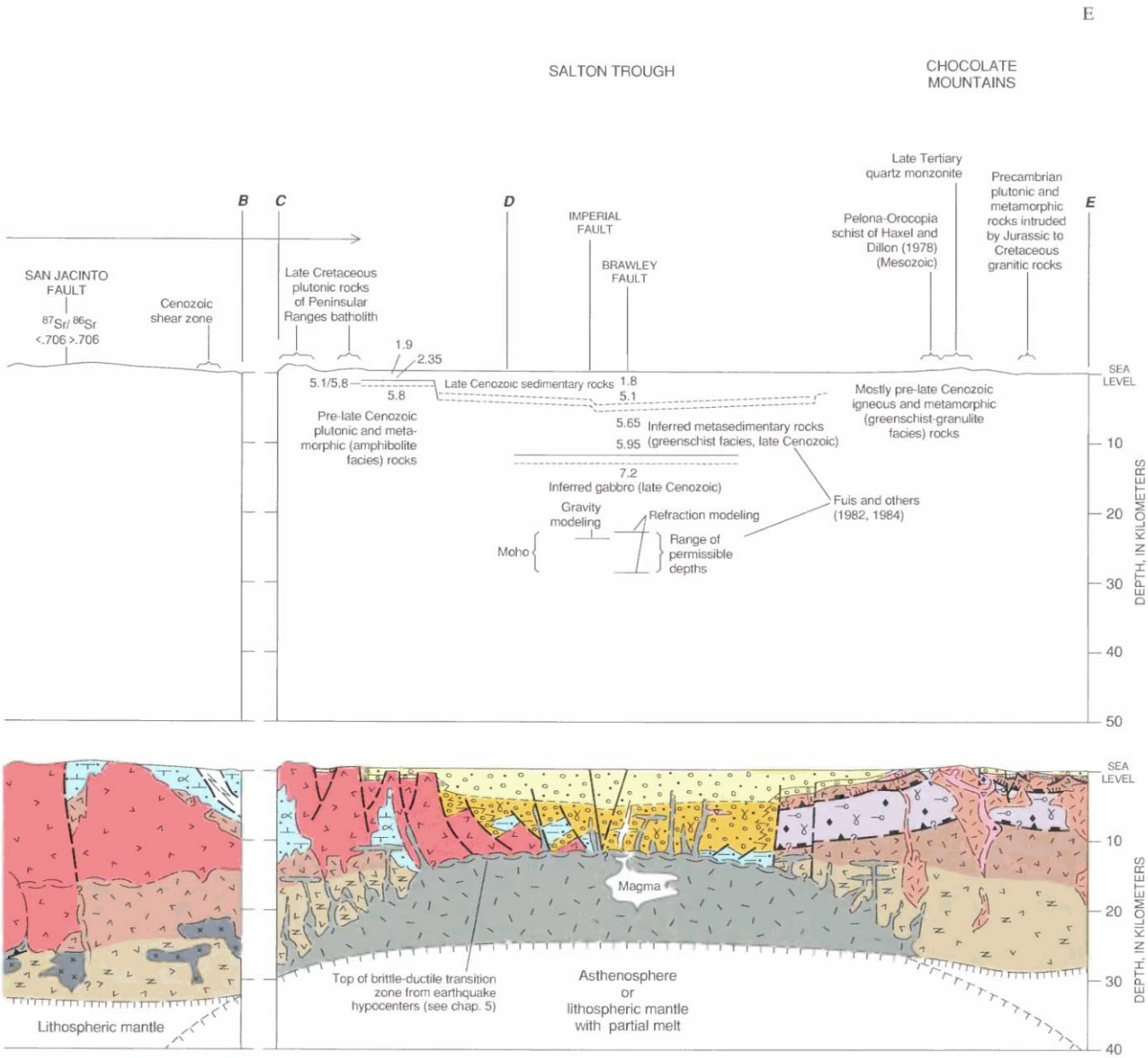
An additional constraint on crustal structure is the modeling by Jachens and others (1986; R.C. Jachens, written commun., 1988) of strong magnetic and gravity steps (500 nT and 40 mGal, respectively) in the central Peninsular Ranges: A moderately east dipping boundary is modeled between more magnetic, dense rocks on the west and less magnetic, lighter rocks on the east. This boundary is poorly defined at the latitude of our transect; it correlates approximately (within 15 km or so) with the boundary between the east and west halves of the



spreading center; and (4) Pelona-Orocopia schist of Haxel and Dillon (1978) (similar to the Franciscan assemblage), interpreted to compose tectonic wedge. Tectonic wedge in feature 4 is postulated to have been obducted onto continental crust (see text); its tip would lie well east of east end of cross section. This reinterpretation differs from Howell and others' (1985) primarily in interpreting mafic crust at shallower depths beneath the borderland and western Peninsular Ranges (5–8 km versus 11–15 km) to better match seismic and potential-field results. See figures 8.2 and 8.3 for location of Transect C3; see figure 8.4 for explanation. No vertical exaggeration.

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Peninsular Ranges batholith, as discussed above (fig. 8.6*A*). In the cross section (fig. 8.6*B*), we interpret an eastward deepening of mafic rocks, including prebatholithic and (or) batholithic mafic rocks (gabbro, diabase, and metamorphic rocks), along this magnetic/gravity boundary. R.C. Jachens (oral commun., 1989) indicated that, in some places, this boundary is so planar as to be interpretable as a fault. As beneath the borderland, the mafic rocks beneath the Peninsular Ranges may have reached their current thickness by thrust imbrication, tectonic underplating, or magmatic underplating. We speculatively show some tectonic underplating on the west side.

SALTON TROUGH

The Salton Trough is the landward extension of a ridge/transform-fault system, the East Pacific Rise, of the Gulf of California (see fig. 3.13). This system became well established during the late Cenozoic (approx 5 Ma) as the plate boundary jumped inland from offshore Baja California (Atwater, 1970, 1989; Humphreys and Weldon, in press).

The Salton Trough is underlain by upper Cenozoic sedimentary rocks and minor amounts of volcanic rocks, which are exposed chiefly around its edge and are penetrated in wells. Onset of rifting and major subsidence in the Salton Trough was followed by marine incursion during the latest Miocene to late(?) Pliocene, as indicated by the Imperial Formation (Dibblee, 1954; Powell, 1984). The thick Cenozoic sedimentary section is offset by Quaternary faults, both exposed and buried, and is intruded by Quaternary volcanic rocks, both silicic rocks that form volcanoes at the two inferred onshore spreading centers (fig. 8.7) and mafic rocks that are penetrated in geothermal wells (Elders and others, 1972; Robinson and others, 1976). Faulting in the Salton Trough occurs primarily on conjugate northwest- and northeast-striking faults and is largely strike slip (Johnson and Hadley, 1976; Johnson, 1979; Fuis and others, 1982). North-south-striking faults, however, such as the north end of the Imperial fault, the Brawley fault, and north-south-striking seismicity lineaments (that outline inferred spreading centers; figs. 8.1, 8.7), have normal components and lead to the subsidence that ultimately created the Salton Trough. Earthquake hypocentral depths indicate that brittle fault motion extends to about 12-km depth in the Imperial Valley but deeper in the adjacent Peninsular Ranges along the San Jacinto fault (Doser and Kanamori, 1986).

Detachment faulting on the east flank of the Salton Trough, in the Chocolate Mountains and other ranges, preceded the Pliocene and later basin-forming tectonics in the Salton Trough (Dillon, 1975; Berg and others, 1982; Frost and others, 1982). Similar faulting on the west flank of the Salton Trough, however, may have both preceded and overlapped in time the tectonics in the Salton Trough (Wallace and English, 1982; Schultejahn, 1984; Isaac and others, 1986).

Biehler and others (1964) and Fuis and others (1982, 1984) demonstrated from seismic surveys that the sedimentary rocks (1.8–5.5 km/s) in the central Salton Trough are as much as 5 km thick (fig. 8.6*A*). Below 5-km depth, a low-velocity (5.6 km/s) "basement," which is not separated from the overlying sedimentary rocks by a velocity discontinuity, is inferred to be metamorphosed (greenschist facies) sedimentary rocks (Fuis and others, 1982, 1984); this "basement" layer extends to 12-km depth. High heat flow in the Salton Trough (see Lachenbruch and others, 1985) is inferred to cause the metamorphism of the sedimentary rocks. Thus, the entire section of inferred upper Cenozoic sedimentary rocks, metamorphosed and unmetamorphosed, is as much as 12 km thick.

Below 12- to 14-km depth in the Salton Trough, a high-velocity (7.1–7.2 km/s) "subbasement" that is indicated by seismic-refraction data (fig. 8.6*A*) is inferred to be gabbro generated at one of the nearby spreading centers (Fuis and others, 1982, 1984). Modeling of seismic-refraction and gravity data indicate that the Moho in the central Salton Trough is 23 to 28 km deep (Fuis and others, 1982, 1984). The central Salton Trough is interpreted to be underlain entirely by late Cenozoic crust (fig. 8.6*B*).

Buried scarps separating old crust (plutonic and metamorphic rocks; 5.9–6.0 km/s) from new crust (sedimentary and basaltic rocks; 1.8–7.2 km/s) are visible by seismic methods on both sides of the Salton Trough (Fuis and others, 1982; Fuis and Kohler, 1984). On the west side of the rift, where the new-crust/old-crust boundary is ragged in outline (fig. 8.7), we interpret normal faults

FIGURE 8.7.—Tectonic block motion in southern California (modified from Weldon and Humphreys, 1986, and Humphreys and Weldon, in press). Various blocks (italicized names near motion vectors) move through region where the San Andreas fault trends obliquely to plate motion, between the Big Bend and the Salton Trough, without major convergence with each other. Through this region they move counterclockwise, following nearly concentric arcs (arcs and radii, thin red lines). New crust, which is forming in wake of the Salton and Perris blocks in the Salton Trough, is created by sedimentary-basin fill and gabbroic intrusions at onshore spreading centers, outlined by seismicity lineaments. High-velocity mantle beneath the Transverse Ranges is interpreted as cold, sinking lithospheric mantle, and low-velocity mantle beneath the Salton Trough as hot upwelling asthenosphere or lithospheric mantle containing partial melt (Humphreys and others, 1984; Humphreys and Clayton, in press). Motion vectors for the Mojave Desert and Sierra Nevada modified to incorporate results of Sauber and others (1986).

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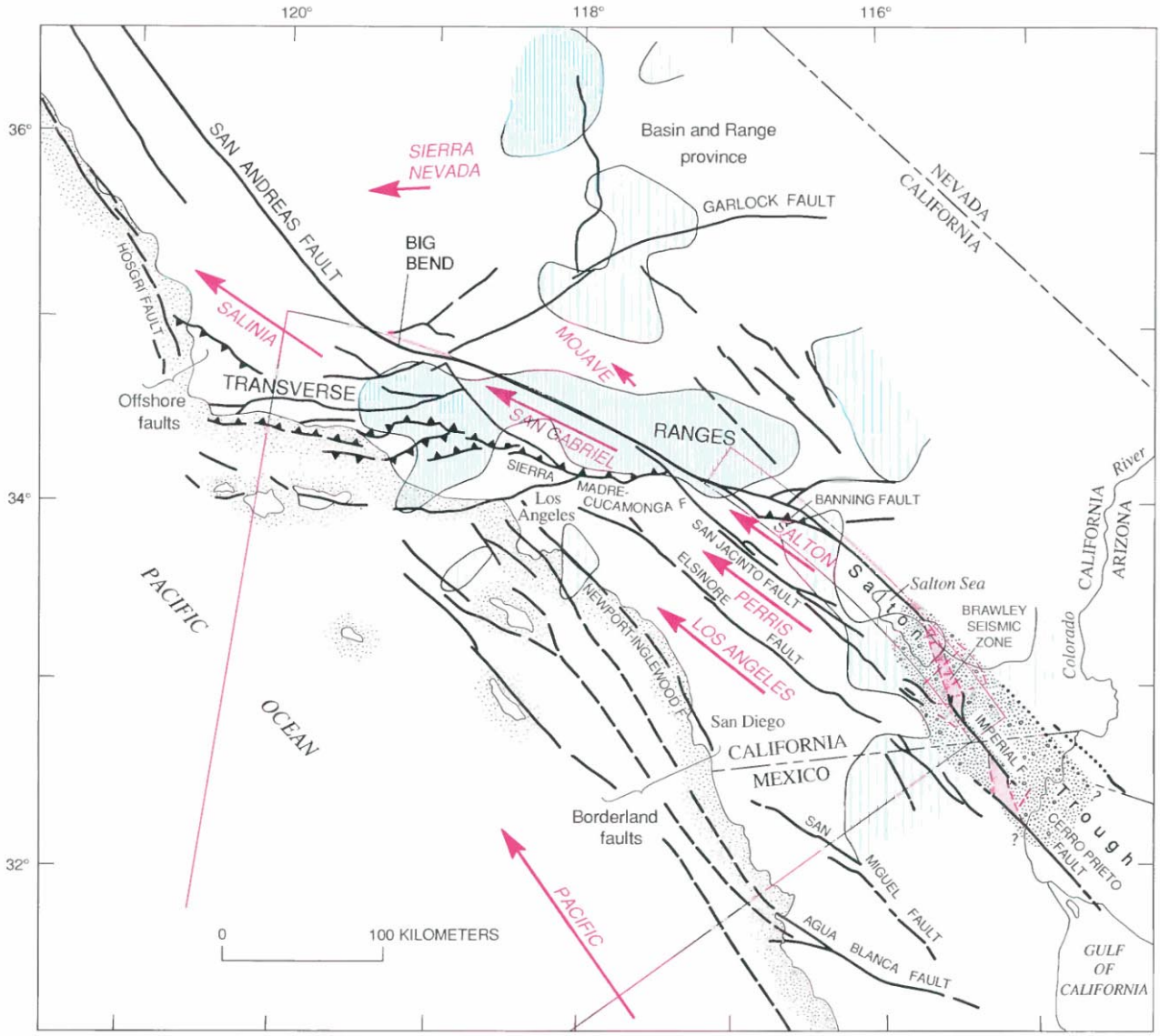
(fig. 8.6*B*); on the east side, where this boundary is linear, we interpret a strike-slip fault. In our cross section, faults on the west side of the Salton Trough are inferred to have originated by pullaway from the Cerro Prieto spreading center to the southeast; the fault on the east side is inferred to be a largely passive suture (figs.



EXPLANATION

- Motion vector of tectonic block—Relative to North America (Vector scale 20 mm/yr)
- New crust (late Cenozoic)
- Onshore spreading center
- High-velocity mantle
- Low-velocity mantle
- Seismicity lineament
- Fault—Dashed where approximately located; dotted where buried
- Thrust fault—Dashed where approximately located. Sawteeth on upper plate

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8.6*B*, 8.7; Fuis and others, 1982). A similar rift configuration is seen, for example, in the Gulf of Elat (Gulf of Aqaba, Red Sea; Ben-Avraham, 1985).

CHOCOLATE MOUNTAINS

Rocks on the east flank of the Salton Trough are igneous and metamorphic rocks that compose two or more fault-bounded packages, or tectonostratigraphic terranes (see Howell and others, 1985). A complex of metasedimentary and mafic metaigneous rocks described by Dillon (1975) may include two Precambrian terranes, the Joshua Tree and San Gabriel terranes, described farther north by Powell (1981). This complex is intruded by intermediate to felsic Mesozoic plutons and rests on the low-angle Chocolate Mountains thrust fault above the (informal) Pelona-Orocopia schist of Haxel and Dillon (1978; see also Haxel, 1977). The Pelona-Orocopia schist consists chiefly of metagraywacke and lesser metapelite, metabasite, metachert, marble, and serpentinite (albite-epidote-amphibolite facies) of uncertain but probable late Mesozoic or early Tertiary age (Conrad and Davis, 1977; Miller and Morton 1977, 1980). It resembled the Franciscan assemblage but lacks melange.

Many workers have speculated on the depositional environment and origin of the Pelona-Orocopia schist. Haxel and Dillon (1978) postulated formation in an ensimatic rift basin with continent on both sides—not unlike the current Salton Trough. Powell (1981) favored an origin as a parautochthonous continental-marginal deposit. In any case, from its quartz content, the Pelona-Orocopia schist clearly originated near a continent and incorporated continental detritus. It was thrust beneath the continental metasedimentary-metaigneous complex some time after Mesozoic plutonism (80 Ma; Powell, 1981) and before Oligocene volcanism (35 Ma; Crowe 1978; Crowe and others, 1979). The thrust fault may have been reactivated one or more times as a low-angle normal, or detachment, fault (Frost and others, 1982).

Evidence from refraction profiling in the western Mojave Desert across the Rand schist, which has been correlated with the Pelona-Orocopia schist (Ehlig, 1968), indicates relatively low-velocity crust beneath this body (max 6.4 km/s; Fuis and others, 1986) that we infer to be continental crust. We speculate that the Pelona-Orocopia schist also rests on continental crust and that the Rand and Pelona-Orocopia schists were emplaced as a tectonic wedge into continental crust in a manner similar to the Franciscan assemblage of central and northern California. We hypothesize that the metasedimentary-metaigneous complex structurally above the schist is analogous to either (1) rocks of the Coast Range ophiolite/Great Valley sequence which rode passively atop the wedge in central and northern California after being extended during uplift of the Franciscan assemblage, or (2) rocks of the Great Valley sequence which were peeled up along backthrust faults during landward movement of the wedge. In southern California, tectonic wedging clearly occurred before the present transform regime, presumably during subduction of the Farallon plate (or its derivative). The geologic data discussed above indicate that the Salton Trough has undergone extension, rather than compression, for approximately the past 5 Ma (probably even longer; see Humphreys and Weldon, in press).

Crustal thickness is unknown in the Chocolate Mountains; however, the Colorado Desert, to the east and north, has a generally thin (26–28 km) crust (fig. 8.3) and a local root (32 km deep) under the Whipple Mountains metamorphic-core complex (Fuis, 1981; Jill McCarthy, written commun., 1988).

TECTONICS—THE THREE-DIMENSIONAL PICTURE

The geology and, presumably, the deep structure of southern California illustrated along transect C3 (fig. 8.6) is grossly two dimensional as far north as the Transverse Ranges. In the Transverse Ranges, the rocks on the southwest side of the San Andreas fault are similar to those in the Chocolate Mountains. These rocks are bounded on the south and west by older, deformed strands of the San Andreas fault system (fig. 8.7; Powell, 1981). The tectonics also changes in the Transverse Ranges: Crustal-block motion swings to the west to follow the trend of the San Andreas fault, as discussed below.

Using Quaternary geologic and geodetic evidence, Weldon and Humphreys (1986) documented complex motion of crustal blocks in southern California that is not simply predictable from the motion vectors of the Pacific and North American plates. These motion vectors predict a large component of convergence across the San Andreas fault in the Transverse Ranges between the Big Bend and the Salton Trough (fig. 8.7). For a total offset on the San Andreas fault system of about 300 km (Hill and Dibblee, 1953; Crowell, 1962, 1981; Powell, 1981), a maximum of 45 km of uplift in the Transverse Ranges would be expected (Weldon and Humphreys, 1986). However, the preservation in the Transverse Ranges of upper Cenozoic sedimentary rocks and of offset bedrock features on either side of the San Andreas fault argues against such major uplift and associated consumption of crust, as does the relatively minor crustal root in the Transverse Ranges (fig. 8.3). Weldon and Humphreys (1986) constructed a kinematic model in which crustal blocks between the San Andreas fault and a system of borderland and other offshore faults rotate counterclock-

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wise, parallel to the San Andreas fault, between the Salton Trough and the Big Bend (fig. 8.7). Approximately two-thirds of the relative northwestward motion of the Pacific plate past the North American plate is taken up by the San Andreas fault system, including the San Jacinto fault; approximately one-third of it is taken up by the Elsinore fault, a system of borderland faults, and offshore faults in central California, including the San Gregorio-Hosgri fault (fig. 8.7); and only a minor fraction of it is taken up within the blocks (see Humphreys and Weldon, in press).

A marked advance in the *P*-wave traveltimes of teleseismic arrivals in southern California is associated with the Transverse Ranges and extends across the San Andreas fault (Hadley and Kanamori, 1977; Raikes, 1980). Tomographic analysis of this anomaly indicates that it results from a vertical slablike region of relatively high velocity in the mantle which extends downward as far as 250 km (Humphreys and others, 1984; Humphreys, 1985; Humphreys and Clayton, in press). The amount of velocity increase, a maximum of 3 percent, is most reasonably explained by a thermal difference in the mantle. This velocity increase, coupled with a velocity decrease in the upper 90 km or so of mantle beneath the Salton Trough, led Humphreys and Hager (1984 and in press) to infer small-scale mantle convection between the Salton Trough and the Transverse Ranges. This convection involves passive rising of asthenosphere beneath the Salton Trough and cooling and sinking of lithosphere beneath the Transverse Ranges. The vertical extent of the inferred lithospheric slab beneath the Transverse Ranges, 250 km, is similar to the 300-km estimate of total offset along the San Andreas fault system. However, because the cooled mantle slab extends across the San Andreas fault, most of the mantle seems to be moving independently of the crust (fig. 8.8; Hadley and Kanamori, 1977; Humphreys and others, 1984; Humphreys, 1985; Humphreys and Hager, in press). The horizon of decoupling is apparently at or below the Moho because crustal material is not entrained in the slablike feature. Additional decoupling may be occurring in the crust, similar to that postulated for central California (Yeats, 1981; Webb and Kanamori, 1985). Decoupling at the Moho requires that the deformational style and (or) location of the San Andreas fault system change from the crust to the mantle (fig 8.8). We note that mantle drag on the crust is required to maintain the Big Bend in the San Andreas fault because plate-edge forces alone would tend to "short-circuit" the San Andreas fault south of the Big Bend and cause most plate motion to be taken up on the San Jacinto, Elsinore, or more westerly faults (Kosloff, 1978; Humphreys, 1985).

To summarize, block motions in the region between the Big Bend and the Salton Trough result in only minor interblock convergence in the crust. In contrast, major convergence in the lithospheric mantle is indicated by the presence of an inferred, sinking lithospheric slab.

STRUCTURE OF THE UPPER MANTLE

In addition to the Transverse Ranges and Salton Trough, other regions in California show mantle velocity anomalies that imply structure within the lithospheric mantle and even the asthenosphere. The seismic networks in California (see chap. 5) provide an abundant source of regional earthquake and teleseismic arrivals that have been used to determine this upper-mantle structure.

A detailed study of the compressional-wave velocity of the uppermost mantle in central California reveals a normal velocity of about 8.0 km/s and no evidence for

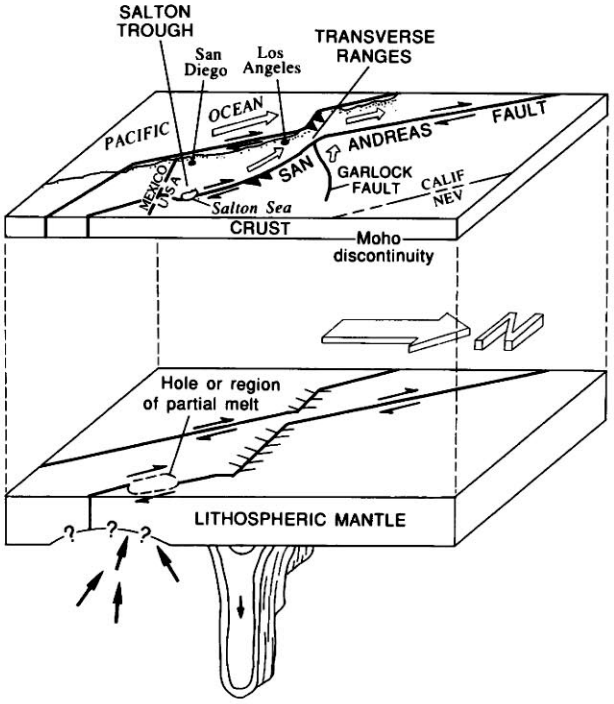

FIGURE 8.8.—Motion of crustal blocks in southern California (open arrows; see fig. 8.7) and somewhat different motion of lithospheric mantle below (solid arrows) (modified from Humphreys, 1985, and Humphreys and Hager, in press). Mantle convection cell is envisioned between the Salton Trough and the Transverse Ranges. Crust and lithospheric mantle appear to be moving independently of one another, as the San Andreas fault trends obliquely across region of inferred, sinking lithospheric mantle beneath the Transverse Ranges (see fig. 8.7). Small arrows, relative fault motion; sawteeth, upper plates of crustal thrust faults; crosslines, subduction zones in lithospheric mantle.

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velocity anisotropy (Oppenheimer and Eaton, 1984). A similar study in southern California finds nearly the same average velocity, 7.95 km/s, with evidence for 2-percent velocity anisotropy (Vetter and Minster, 1981; Hearn, 1984). The fast direction is N. 75° W., approximately parallel to the San Andreas fault in southern California. Seismic-velocity anisotropy in the upper mantle has been reported elsewhere, notably in oceanic crust, and is commonly attributed to alignment of olivine in the mantle along a shear-stress direction (Bamford and others, 1979). In southern California, this shear would presumably be that associated with the motion of crustal blocks above the lithospheric mantle.

Lithospheric thickness along the San Andreas fault has been investigated by using delay times of teleseismic arrivals and thermal models (Zandt and Furlong, 1982). These studies indicate a lithospheric thickness of only 30 to 60 km for much of western California, and as little as 20 km for northern California just south of Cape Mendocino. These lithospheric thicknesses contrast with averages of 60 to 80 km for the Western United States and 120 to 170 km for the Central and Eastern United States (Iyer and Hitchcock, 1989). The thinness of the lithosphere in northern California south of Cape Mendocino is due to the creation of the San Andreas fault system itself: The transform fault is lengthening as the Mendocino triple junction migrates northward. As this junction migrates northward, the west edge of North America is sliding off the edge of the northward-moving, subducting Gorda plate, thereby creating a "window" where no subducting lithospheric slab is present (Dickinson and Synder, 1979). In this slabless window, the North American crust is initially in direct contact with the asthenosphere that has welled upward to fill the hole left by the Gorda plate (Zandt and Furlong, 1982). This geometry produces the thinnest lithosphere in California and, probably, in North America. In contrast, the lithosphere is abnormally thick (250 km) in the Transverse Ranges, where "subduction" of lithospheric mantle is occurring, as discussed above.

Velocity anomalies appear to extend even into the asthenosphere beneath western California. Aki (1982) summarized the results of Cockerham and Ellsworth (1979) and Raikes (1980) in a combined velocity-anomaly model for a depth range of about 100–225 km in the mantle (fig. 8.9). Aki suggested that the low-velocity region in central California is hot, mobile material associated with the slabless window. Such an association appears likely for the northwest-trending prong of this anomaly, as refined by the recent work of Benz and others (1990); however, the center of the anomaly, located near Long Valley caldera (figs. 8.2, 8.9), apparently has a different origin. Low-velocity regions are also associated with the Salton Trough, where asthenospheric upwelling is inferred, and the eastern Mojave Desert, where crustal extension has occurred. The high-velocity region that crosses the San Andreas fault in southern California is similar to the one discussed above (fig. 8.7).

SUMMARY

The crust along the San Andreas fault system thickens from about 16 km at Cape Mendocino, in northern California, to about 30 km in southern California and thus is significantly thinner than the average thickness (36 km) for the conterminous United States. Lithospheric thickness (20–60 km) is also substantially less along most of the San Andreas fault system than is typical for continental areas (60–170 km). The lithosphere is thinnest at both ends of the fault system, at the Mendocino triple junction on the north, where the North American plate is sliding off the edge of the Gorda plate as it moves northward, and in the Salton Trough on the south, where

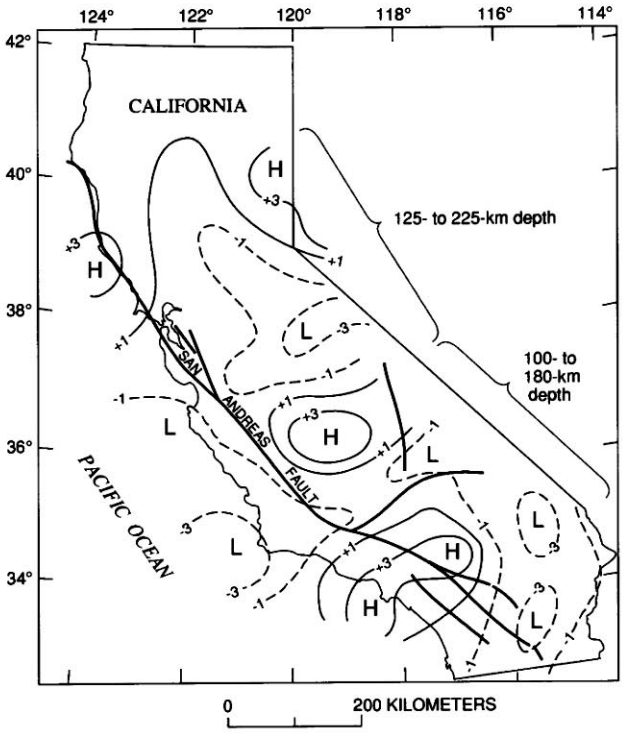

FIGURE 8.9.—Seismic-velocity anomalies in upper mantle (chiefly asthenosphere), derived from teleseismic delay-time data (Aki, 1982), for depth ranges 125–225 km (central California; Cockerham and Ellsworth, 1979) and 100–180 km (southern California; Raikes, 1980). H, high velocities (contours solid); L, low velocities (contours dashed). Contour interval, 2 percent. High seismic velocities that cross the San Andreas fault in southern California are similar in pattern to those shown in figure 8.7. Heavy lines, major faults.

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onshore spreading centers of the East Pacific Rise are generating new crust in a rift between the North American and Pacific plates. In contrast, the lithosphere is abnormally thick (250 km) in the Tranverse Ranges, where "subduction" of lithospheric mantle is occurring.

The crust of central California was formed at an Andean-type continental margin and has been modified by large offsets along strike-slip faults of the San Andreas fault system. East of the San Andreas fault, the Andean-marginal sequence includes a subduction complex (Franciscan rocks), a forearc basin (Great Valley sequence), and a magmatic arc (plutons of the Sierra Nevada). The subduction complex appears to have been emplaced as a tectonic wedge beneath sedimentary rocks of the forearc basin. West of the fault, displaced blocks constitute an Andean-marginal sequence that has been shortened by strike-slip faulting.

The tectonic wedge of Franciscan rocks east of the fault is reinterpreted to extend from its tip beneath the Great Valley all the way to the San Andreas fault. This interpretation is motivated by the apparent continuity between crystalline basement rocks beneath the Great Valley and mafic rocks at midcrustal depths in the Diablo Range, beneath the Franciscan rocks. The presence of extended crust atop the tectonic wedge (outliers of Coast Range ophiolite and Great Valley sequence) has led us to propose the following tectonic evolution for the wedge. (1) Franciscan rocks were uplifted and upper-plate rocks (those above the subduction zone) were extended during the Cretaceous (or, possibly, early Tertiary) well west of their current position in the Coast Ranges. (2) The Franciscan rocks and overlying extended crust were subsequently forced landward during one or more episodes in the form of a wedge that largely followed the contact between Great Valley basement and the Great Valley sequence. (3) Wedge movement began during the subduction of the Farallon plate (or its derivative) beneath central California; however, it apparently is also occurring at present, in the San Andreas transform regime. Present movement is interpreted to result from compression across the San Andreas fault system coupled with differential motion between the upper and lower crust; this differential motion is interpreted to occur on thrust fault(s) at the base of the wedge that sole into the brittle-ductile transition zone.

The crustal structure in southern California shares several features in common with central California, including, west of the fault, an Andean-marginal sequence that has been shortened or, at least, shuffled by strike-slip faulting, and, east of the fault, subduction-complex rocks that are inferred to have moved landward as a tectonic wedge into the continental rocks. However, major differences are apparent in southern California. First, east of the San Andreas fault, the Andean-marginal sequence is incomplete: A forearc basin is absent, and the magmatic arc is diffuse. Second, new continental crust has formed in the Salton Trough, an active crustal pullapart basin, by a combination of rapid sedimentation, metamorphism, and magmatic intrusion at the onshore spreading centers. In addition, the motions of the crust and lithospheric mantle differ in southern California: The crust is moving as a collage of blocks, with only minor interblock convergence, whereas the lithospheric mantle is converging and "subducting" beneath the Transverse Ranges.

The interpretations of (1) a midcrustal detachment in the brittle-ductile transition zone in central California and (2) a crust-mantle detachment in the Transverse Ranges of southern California would appear to require that the deformational style and (or) location of the San Andreas fault system change with depth in these regions.

The properties of the lithosphere along the San Andreas fault are not at all typical of continental areas, and further characterization of these properties presents a significant scientific challenge.

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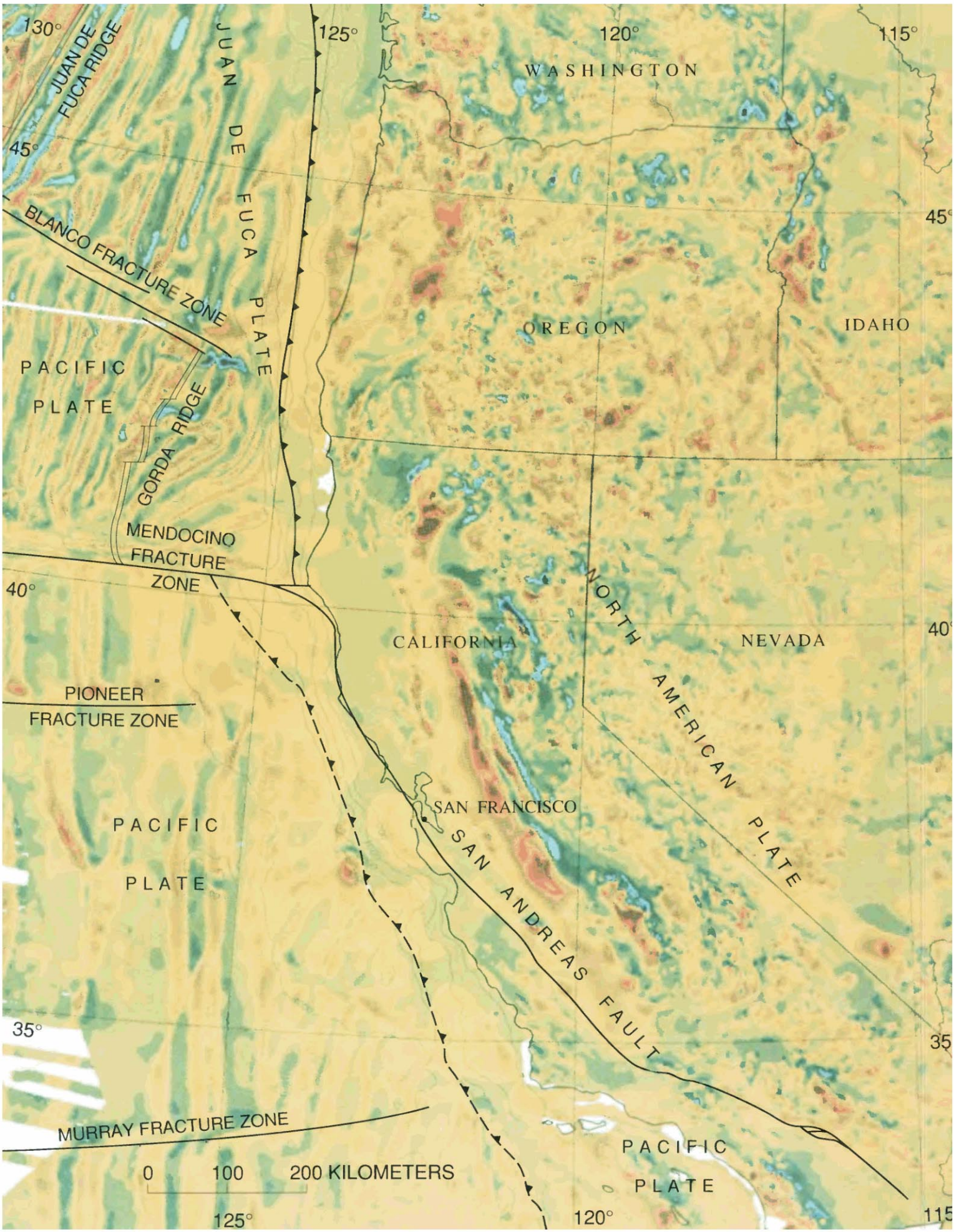

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Studies on the gravity and magnetic fields of the San Andreas fault system span more than 30 years, but only recently have the fundamental data sets become adequate to provide a general view of the entire system. Modeling these new data defines the three-dimensional geometries of the faults and helps unravel the tectonic history of the system by "seeing through" the relatively thin cover of young sedimentary deposits and water to the older rocks below.

9. CRUSTAL AND LITHOSPHERIC STRUCTURE FROM GRAVITY AND MAGNETIC STUDIES

By ANDREW GRISCOM and ROBERT C. JACHENS

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INTRODUCTION

Studies of the San Andreas fault system using the Earth's gravity and magnetic fields began before 1960 but received their main impetus during the 1970's, when work on the possibility of predicting earthquakes on this system began in earnest. Early investigations focused mainly on short segments of the faults because only limited data were available. More extensive potential-field data sets that have been published in recent years now permit the gravity and magnetic expression of the entire fault system to be viewed in a regional context (fig. 9.1).

Gravity and magnetic data reflect, respectively, the density and magnetization of the rocks beneath the surface; and, in many situations, these properties can be closely correlated with the rock types seen in outcrop. Anomalies in the Earth's gravity and magnetic fields—for example, local deviations of the measured fields from those predicted on the basis of simplified Earth models—primarily reflect lateral variations in density and magnetization that generally are not included in such simple models. These anomalies can be interpreted qualitatively to infer the general spatial distribution of rock types in the subsurface, and quantitatively, through the use of efficient computer-based modeling techniques (Saltus and Blakely, 1983; Chuchel, 1985; Blakely and Simpson, 1986), to determine the geometries and specific locations of concealed rock bodies. Although all such interpretations are nonunique, both because many different distributions of density and magnetization can give rise to identical anomalies and because density and magnetiza-

◀ FIGURE 9.1.—Magnetic map of the Western United States and eastern Pacific Ocean, showing locations of major plate boundaries: solid line, present boundary; dashed line, former boundary; double line, spreading ridge; single line, transform fault; toothed line, subduction-zone fault or transpressional fault (sawteeth on upper plate). From Geological Society of America (1987); used with permission. Plate boundaries from King (1969), McCulloch (1987), and Wilson (1989). Each color band represents 100 nanoteslas; values range from low (blue) to high (red); white area, no data. Bathymetric contours in meters.

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tion do not uniquely define a specific rock type, the combined use of gravity and magnetic data with geologic, geochemical, and other geophysical data can be especially effective in limiting the number of acceptable interpretations.

In the sections below, we first present regional gravity and magnetic maps covering the San Andreas fault system and briefly discuss the sources, compilation methods, and limitations of the data from which they were produced and, in general terms, the sources of the anomalies shown on them. We then summarize the results of individual studies of sections of the major faults in the system and attempt to synthesize these results in terms of the geometries of the faults, the structures and rock types in the surrounding areas that are related to the faults, and the properties of the fault zones. Next, we focus on studies that relate to movement on the faults, including constraints on total displacements. Finally, we discuss the plate-tectonic implications of potential-field investigations of the fault system.

ISOSTATIC RESIDUAL GRAVITY MAP

An isostatic residual gravity map of the region surrounding the San Andreas fault system is shown in figure 9.2. We have chosen to present the gravity data in this form rather than in terms of the more common Bouguer or free-air gravity because of the generally closer correlation between isostatic residual gravity and mapped geology (Jachens and Griscom, 1985; Simpson and others, 1986). Most long-wavelength anomalies (longer than approx 250 km) on a Bouguer gravity map are caused by deep-seated density distributions that buoyantly support the topography in a manner consistent with the principle of isostasy (Simpson and others, 1986). Bouguer gravity anomalies related to isostasy are prevalent in California because of the extreme topographic relief in the State (Oliver, 1980; Jachens and Griscom, 1985), and they are particularly strong near the coast, where an eastward to northeastward decrease in gravity reflects the transition from thin oceanic crust to thicker continental crust. In such areas as California, the Bouguer gravity anomalies associated with isostatic support of topography are so strong that they tend to distort or even mask the lower-amplitude anomalies caused by density distributions in the middle to upper crust, those anomalies most easily correlatable with rocks exposed at the surface (Jachens and Griscom, 1985). Our isostatic residual gravity map has these long-wavelength isostatic effects removed, at least to first order. We emphasize that the anomalies remaining on our map are predominantly caused by lateral density variations in the middle to upper crust and, as such, do not represent areas that are out of isostatic balance (Jachens and Griscom, 1985).

Our isostatic residual gravity map (fig. 9.2) is based on the new isostatic residual gravity map of the conterminous United States by Simpson and others (1986), who presented a detailed discussion of the data sets and procedures used to generate this map. The basic gravity-data set was compiled for the "Gravity Anomaly Map of the United States" (Society of Exploration Geophysicists, 1982) and includes 1 million on shore and 0.8 million offshore gravity observations. These data were sampled on a rectangular grid with a grid spacing of 4 km, containing Bouguer gravity values onshore and free-air gravity values at sea (Godson, 1985). To produce our isostatic residual gravity map, the offshore free-air gravity values were converted to Bouguer gravity values. The gravitational effects of the deep density distributions that support the topography within 166.7 km of each grid intersection were computed according to the Airy-Heiskanen model of isostasy (Heiskanen and Moritz, 1967) using a 5- by 5-minute topographic-bathymetric data grid and model parameters as follows: topographic density, 2.67 g/cm^3; crustal thickness at sea level, 30 km; and density contrast across the base of the model crust, 0.35 g/cm^3. Combined isostatic and topographic effects for the region from 166.7 km to the antipode of each grid intersection were obtained from the maps by Karki and others (1961). This model gravity field was subtracted from each Bouguer gravity grid value to yield a grid of isostatic residual gravity values; the resulting grid was contoured by computer and displayed in color-band intervals of 10 mGal to produce figure 9.2.

Limitations on the use of this map stem both from uncertainties in the point data from which the grid was constructed and from characteristics generated by the gridding process. For onshore data, uncertainties in the point data values resulting from errors in observed gravity, elevation, terrain corrections, and isostatic reductions are estimated to be less than 2 to 3 mGal for most stations, possibly larger in areas of extreme topographic relief (Simpson and others, 1986). In offshore areas, the greatest uncertainty results from conversion of the original free-air gravity data to Bouguer gravity values, using the 5- by 5-minute average bathymetry. Where the sea-bottom topography is relatively gentle, this conversion probably results in uncertainties of about 5 mGal, but in such areas as parts of the California Continental Borderland (south of lat 34° N.) and over the edge of the Continental Shelf, where water depths change rapidly, errors of several tens of milligals are possible. These conversion errors generally appear as high-amplitude, nearly circular anomalies with diameters of as much as 40 km.

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Although gravity coverage along most of the San Andreas fault system is quite dense when viewed at the scale of figure 9.2, sampling of these data on a 4-km grid means that anomalies with characteristic dimensions less than several times the grid spacing are not faithfully portrayed. Our isostatic residual gravity map (fig. 9.2) is sufficient for qualitative and quantitative interpretation at the scale shown, but for more detailed interpretations, especially quantitative modeling, the reader is referred to the original data sources, such as Oliver and others (1980), Roberts and others (1981), Snyder and others (1982), and the other reports cited throughout this chapter.

MAGNETIC ANOMALY MAP

A magnetic anomaly map of the region surrounding the San Andreas fault system is shown in figure 9.3. This map is based on the magnetic anomaly map of the Western United States by Bond and Zietz (1987), which was compiled from hundreds of magnetic surveys with widely differing flight heights, flightline spacings, and sensor types.

In contrast to the lengthy series of reduction steps that were required to convert the gravity observations to the form shown in figure 9.2, very little was done to the observed magnetic data to prepare them for compilation. Although the original data were collected at many different heights, no analytic procedures were used to continue them to a common elevation. Instead, the various surveys were referenced to the International Geomagnetic Reference Field (IGRF) adjusted for the date of the survey and an arbitrary zero datum, and then combined manually by inspection. Long profiles of magnetic data collected under the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy and by the U.S. Naval Oceanographic Office (NOO) served as guides for determining the zero datum for the various surveys. The resulting data are presented at a color contour interval of 100 nT (gammas) in figure 9.3.

Our magnetic anomaly map (fig. 9.3) is the most complete compilation available for the San Andreas fault system and is useful for qualitatively determining the location, shape, and regional setting of large magnetic bodies. However, because of the compilation methods used to construct this map and because the contour interval is relatively coarse (100 nT), it will not, in general, be adequate for detailed qualitative or quantitative examination of individual anomalies. Where detailed information is required, the reader is referred to the original sources from which our map was compiled; a comprehensive listing of these sources is given by Bond and Zietz (1987).

A particularly valuable source of aeromagnetic data over the San Andreas fault system is the profile data collected under the NURE program. In general, these data were collected along long profiles oriented east-west at a nominal height of 120 m above terrain and spaced about 5 km apart. The wide flightline spacing and low altitude of the survey lines preclude constructing realistic contour maps from these data in most places, but the long profiles are well suited for quantitative modeling. These data are available in the form of atlas folios or digital tapes for individual 1° by 2° quadrangles from the U.S. Department of Energy, Grand Junction, Colo.

When interpreting magnetic data, the inclination of the Earth's magnetic field must be taken into account because the magnetization induced in the magnetic source rocks by this field will have a similar inclination. Along the San Andreas fault, this inclination ranges from 58° to 64° downward toward magnetic north. Contoured magnetic anomalies over inductively magnetized or normally magnetized sources at these field inclinations will commonly display a dipole response, namely, magnetic lows associated with the north sides of magnetic highs. Inspection of our magnetic-anomaly map (fig. 9.3) indeed identifies numerous such magnetic lows on the north or northeast sides of major magnetic highs. In general, each magnetic low is located directly beyond the north or northeast contact of the causative magnetic mass.

SOURCES OF GRAVITY AND MAGNETIC ANOMALIES

Conspicuous features of the gravity field over the San Andreas fault system are linear highs and lows that trend subparallel to the major faults in the system. Highs (≥10 mGal) generally occur over exposed crystalline rocks of the Salinian block southwest of the San Andreas fault, over mafic granitic and metamorphic rocks of the Sierra Nevada and the Mojave Desert, and over Mesozoic and Tertiary layered rocks of the Franciscan assemblage, particularly in areas containing large amounts of mafic volcanic rocks (generally part of an ophiolite belt) or high-pressure metamorphic-mineral facies. Most of the deepest lows are caused by thick accumulations of low-density Cenozoic sedimentary rocks that fill tectonic basins adjacent to the faults and in the surrounding areas. Shallower lows occur over certain large serpentinite bodies within the Franciscan assemblage, over felsic plutons in the granitic terranes of California, and over a young concealed granitic pluton associated with the Geysers geothermal area at lat 39° N., long 122°45′ W. (Chapman, 1975; Isherwood, 1976).

Magnetic anomalies in the vicinity of the San Andreas fault system typically are caused by any one of three

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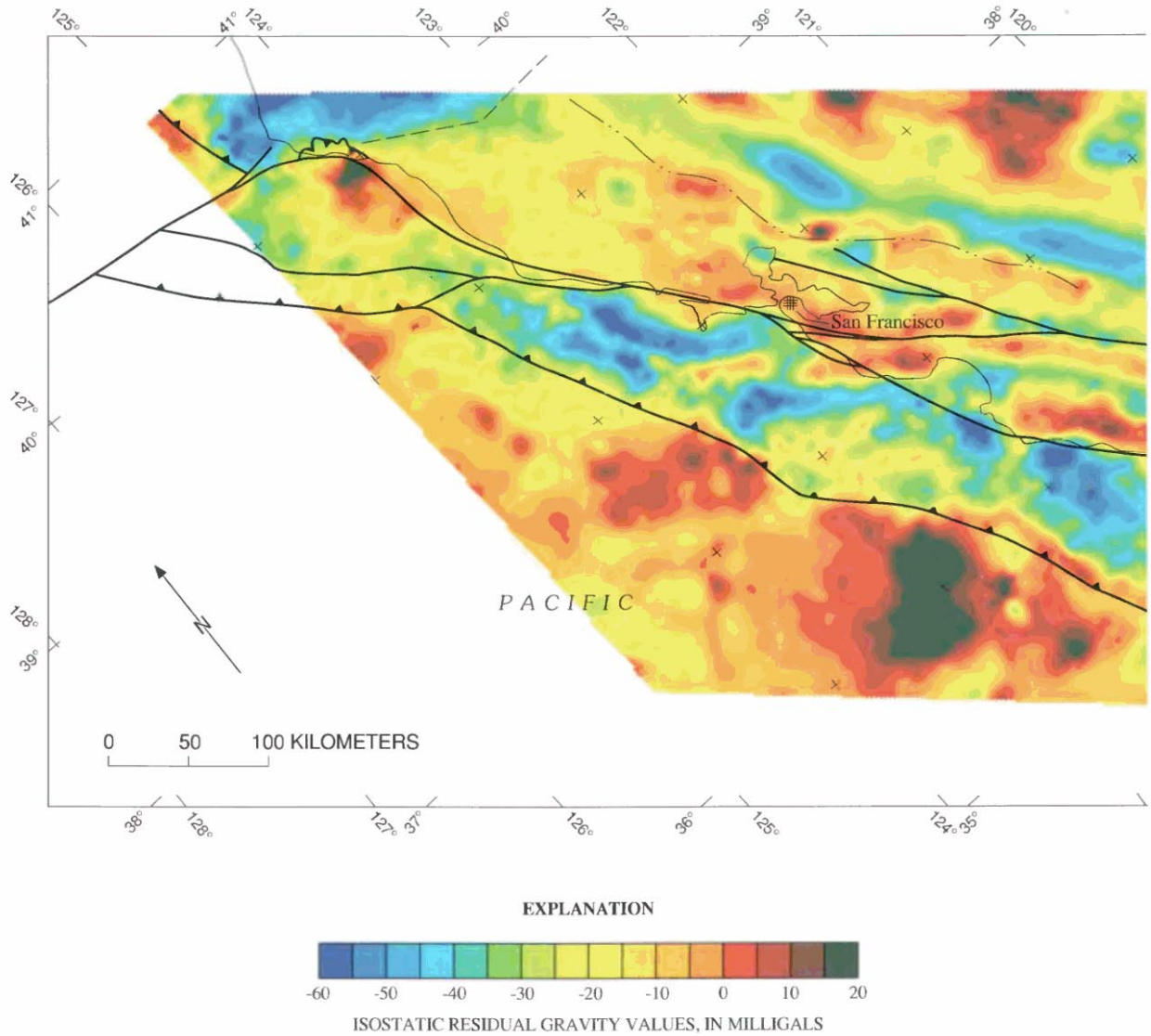

FIGURE 9.2.—Isostatic residual gravity map of the San Andreas fault system. Contour interval, 5 mGal. Faults simplified from Jennings and others (1977), McCulloch (1987), and Vedder (1987). Fault names and explanation in figure 9.4.

different rock types. The strongest anomalies generally reflect tabular bodies of serpentinite associated with the Franciscan assemblage and may also reflect the ophiolitic rocks, especially serpentinite, that locally lie above it. Mafic plutonic rocks, such as those exposed in the western Peninsular Ranges and along the west edge of the southern Sierra Nevada, can produce moderate to strong magnetic anomalies. Plutonic sources, not necessarily mafic only, probably account for most of the anomalies in the Salinian block, southwest of the San Andreas fault. Although younger volcanic rocks, in particular the mafic varieties, commonly are highly magnetic, such rocks do not cause significant magnetic features near the San Andreas fault as shown on our magnetic anomaly map (fig. 9.3) because magnetic volcanic rocks are volumetrically unimportant at the scale of this map.

In most areas, sedimentary rocks are considered nonmagnetic because they fail to cause aeromagnetic anomalies. Along the San Andreas fault system, however, several sedimentary-rock units cause magnetic anomalies as large as 150 nT. These units include rocks of Mesozoic and Tertiary age; other units composed primarily of detrital serpentinite also produce anomalies of this

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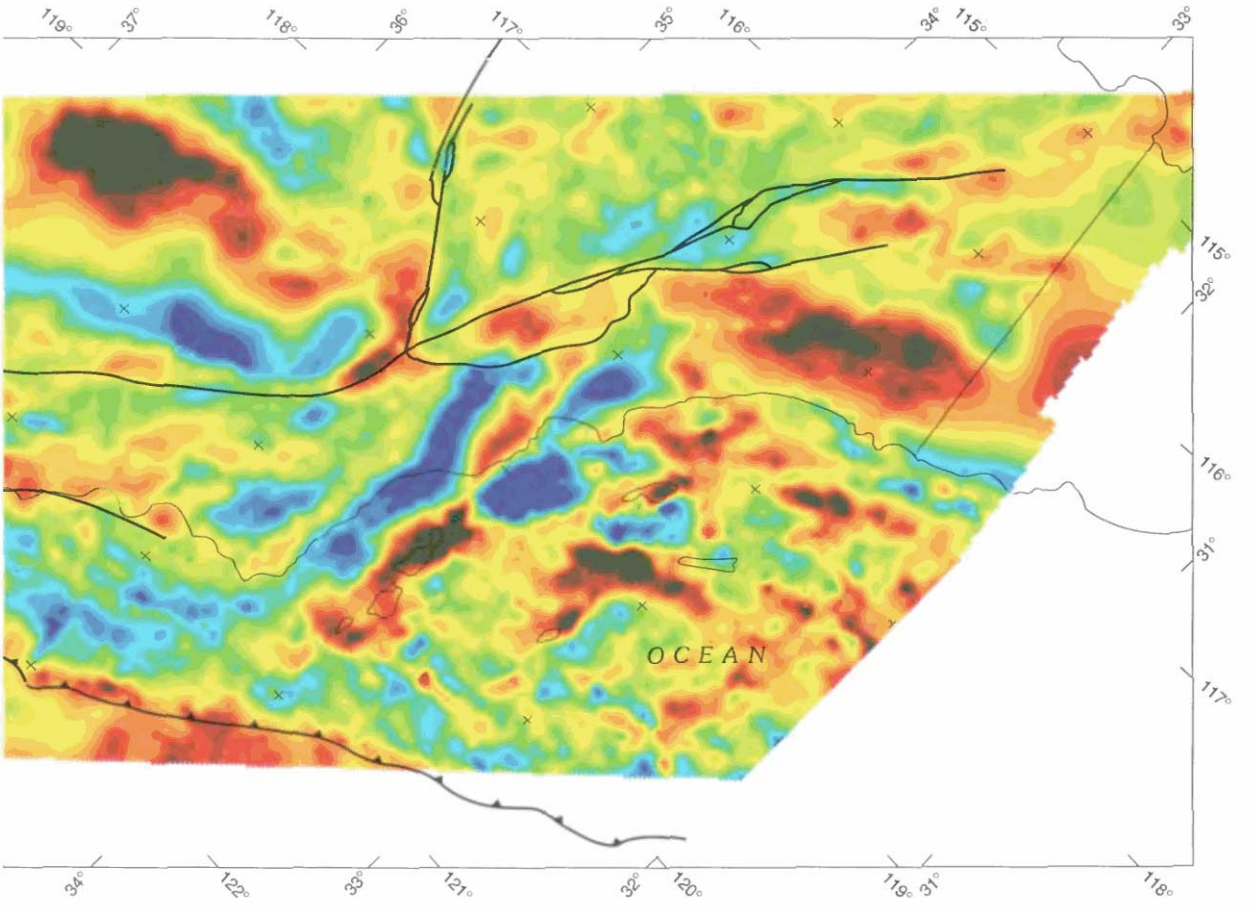

FIGURE 9.2.—Continued.

magnitude. None of these sedimentary units are areally large enough to produce magnetic anomalies visible at the scale of our magnetic anomaly map (fig. 9.3).

Near the north end of the San Andreas fault, several magnetic anomalies project landward from the linear pattern of anomalies that characterizes the oceanic crust. These anomalies reflect remanent magnetization in the oceanic crust; the source rocks are primarily basaltic volcanic rocks.

GEOMETRY OF FAULTS IN THE SAN ANDREAS SYSTEM

PLAN VIEW

The usefulness of potential-field data along the San Andreas fault system is maximized where rock masses with differing physical properties are juxtaposed. Under these conditions, geophysical anomalies arise from which the location and attitude of the fault may be calculated (Blakely and Simpson, 1986). In general, the fault is expected to be situated at or near the steepest gradient of the anomaly. These sites are particularly helpful in areas where the fault trace or zone is concealed by young sedimentary deposits or by the Pacific Ocean. In addition, we have found that some of these data are useful in identifying the main strand of the fault zone where the presently active fault trace may not, in fact, be the original plate boundary. Some areas where the potential-field data define the locations of faults are shown on figure 9.4 and are discussed below.

Although the location of the San Andreas fault between Point Arena and Cape Mendocino is concealed by the Pacific Ocean, the aeromagnetic data show a linear magnetic anomaly, striking northwest within the Pacific plate, that is inferred to be obliquely cut off by the fault about 20 km northwest of Point Arena. Farther north, the fault trace just south of Cape Mendocino has proved particularly difficult to locate because it may be too close to shore to be resolved by marine geophysical surveys. A

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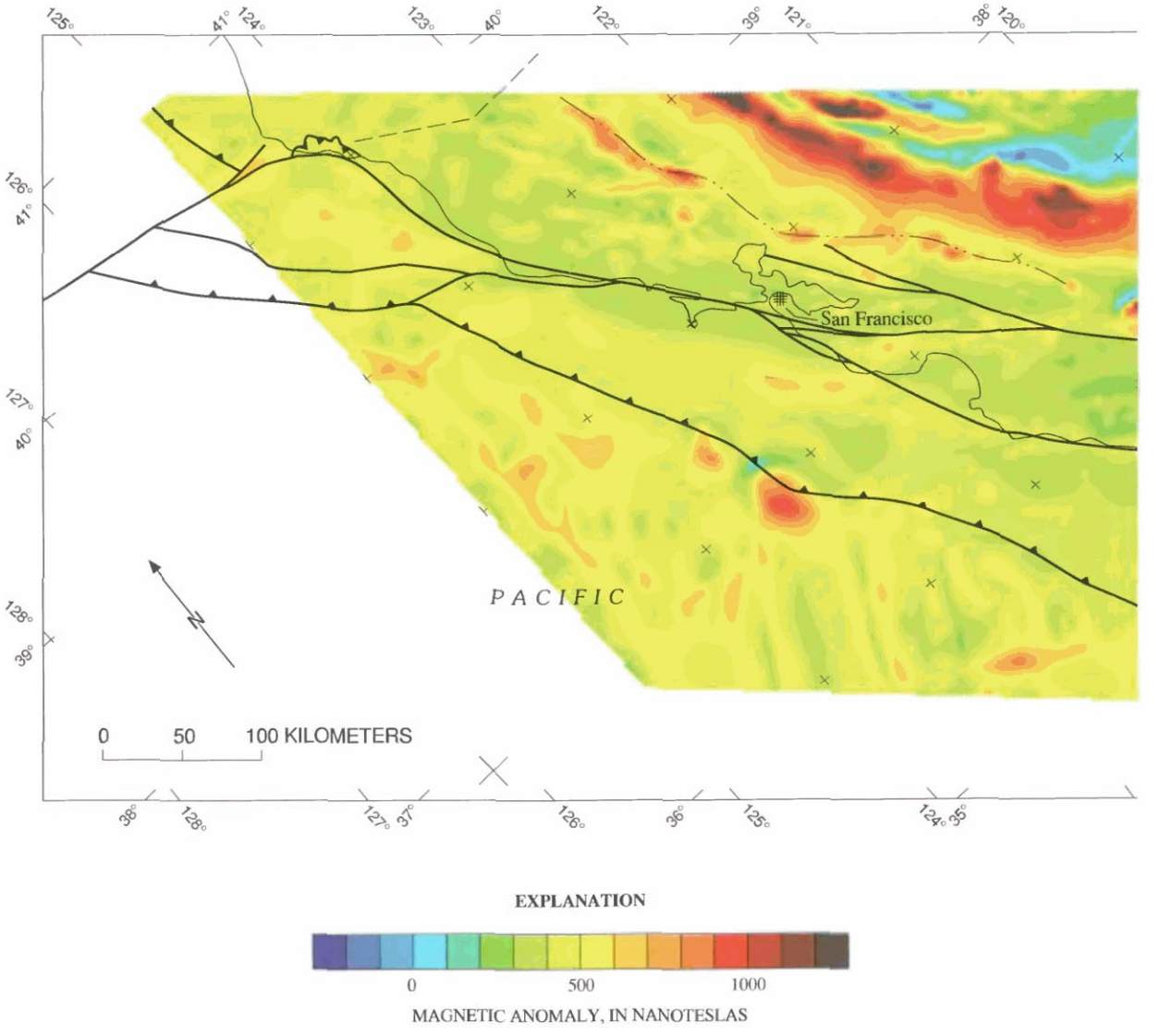

FIGURE 9.3.—Magnetic map of the San Andreas fault system (from Bond and Zietz, 1987). Contour interval, 100 nT. Faults simplified from Jennings and others (1977), McCulloch (1987), and Vedder (1987). Same symbols as in figure 9.4.

recent aeromagnetic map of this problematic area has, indeed, displayed a magnetic boundary trending close to and along the shore, thus representing the likely location of the San Andreas fault (Griscom, 1980a).

Aeromagnetic surveys over the Pacific Ocean at the entrance to the San Francisco Bay (Brabb and Hanna, 1981) show that the offshore extension of the Pilarcitos fault (an inactive fault branching westward from the San Andreas fault) is cut off by the offshore northward extension of the San Gregorio fault. The San Gregorio fault can be traced northward by using a detailed aeromagnetic map to the point where it intersects the San Andreas fault at Bolinas Lagoon, about 20 km northwest of the bay mouth (see McCulloch, 1987, fig. 15).

From San Francisco southward to lat 35°15′ N., the detailed gravity and magnetic data indicate that, in general, the westernmost strand of the main San Andreas fault zone is the major plate boundary. The layered Franciscan assemblage to the east may be less competent than the granitic basement of the Salinian block to the west, and new strands may be more likely to appear in the less competent rocks. An exception to this generalization is found at lat 36° N., where a thin fault sliver of

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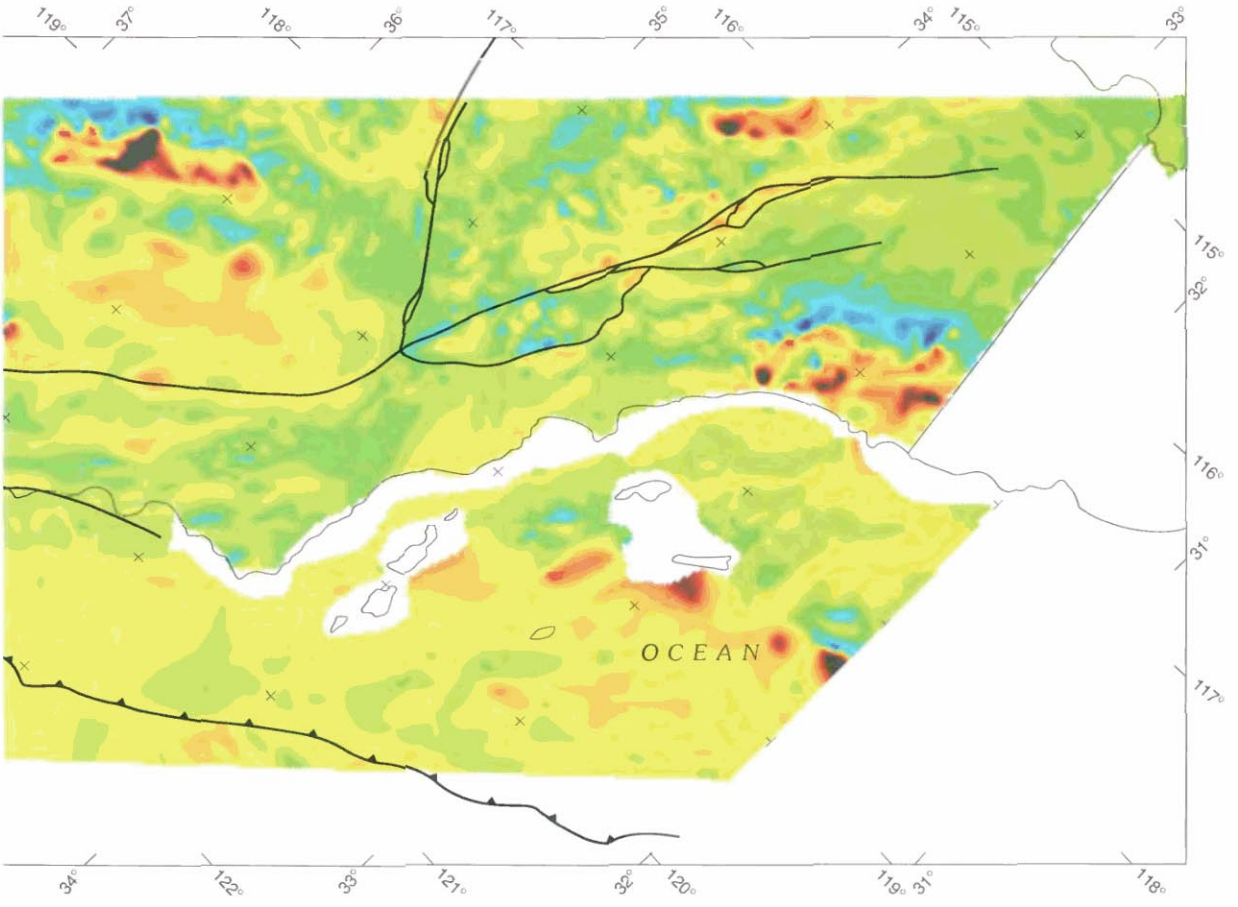

FIGURE 9.3.—Continued.

hornblende-quartz gabbro occurs at Gold Hill (Ross, 1970) that has been used to estimate offset on the San Andreas fault. The magnetic anomaly associated with this gabbro body indicates that it is at most 10 km long by 2 km wide (U.S. Geological Survey, 1987).

Farther south along the San Andreas fault, a linear magnetic high extends along the fault approximately between long 116° and 118° W. (fig. 9.3). On the basis of local model studies of this anomaly, Simpson and others (in press) show that this feature probably reflects the edge of an extensive block of magnetic rocks on the northeast side of the San Andreas fault, where the magnetic material is Precambrian igneous and metamorphic rocks, as well as Mesozoic plutonic rocks. Using detailed magnetic data (U.S. Geological Survey, 1979), the south border or magnetic boundary of this magnetic block (fig. 9.4) can be traced from west to east along a series of fault segments; from long 117°15′ W., the boundary follows the southern fault trace to long 116°15′ W., then crosses over to the northern trace along the short, east-west-trending fault segment, and finally continues eastward along the northern trace. These faults thus may represent the original fault boundary (now somewhat kinked) between the two plates. The geologic observation that rocks on the north side of these fault segments are native to the San Bernardino Mountains and contrast with compositionally different rocks on the south side (Matti and others, 1985) agrees with the magnetic interpretation. The magnetic boundary continues southeastward along the San Andreas fault in Coachella Valley to long 116°08′ W. A possible farther continuation of this linear magnetic high extends southeastward at a lower amplitude and diverges eastward from the present San Andreas fault, generally following and lying northeast of the Clemens Wells fault, a possible earlier strand of the San Andreas fault.

In Coachella Valley, the San Andreas fault (North Branch or Coachella segment) is situated along the northeast side of a substantial linear gravity low caused by at least 4.7 km of low-density sedimentary rocks

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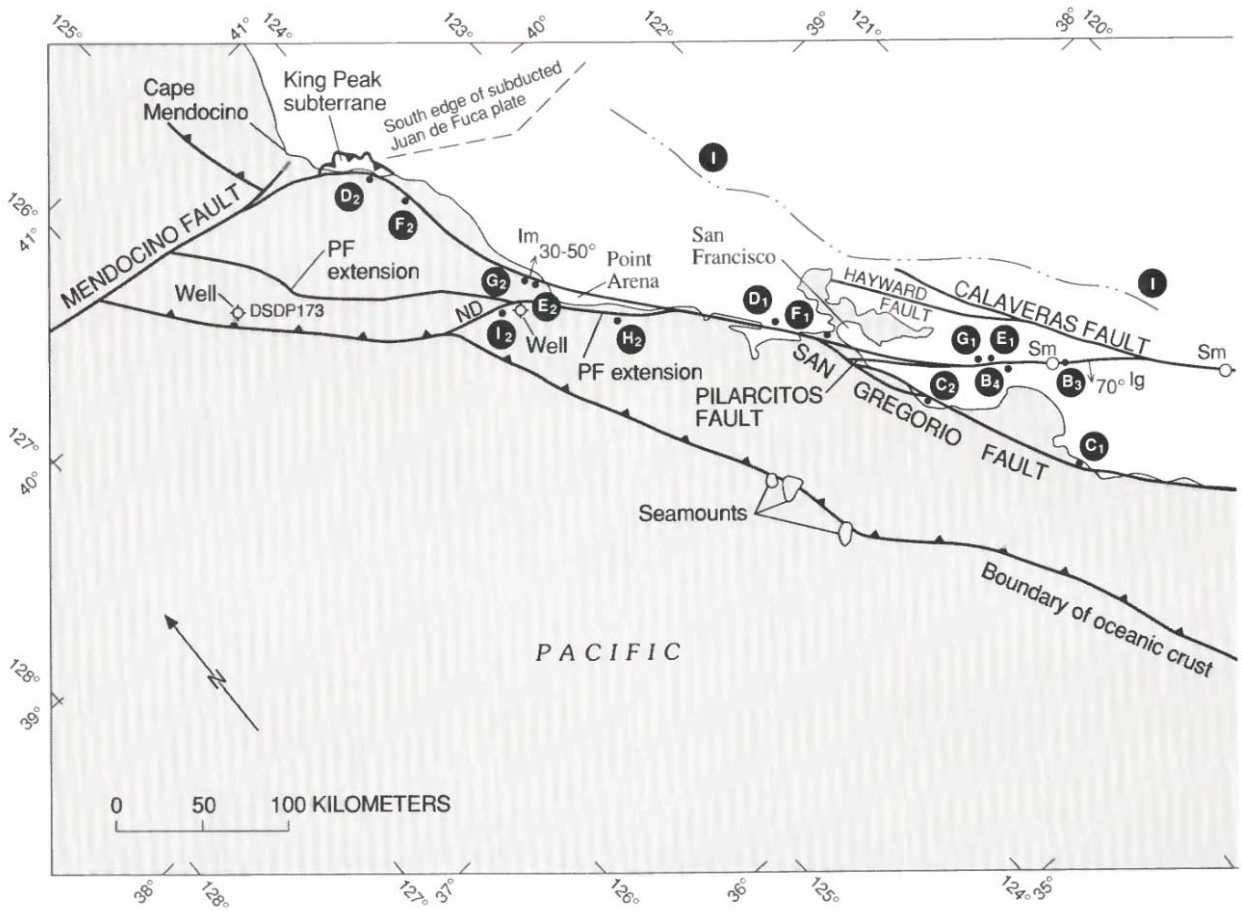

EXPLANATION

Sg, 70° — **Fault**—Arrow indicates direction and amount of dip; circle, vertical dip. Capital letter, approximate depth to which dip is valid (S, shallow, about 2 km; I, intermediate, 2-5 km; D, deep, 5-10 km); lower case letter, geophysical data used for calculation of dip (m, magnetic; g, gravity)

Thrust fault—Sawteeth on upper plate

Crest of magnetic anomaly

Location of offset geophysical anomaly

Magnetic boundary (J_1 and J_2) discussed in text

Well

FIGURE 9.4.—San Andreas fault system, showing fault dips calculated from gravity and magnetic data, locations of offset geophysical anomalies, and south border of the subducted Juan de Fuca plate. Note wells at lat 39° and 40° N. ND, Navarro discontinuity; PF, Pilarcitos fault.

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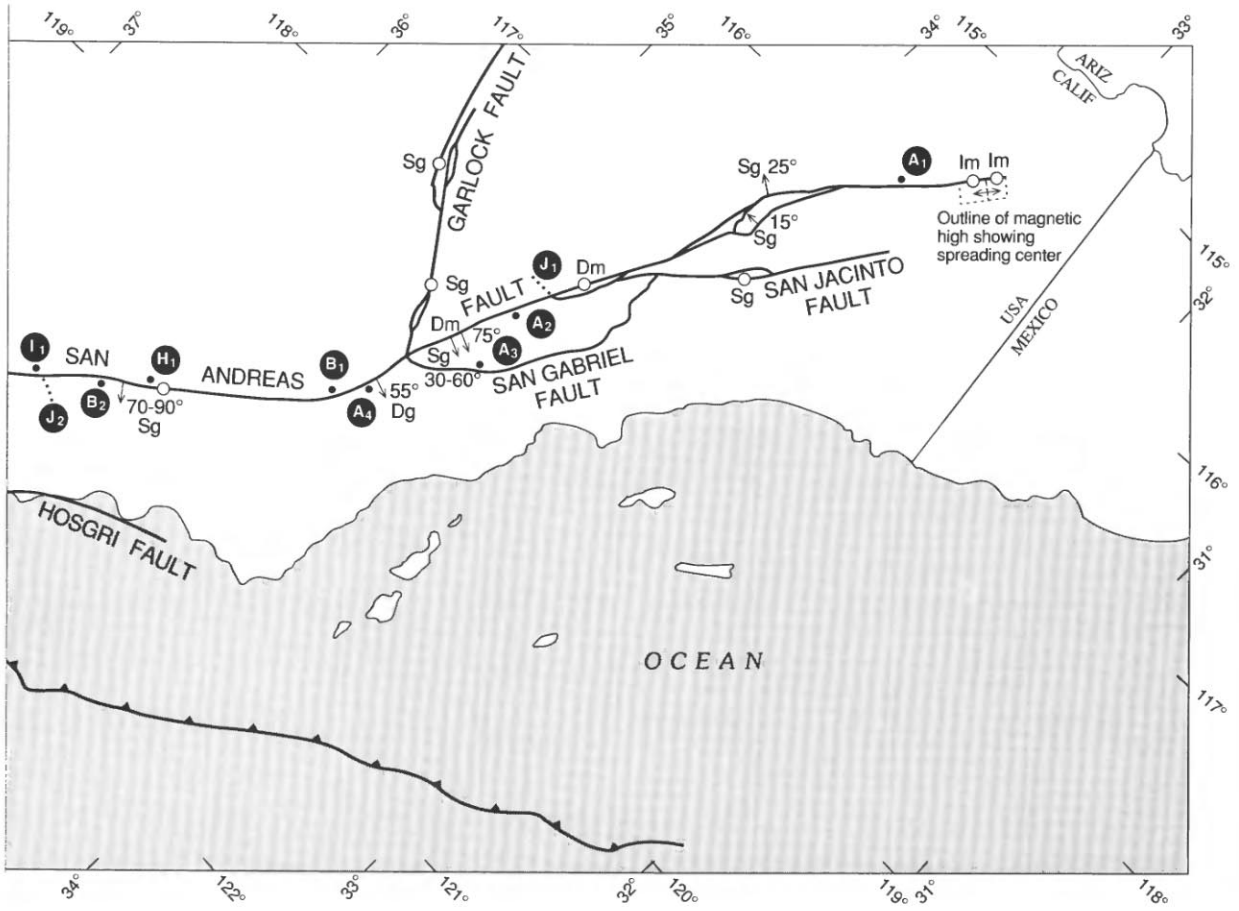

FIGURE 9.4.—Continued.

(Biehler, 1964) filling the valley. Gradient studies on the relatively detailed gravity data in this valley by one of us (Griscom) identify numerous fault strands, including the northern and southern branches of the San Andreas fault (the latter, the Banning fault), as well as several possible fault segments on the southwest side of the valley.

The Garlock fault at long 118° W. changes direction and forms a zone as much as 8 km wide. Models of both the magnetic and gravity fields calculated normal to the fault indicate that here the main lithologic boundary is the most northerly fault (fig. 9.4); the granitic rocks farther north are more magnetic and less dense than those to the south.

ATTITUDE

At several sites along the San Andreas fault, the juxtaposition of large masses with contrasting densities and (or) magnetizations causes characteristic potential-field anomalies that reflect the attitude of the fault. Information on the dip of the fault most commonly is obtained through quantitative modeling of these anomalies, but in some cases, the anomalies are so diagnostic that qualitative interpretations suffice to indicate the direction and approximate attitude of the fault plane.

The results of such interpretations at 16 sites primarily along the main trace of the San Andreas fault are shown in figure 9.4. The dip and depth-extent of the density or magnetization interfaces that are assumed to define the fault plane at these sites are somewhat uncertain because of the inherent ambiguity of gravity and magnetic interpretations, particularly those based on magnetic data, because rock magnetizations can have anomalous directions associated with their remanent components and because magnetic susceptibilities seldom are known with sufficient accuracy to serve as effective independent constraints. Thus, where the magnetic anomalies can be compatible with a vertical fault, we show the dip as vertical. The reader should be aware, however, that a

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dipping interface extending to shallower depth would also be compatible with the data in some places.

Although major strike-slip faults probably are vertical over much of their reach, some have inferred dips of less than 90°, as indicated by many of the attitudes shown in figure 9.4. Just north of Point Arena, a buried magnetic body truncated on the east by the San Andreas fault has an east boundary that dips east beneath the trace of the fault (fig. 9.5*A*); its precise dip is uncertain but probably falls in the range 30°–50°. To the south, near the junction of the San Andreas and Calaveras faults, gravity modeling (Pavoni, 1973) suggests that the fault dips 70° SW. to a depth of about 6 km. A detailed study of seismicity along this section of the fault (Spieth, 1981) shows that hypocenters define a plane dipping 70° SW., thus strongly supporting the interpretation by Pavoni (1973). Robbins (1982) also found a southwest-dipping density interface at this site but argued that the fault plane was vertical, on the basis of a magnetic anomaly that he believed reflected a magnetic body, extending from 3- to 5-km depth, with a southwest edge directly beneath the surface trace of the fault. More recent, detailed magnetic measurements indicate that this magnetic body is much shallower (probably cropping out) than modeled by Robbins (1982) and thus weaken the argument for a vertical dip.

Near the intersection of the San Andreas and Garlock faults, gravity modeling by Andrew Griscom and K.G. Freeman (Griscom and Oliver, 1980) suggests that the fault dips 55° SW. to a depth of 6 km and thence vertically to a depth of at least 10 km (fig. 9.5*B*). About 60 km farther southeast, gravity data also indicate a southwesterly dip for the fault, but the angle of dip (30°–60°) is uncertain, owing to difficulty in interpreting the complex gravity field that results from large lateral density variations in the region southwest of the fault. Farther southeast, where the San Andreas fault splits into numerous branches (long 116°00′ W.), gravity data on two branches indicate that both faults dip northeast, with Precambrian crystalline rocks in the upper plate overlying young sedimentary rocks and alluvium. The gravity models suggest dips of 15°–25° NE. to depths of 1.5 to 2.5 km but do not resolve the fault attitude at greater depth (fig. 9.5*C*). Geologic mapping, which shows part of the southern branch of the San Andreas fault as a north-dipping thrust fault (Matti and others, 1985), and a study of recent earthquakes in this area, which yielded fault-plane solutions of predominantly oblique-slip motion and

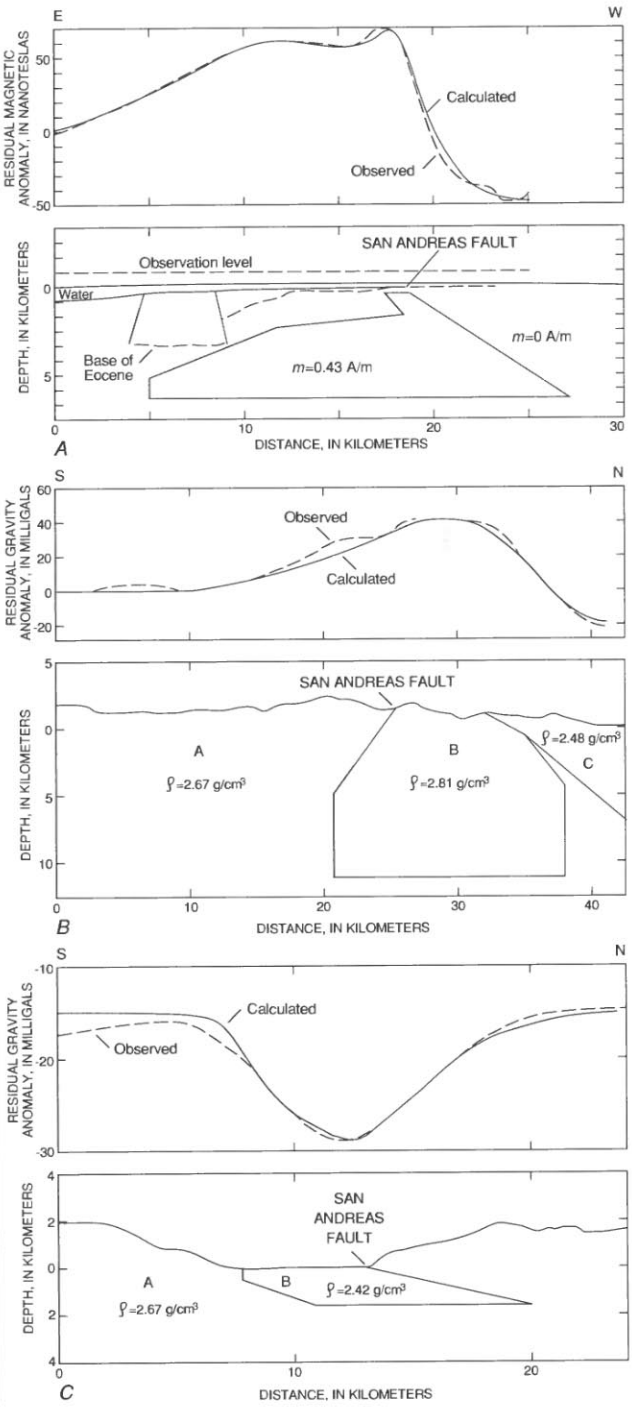

FIGURE 9.5.—Magnetic and gravity models across the San Andreas fault. m, magnetization; ρ, density. *A*, Magnetic model just north of Point Arena (long 123°40′ W.). *B*, Gravity model near junction of the San Andreas and Garlock faults (long 119°07′ N.). A, Mesozoic and Precambrian crystalline basement mantled by older Tertiary sedimentary rocks to south; B, mafic igneous rocks of the southern Sierra Nevada batholith; C, Tertiary and Quaternary sedimentary rocks of the Great Valley. *C*, Gravity model across southern branch at long 116°40′ W. A, Mesozoic and Precambrian crystalline basement; B, Tertiary and Quaternary sedimentary rocks of Coachella Valley.

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including low-angle thrust solutions dipping 30° N. (Nicholson and others, 1986), both support the gravity interpretation of northeast-dipping faults in this area.

The inferred fault attitudes shown in figure 9.4 suggest a relation between attitude and plan-view geometry. Faults tend to be vertical except where they undergo abrupt changes of strike. The sinistral bends in the San Andreas fault near its junction with the Calaveras fault and in the Big Bend region southeast of its junction with the Garlock fault create regions likely to be subject to compression due to relative southward movement of the North American plate with respect to the Pacific plate. The dipping fault planes in these regions may reflect a thrust component of fault movement that accommodated the compression. Similarly, the region around the broad dextral bend in the San Andreas fault north of Point Arena may have a component of extension parallel to the direction of relative plate motion, and the low- angle eastward dip of fault plane there may reflect accommodation of the extension by low-angle normal faulting.

The number of examples on which the above speculations are based is quite limited, and further detailed investigations at critical sites along the San Andreas fault system are needed to test the relation between fault attitude, change of strike, and relative plate-motion direction.

FAULT-ZONE CHARACTERISTICS

Millions of years of strike-slip movement along faults of the San Andreas system have produced, in many places, a narrow fault zone in which physical properties differ from those in the surrounding rock masses. These differences are due to the presence within the fault zone of fractured or pulverized rock, exotic rock slivers that have been transported along the fault from other places, and such mobile materials as fluids and serpentinite that have migrated along the fault zone. A few investigators have used gravity and magnetic data to study the properties of this zone.

Although Stierman (1984) and Wang and others (1986) sought to explain gravity lows along the fault as the result of a substantial increase in porosity by fracturing, gravity lows not directly associated with basins filled by Cenozoic sedimentary rocks along the faults are very uncommon. These rare lows amount, with few exceptions (such as the 10–12-mGal low studied by Stierman, 1984), to amplitudes of only a few milligals. Feng and McEvilly (1983) and Trehu and Wheeler (1987) inferred from seismic data that zones of low seismic velocity 5 to 10 km wide and more than 10 km deep are associated with the San Andreas fault zone and, presumably, with fractured rocks. The low-velocity zone of Trehu and Wheeler (1987), however, has no associated gravity low, even though calculations by Andrew Griscom indicate that this zone might be expected to produce a gravity anomaly of about –25 mGal and more than 10 wide, using the standard velocity-density relations of Hill (1978). An explanation for this unexpected result can be found in the borehole gravity and seismic-velocity results (Schmoker, 1977; Stierman and Kovach, 1979) from a 600-m-deep borehole in diorite located 1.2 km from the San Andreas fault. For the lower half of this borehole, the seismic velocity averages only 3.1 km/s (although saturated core samples measured 6.6 km/s in the laboratory), and the average computed rock densities are as follows: bulk density from cores, 2.72 g/cm^3; borehole density from gravity measurements, 2.60 g/cm^3; and computed density from borehole velocities (density-velocity relations of Hill, 1978), 2.36 g/cm^3. Correcting for a nearby low-density sedimentary section that causes a gravity gradient along the hole raises the borehole density (from gravity measurements) closer to the bulk density. The results described above indicate that macrofractures can cause large decreases in seismic velocity but much smaller decreases in density than those predicted from standard velocity-density relations.

Allen (1968) pointed out a possible relation between the style of fault movement and the presence of serpentinite within fault zones of the San Andreas, Calaveras, and Hayward faults. He noted that serpentine is common within the fault zone along the creeping section of the San Andreas fault between Hollister and Cholame, whereas it is absent along the locked segments to the north and south. Irwin and Barnes (1975) noted the same relation between serpentinite and fault creep and discussed the possible role of metamorphic fluids on the seismic behavior of fault segments. Hanna and others (1972) studied aeromagnetic data along the San Andreas fault between San Francisco and San Bernardino and found that the creeping segment of the fault is characterized by broad aeromagnetic anomalies, which they interpreted as reflecting large concealed masses of serpentinite. Linear magnetic anomalies that most likely reflect serpentinite also are present along the creeping section of the Hayward fault east of the San Francisco Bay (fig. 9.3). These magnetic data support the speculation that appreciable amounts of serpentinite contained within a fault zone can influence the style of movement on the fault.

OFFSETS OF ANOMALIES

Strike-slip movement on the faults of the San Andreas system has produced offsets in formerly continuous geophysical anomalies. As might be expected, on those faults where the geologic offset is at most a few tens of kilometers, it is generally easy to identify corresponding magnetic or gravity features that are offset by similar

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distances. Examples of such faults are the Elsinore fault and the rectilinear system of minor strike-slip faults in the Mojave Desert block northeast of the San Andreas fault. In figure 9.4, the two or more piercing points of an offset geophysical anomaly are labeled with the same letter, and the specific points being described are designated with subscripts, numbered consecutively from northeast to southwest across the fault system.

Offset along the San Andreas fault system in southern California is believed to be approximately 300 km in a right-lateral sense, based on offset of the Pelona-Orocopia schist belts, together with associated characteristic Precambrian and Triassic rock assemblages of the thrust plate overlying the schist belts (Crowell, 1962; Clarke and Nilsen, 1973; summarized in Hamilton, 1978). Isostatic gravity highs are associated with the Orocopia Schist (point A_1 at lat 33°35′ N., northeast side of fault), with the Pelona Schist of the Sierra Pelona/Soledad area (points A_2, A_3 at lat 34°35′ N., between the San Andreas and San Gabriel faults), and adjacent to the south side of the Pelona Schist of the Tejon/Garlock area (point A_4 at lat 34°50′ N., south of the San Andreas fault and west of the San Gabriel fault). Point A_4 is not well determined. The offsets of the gravity highs are, respectively, 240 km along the San Andreas between the first two highs (A_1 and A_2) and 60 km along the San Gabriel between the second two highs (A_3 and A_4), for a total of 300 km along the San Andreas fault system, in agreement with Crowell (1962). The source of the gravity highs is not obvious and may not be any of the rocks exposed at the surface (Griscom, 1980b), both because the density of the schist coring the antiforms is probably similar to or slightly lower than that of the surrounding Precambrian crystalline rocks and because other large areas of Pelona/Orocopia schist do not display associated gravity highs. The schist is marine in origin, predominantly metagraywacke of low metamorphic grade (Haxel and Dillon, 1978), and may be underlain by subducted oceanic crust. The gravity highs may indicate relatively uplifted oceanic crust beneath these specific antiformal exposures of the schist, or else the proportion of greenstone interbedded with schist may increase here with depth.

As mentioned above in the subsection entitled "Plan View," a linear magnetic high that extends along the San Andreas fault from long 116° to 118° W., a distance of about 200 km, indicates that a large area north of the fault in this region is composed of magnetic rocks, predominantly Mesozoic granitic plutons; the northwest limit of this magnetic area (J_1) is shown in figure 9.4. A similar large area of magnetic basement, also predominantly Mesozoic granitic rocks, that extends along the southwest side of the San Andreas fault is displaced from the former area right-laterally approximately 300 km; the northwest limit of this correlative area (J_2) is also shown in figure 9.4. This second area of magnetic rocks does not produce a significant magnetic high directly at the fault because the fault is on the northeast side of the magnetic mass and a magnetic low should occur for this geometry.

Several significant geophysical anomalies are found along the central section of the San Andreas fault north of its junction with the Garlock fault. A pronounced gravity high is located on the northeast side of the fault at lat 34°55′ N., where the southern "tail" of the Sierra Nevada is exposed. The associated rocks are hornblende-quartz gabbro and anorthositic gabbro (Ross, 1970, 1984) that also produce a substantial aeromagnetic high (point B_1, fig. 9.4). Similar rocks (Ross, 1970) are found within the San Andreas fault zone at Gold Hill (point B_2 at lat 35°50′ N., too small to show at this scale) and at Logan (point B_3 at lat 36°52′ N.), where magnetic anomalies (U.S. Department of Energy, 1981; U.S. Geological Survey, 1987) indicate that the gabbro bodies are thin slivers within the fault zone. The Logan outcrops are offset about 290 km from the gabbro of the Sierran "tail." A major northwest-trending magnetic anomaly extends northwestward of Logan near the coast (from point B_4 at lat 37°08′ N.). The source rocks for this magnetic anomaly are interpreted to be gabbro, similar to that exposed near Logan (Hanna and others, 1972a), because the anomaly requires a source body several kilometers thick. These corresponding offset geophysical anomalies support the geologic correlations implying about 300 to 320 km of offset.

The additional 100 km of granitic rocks extending northward from Logan to Montara Mountain (lat 37°35′ N.) along the southwest side of the San Andreas fault does not have any correlative rocks exposed on the northeast side of the fault north of the gabbro of Sierran "tail," but the concealed crystalline basement rocks beneath the sedimentary rocks of the Great Valley may be correlative. Indeed, recent work on the Tertiary sedimentary rocks that overlie this additional 100 km of granitic rocks on the San Francisco peninsula suggests a lithologic and paleogeographic correlation with similar sedimentary rocks of the Great Valley (San Joaquin Basin) that are relatively offset 320 to 330 km to the southeast (see fig. 3.4; Stanley, 1987).

Movement on the San Andreas fault north of San Francisco (Griscom and Jachens, 1989) is complicated by right-lateral displacement added by the presently active San Gregorio-Hosgri fault, which intersects the San Andreas fault at San Francisco and provides an additional 115 km (Graham and Dickinson, 1978) or 150 km (Clark and others, 1984; Ross, 1984) of offset. The total offset on the San Andreas fault system here is further complicated by movement on branch faults to the east (Calaveras and Hayward fault systems of unknown offset) and, more importantly, by past movement along the Pilarcitos fault,

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the presently inactive fault strand branching westward from the San Andreas fault on the San Francisco peninsula. Probably most of the 300 to 320 km of displacement on the San Andreas fault has taken place along this strand because the presently active strand of the San Andreas fault that lies directly east of the Pilarcitos fault demonstrates only about 26 km of offset of a characteristic limestone belt within the Permanente terrane of the Franciscan assemblage (Bailey and others, 1964, p. 69; M.C. Blake, Jr., oral commun., 1987). The Pilarcitos fault (now truncated to the northwest by the San Gregorio fault) may have its former extension on the ocean side of the San Gregorio-San Andreas fault at about lat 38°30′ N. (see fig. 9.4), as proposed by Graham and Dickinson (1978). This proposed extension may have granitic rocks on the southwest side (more than the additional 100 km already discussed) that have no correlatives northeast of the San Andreas fault, unless the total offset on the San Andreas system substantially exceeds 300 km or unless granitic rocks underlie thrust blocks of Franciscan assemblage near the south end of the Great Valley (see preceding paragraph). There may be other, unidentified faults within the Salinian block that allow for this additional offset.

Offsets of geophysical anomalies along the San Gregorio-Hosgri fault support a total right-lateral movement of about 100 to 130 km that has been added to the total offset on the San Andreas fault system north of its junction with the San Gregorio fault. An offset gravity high (Silver, 1974) is located on the northeast side near Point Sur (point C_1 at lat 36°30′ N.) and on the southwest side at Año Nuevo (point C_2 at lat 37°15′ N.), with an offset of 105 to 130 km as remeasured by Graham and Dickinson (1978). We prefer an offset of 105 km (max 115 km) because any larger displacement will place the offset extension of the Pilarcitos fault on land north of lat 38°30′ N., where no such fault is known.

Displacements along the San Andreas fault north of lat 38°30′ N. have proved difficult to measure, both because the rocks exposed southwest of the fault near Point Arena have no obvious correlatives on the opposite side of the fault and because most of the fault trace is concealed beneath the Pacific Ocean (Griscom and Jachens, 1989). The rocks cropping out southwest of the fault near Point Arena are Upper Cretaceous and Tertiary marine sedimentary rocks, together with some older spilitic volcanic rocks that may be part of the Franciscan assemblage (Wentworth, 1968). Little basement information from rock samples is available in the shelf areas west of the San Andreas fault between Point Arena and the Mendocino fault. An important well 20 km west of Point Arena (fig. 9.4) recovered quartz-mica schist and slate basement cuttings (Hoskins and Griffiths, 1971) at a depth of about 1.43 km. This description resembles rocks either from the eastern metamorphosed Franciscan assemblage south of San Francisco or from roof pendants in the Salinian block, implying that a major strike-slip fault is located between the well and Point Arena. The proposed Pilarcitos fault extension is thus interpreted to lie here between the well and the coastline on a major fault shown by McCulloch (1987). Location of this proposed Pilarcitos fault extension farther northwest than Point Arena is uncertain, although the fault presumably continues to the former triple junction. McCulloch (1986; 1987, fig. 2b) described a boundary, termed the "Navarro discontinuity," trending east-west from the Point Arena area to the lower continental slope, on the basis of regional differences in magnetic pattern and physiography; this boundary may be the fault extension or an earlier strike-slip fault of this system. Griscom and Jachens (1989) also hypothesized a more northwestward extension, approximately colinear with the fault segment south of Point Arena, following a fault trace interpreted from seismic-reflection profiles (McCulloch, 1987, fig. 14).

Distinctive gravity and magnetic anomalies characterize the poorly known shelf area lying north of Point Arena and between the San Andreas fault and the proposed Pilarcitos extension (figs. 9.2, 9.3). The sources of these anomalies lie in the basement, with their upper surfaces at the basement interface below Tertiary sedimentary rocks, according to geophysical models and basement-depth calculations. A major gravity high (+20 mGal) is located near lat 40° N. (point D_2, fig. 9.4). We believe that the high-density basement rocks which cause this high extend southward along the west side of the San Andreas fault at least as far as at Point Arena (E_2, fig. 9.4), even though the gravity values on the map fall below 0 mGal along the southern part of this reach. The basement along the postulated southern part of the high is mantled by 1 to 3 km of Tertiary sedimentary rocks (Hoskins and Griffiths, 1971), which probably cause gravity lows (–15 to –30 mGal) that here mask the gravity high caused by the basement. Two magnetic anomalies on the shelf are truncated by the San Andreas fault at point F_2 and at a place a few kilometers south of point G_2 (fig. 9.4), which is located where the steepest gradient on the northeast side of the second anomaly is truncated by the fault (see McCulloch, 1987, fig. 17).

Our search for geophysical anomalies or features matching points D_2, E_2, F_2, and G_2 on the opposite (northeast) side of the San Andreas fault (see Griscom and Jachens, 1989) began with the observation that gravity highs are not characteristic of much of the Franciscan assemblage and are observed only extending along the San Andreas fault between approximately lat 37° and 38° N. (fig. 9.2). We have selected points D_1 and E_1 (fig. 9.4) as the approximate limits of the gravity highs

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on the northeast side and propose to correlate these points and their connecting strip of high gravity with the corresponding points D_2 and E_2 and associated gravity high discussed in the previous paragraph. The positions of these points (D and E) along the fault vary in reliability but are probably no more accurate than ±20 km; point E_2 is the most uncertain. The total offset of the gravity high by the San Andreas fault is thus about 250±40 km. We have used the gravity results to explore our magnetic-anomaly map (fig. 9.3) for additional correlations. Only one correlation was found within an offset range of 200–300 km. We suggest that point F_1, marking the end of a truncated magnetic high passing through San Francisco, correlates with point F_2 and that point G_1, the truncated end of a magnetic gradient more than 50 km long, correlates with the other truncated gradient at point G_2. The locations of points F_1, F_2, and G_2 along the fault are accurate to within about ±5 km. Point G_1 is located a few kilometers too far to the southeast because a short northwestward extension of the feature was recently cut off by the young segment of the San Andreas fault in the San Francisco peninsula area and now lies between the San Andreas and Pilarcitos faults. The offset of points F_1 and F_2 is 250 km; the offset of points G_1 and G_2 is 263 km. The magnetic anomalies truncated at points F_1 and G_1 are associated with northwest-striking belts of mafic and ultramafic rocks within the Franciscan assemblage and are best shown on the more detailed maps by Brabb and Hanna (1981) and Griscom and Jachens (1989).

We conclude that the total offset of the pairs of corresponding magnetic features is approximately 250±10 km. Of this offset, about 105 km is attributable to the San Gregorio-Hosgri fault, leaving only 145 km for the San Andreas fault south of its junction with the San Gregorio fault. Because the total San Andreas offset south of the San Francisco peninsula is considered to be much larger, namely, about 300 km, we suggest that the missing 155 km is predominantly accounted for by former movement on the Pilarcitos fault and its proposed northwestward extension, which is thought to intersect the San Andreas at about lat 38°30′ N., as described above. This early Pilarcitos fault was thus formerly the main strand of an earlier San Andreas fault system that lay to the west of both magnetic features F and G (that is, before they were offset by faulting). Note that this interpreted fault-movement history and the subsequent plate-tectonic analysis all depend on the correctness of the correlation between the pairs of offset magnetic and gravity anomalies on the San Francisco peninsula and northwest of Point Arena. The magnetic and gravity anomalies northwest of Point Arena and west of the San Andreas fault are such conspicuous features and so obviously truncated by the San Andreas fault that we would expect to find their counterparts somewhere on the opposite side of the fault. Although we can find no alternative correlations for these anomalies other than those indicated in figure 9.4, we are aware that they may not correlate with any anomalies on the opposite side of the fault, although we consider this noncorrelation to be unlikely.

Additional information on offset along the proposed Pilarcitos fault extension is provided by interpretation of two strong magnetic anomalies on the northeast side of the San Andreas fault in central California (H_1 at lat 35°30′–35°40′ N. and lat 36°00′–36°15′ N., respectively). The source bodies for both anomalies appear to be truncated by the fault, and interpretations of the gravity and magnetic fields over both bodies suggest that they are composed of serpentinite (Hanna and others, 1972; Griscom and Jachens, in press). The most likely candidates for corresponding magnetic features on the southwest side of the fault system are the poorly defined anomalies at points H_2 and I_2 west of Point Arena. The magnetic field is poorly known in this area, and so anomaly locations and shapes may not be accurate, but the offset is approximately 435 km from points H_1 and I_1. This distance can be obtained by summing an assumed 320 km for offset on the San Andreas fault south of San Francisco plus 115 km offset on the San Gregorio-Hosgri fault. The location of point I_2 supports the Navarro discontinuity as a possible continuation of the proposed Pilarcitos fault extension, or some earlier continuation. We suggest that the large magnetic-high area bounded by the 500-nT contour and located 25 km south of point I_2 (fig. 9.3) may represent a southerly extension of anomaly I, which north of point I_1 extends for 400 km along the east side of the Coast Ranges. There appear to be no satisfactory alternative anomalies for correlation with points H_1 and I_1 along the southwest side of the present San Andreas fault near Point Arena.

IMPLICATIONS FOR PLATE TECTONICS

In the previous sections, we have discussed how potential-field data provide information on the three-dimensional configuration of the San Andreas fault and on the various offsets along member faults of the San Andreas system in relation to plate tectonics. Here, we interpret the potential-field expression of the two ends of the San Andreas fault system in relation to plate tectonics and lithospheric thickness.

MENDOCINO TRIPLE JUNCTION

At the north end of the San Andreas fault off Cape Mendocino, three lithospheric plates (the Juan de Fuca,

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Pacific, and North American) meet at the Mendocino triple junction, where a trench meets two transform faults, the San Andreas and Mendocino faults. Along this trench to the north, the Juan de Fuca plate is subducting eastward beneath the North American plate. The geometry of this subducted plate has important implications (Jachens and Griscom, 1983) for an understanding of the Mendocino triple junction and its effects on the tectonics of California. During approximately the past 29 Ma, this triple junction has been migrating relatively northwestward along the coast of California from a latitude near Los Angeles (see fig. 3.11; Atwater, 1970; Atwater and Molnar, 1973). As this incipient San Andreas transform fault lengthened over time, eastward subduction continued to the north of the migrating triple junction.

During 29–23 Ma, the major fault of the San Andreas system was probably situated near the base of the continental slope, where an accreted wedge of Miocene(?) sedimentary rocks (McCulloch, 1987) accumulated between lat 35° and 40° N., presumably because of oblique subduction from transpressive forces between the plates. This now-inactive fault forms a contact between oceanic and continental crusts (fig. 9.4) that have major differences in magnetic properties (fig. 9.3). The oceanic crust displays the typical oceanic lineated or striped magnetic pattern striking north-south and northeast, with interruptions striking east-west or southeast that are caused by transform faults. The continental crust adjacent to this inactive fault is magnetically rather smooth and featureless. The magnetic boundary between oceanic and continental crust west of the San Andreas fault is very abrupt in comparison with active subduction zones (compare the magnetic expression of the Cascadia subduction zone off Oregon in Bond and Zietz, 1987); the oceanic stripes terminate at the base of the continental slope, even though reflection profiles show oceanic crust continuing farther east beneath the slope (McCulloch, 1987). The low convergence rate of oblique subduction and the time available since the fault became inactive may have allowed the concealed or subducted oceanic crust to heat up sufficiently beneath the continental margin to destroy the remanent magnetization that causes the stripes.

During early Miocene time (23 Ma), the motion along the transform must have been essentially strike slip and was substantially transferred to the present San Andreas fault system in central California. Without subduction east of the elongating transform, an ever-enlarging triangular hole or window (Dickinson and Snyder, 1979) developed in the slab of lithosphere subducted beneath the continent. This window model is also applicable to the time interval (29–23 Ma) but needs modification to include effects of transpression along the earlier San Andreas fault. The north boundary of this window is the subducted south edge of the Juan de Fuca plate, and hot upwelling asthenospheric material presumably occupies the window. The south edge of the Juan de Fuca plate lies beneath the North American plate at the shore about 20 km south of Cape Mendocino and can be identified by an east-west magnetic anomaly (Griscom, 1980a), as well as by the distribution of seismicity (Hutchings and others, 1981). This position coincides with a steep gravity gradient (here called the Cape Mendocino gravity anomaly) that slopes downward into a large gravity low (−50 mGal) to the north and east. The spatial coincidence between the position of the Cape Mendocino gravity anomaly at the coast and the place where the south edge of the Juan de Fuca plate passes beneath the coastline strongly suggests that this gravity anomaly reflects the south edge of the subducted plate (fig. 9.4). At least three other characteristics (Jachens and Griscom, 1983) of the anomaly support this interpretation. (1) The southeastward trend of the gravity anomaly and then its change to easterly are consistent with the directions of present and past relative motions between the Juan de Fuca and Pacific plates (Nishimura and others, 1981; Wilson, 1986). (2) The gravity anomaly broadens and is less steep toward the southeast, suggesting that its source progressively deepens in this direction; calculated depths along the anomaly to the end of the southeast-trending segment define a line plunging approximately 9° SE. with a depth of only 6 km at the coastline corresponding well to the 8-km depth estimated from aeromagnetic data (Griscom, 1980a). (3) A cross section across this anomaly, using the above depths together with reasonable densities and thicknesses for the subducted Juan de Fuca plate and the asthenospheric window fill to the southwest, produces a calculated gravity model (Jachens and Griscom, 1983) in good agreement with the observed gravity field. We draw the following conclusions from the gravity data (Jachens and Griscom, 1983).

1. Above the south edge of the Juan de Fuca plate, the North American plate must have the shape of a thin lip that gradually thickens eastward, attaining a thickness of possibly only about 30 km at the Coast Range fault; this fault marks the east limit of the Franciscan assemblage about 130 km inland from Cape Mendocino (see chap. 3). Just south of the Juan de Fuca plate, asthenospheric material that filled the slab window should lie beneath the North American plate at a depth comparable to that of the upper surface of the Juan de Fuca plate. Because the North American plate has been moving relatively southward across this boundary for many millions of years, the top of the asthenosphere probably is shallow beneath much of the Coast Ranges in central California, and the thin west lip of the North American plate may be decoupled from much of the mantle, although some underplating by mantle material is likely.

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2. For reasons similar to conclusion 1, the lithosphere of southern California near the San Andreas fault system is thin and may be decoupled from much of the mantle.
3. Relatively thin, decoupled lithosphere may explain why deformation along the boundary between the Pacific and North American plates takes place over a zone 50 to 100 km wide rather than being restricted to the San Andreas fault, and why the plate boundary has been able to migrate eastward from the base of the continental slope to its present position at the San Andreas fault. It may also explain both why certain structural blocks southwest of the fault in southern California have been able to rotate clockwise by as much as 70°–90° during and after the Miocene (Luyendyk and others, 1985; Hornafius and others, 1986) and how extensional basins formed between these blocks. Furthermore, it can help explain why the seismicity of the San Andreas fault generally does not extend below 12-km depth.
4. Thin, relatively cool lithosphere of the southward-moving North American plate has been continuously placed on hot upwelling asthenosphere when crossing the Juan de Fuca plate boundary. As pointed out by Lachenbruch and Sass (1980), this process can explain the heat-flow anomaly in the North American plate that peaks in the Coast Ranges about 300 km south of the latitude of Cape Mendocino (Lachenbruch and Sass, 1973). Calculations by Lachenbruch and Sass (1980) show that, given a velocity of 5 cm/yr for movement of the Pacific plate relative to the North American plate, the heat flow should increase by a factor of 2 approximately 200 km south of the edge of the Juan de Fuca plate because 4 Ma is required for the heat anomaly to reach the surface from 20-km depth. These various parameters agree with the observed heat-flow anomaly. For a heat source as deep as 20 km, the model requires the hot asthenosphere to accrete to the bottom of the North American plate and to be conveyed off southward, so that a continuous supply of vertically moving, hot asthenosphere be supplied to the bottom near the Juan de Fuca plate boundary. This hypothesized coupling involves a rather thin layer of accreting upper mantle that, in turn, is probably decoupled from underlying asthenosphere. The gravitationally predicted depth to the base of the North American plate is within the limits required by Lachenbruch and Sass, (1980) model, at least within 70 km of the San Andreas fault.

Interpretation of geologic and geophysical data for the San Andreas fault system north of San Francisco (Griscom and Jachens, 1989) suggests that eastward migration of the plate boundary from its presumed original position at the base of the continental slope to its present position at the San Andreas transform fault may have occurred by means of a series of eastward jumps of the Mendocino triple junction covering a total distance of about 150 km during the past 29 Ma. Our general model for the history of this triple junction is one of successive eastward jumps, with sustained periods at each position while significant strike-slip motion occurred on the various transform fault systems, including the San Andreas fault. We are aware, however, that the picture in detail may have been far more complex. The present position of the San Andreas fault north of San Francisco is thus interpreted to be relatively youthful. The triple junction was initially situated near the base of the continental slope at the northwest end of the Miocene(?) accreted wedge (but far to the south of its present latitude); the basal fault (McCulloch, 1987) below the subduction complex is shown as a toothed line in figure 9.4 because of the thrust component in this transform fault. The triple junction is interpreted to have been subsequently situated at the north end of the proposed Pilarcitos fault extension and then to have jumped eastward a minimum of about 100 km to the present San Andreas fault trace at what is now approximately lat 38°20′ N. on the North American plate. When this jump occurred, the three faults that formed the junction all had to readjust; the simplest scenario is as follows: (1) The Mendocino fault was extended on strike farther eastward, for the distance of the jump, about 100 km; (2) a new segment of the San Andreas fault broke obliquely through the Franciscan assemblage to the northwest (severing the correlated geophysical anomalies described above) and extended from the new triple junction to the junction of the newly formed (or soon to be formed) San Gregorio fault with the Pilarcitos fault, a distance of about 250 km; and (3) the surface trace of the subduction zone north of the triple junction also jumped eastward 100 km, thus abruptly isolating a thin triangular slab of Franciscan assemblage (probably less than 15 km thick) from the North American plate. This postulated triangular slab of rocks is now gone, most likely subducted away. Further complexity is provided by the King Peak subterrane of the King Range terrane (McLaughlin and others, 1982), which is an elongate mass of turbidites, about 45 km long, just south of Cape Mendocino (fig. 9.4) that is believed to have been obductively accreted from the west during the early Pleistocene (McLaughlin and others, 1986). The King Peak subterrane may have been detached and transported northwestward from the San Francisco area (just south of lat 38°20′ N.) as part of the Pacific plate and then reattached to the North American plate by a very recent local jump of the triple junction westward less than 35 km (McLaughlin and others, 1982); this explanation may account for the anomalously higher thermal metamorphism of this subterrane relative to the terranes that are now adjacent to it. Recent work suggests that the triple

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junction may be on shore at Cape Mendocino (Clarke, 1988; McLaughlin and others, 1988); if so, the King Peak subterrane may still be essentially part of the Pacific plate. The tectonic interpretation detailed above also requires that the San Gregorio-Hosgri fault first began moving and joined the present San Andreas fault at approximately the same time as or shortly after the eastward jump of the triple junction, and thus cut off the proposed northward extension of the Pilarcitos fault, after which the extension became inactive.

The proposed 150-km eastward movement of the triple junction can also explain the submarine topography near Cape Mendocino, where the Continental Shelf south of the Mendocino fault extends about 130 km farther west than that directly north of the fault.

The timing of the jump can be estimated from the horizontal offset of the paired geophysical anomalies, about 250 km, which translates to an age of about 5 Ma, assuming combined strike-slip rates of 4.8 cm/yr (DeMets and others, 1987; Minster and Jordan, 1978) for the San Andreas and San Gregorio faults. This age estimate is crude because it assumes that no other faults were absorbing the relative motion between the two plates. For example, simultaneous movement on the Hayward-Calaveras fault system will cause the computed age of offset to be too young. The eastward jump of the triple junction appears to be associated with a change in stress orientations in this region. The north end of the San Gregorio-Hosgri fault trends about 20° clockwise relative to the older fault traces. In addition, the northward-migrating triple junction subsequently traced out a major right-lateral bend, as shown by the present position of the San Andreas fault north of Point Arena. The central section of this bend is about 100 km long and trends 20° clockwise to the older trace. This change may correlate with the gradual change in absolute motion of the Pacific plate that occurred between 5 and 3.2 Ma (Cox and Engebretson, 1985; Pollitz, 1986), producing a change from strike slip to transpression in this region and a clockwise rotation of 20° (Harbert and Cox, 1986) in the relative-velocity vector for the plate pair, the same angle as the anomalous change in direction for both the San Gregorio fault and the right-lateral bend in the San Andreas fault north of Point Arena. This change in relative motion probably correlates with a change in strike direction of the subducting south edge of the Juan de Fuca plate, as deduced from gravity data (Jachens and Griscom, 1983). Before the jump, this strike was east-west, thus permitting eastward extension of the Mendocino transform fault without interference; after the jump, the strike of the subducting plate edge changed to S. 60° E., making later eastward fault extension more difficult.

Stratigraphic evidence for the postulated eastward jump of the triple junction about 5 Ma may be sought in the late Miocene and Pliocene stratigraphy of Deep Sea Drilling Project (DSDP) Site 173 (fig. 9.4). Depositional hiatuses occur at 5 and 4.3–3.2 Ma (Barron, 1989), whereas a study of both micropaleontology and tephra beds indicates a hiatus from about 4.4 to 2.8-Ma (Sarna-Wojcicki and others, 1987). McCulloch (1987, fig. 25) believed that the middle Pliocene deformation and minor erosion interpreted from reflection profiles correlate with this 4.4–2.8-Ma hiatus at Site 173. We suggest that the eastward jump of the triple junction about 5 Ma was shortly followed by the middle Pliocene deformation and by the hiatus at Site 173. These two correlative events were thus caused both by the jump and by the simultaneous change in the direction of relative plate motion.

SALTON BUTTES SPREADING CENTER

The San Andreas fault terminates to the southeast in a buried spreading center at the south end of the Salton Sea, where a row of five small siliceous volcanic domes ("buttes") protrude above recent sedimentary deposits of the Salton Trough. These domes, in addition to being associated with a local northeast-striking magnetic high, are situated on the crest of a larger, northwest-trending magnetic high (outlined on fig. 9.4) that is interpreted (Griscom and Muffler, 1971) to be caused by a magnetic mass, 30 km long, 3 to 12 km wide, and about 4 km thick, with its top buried more than 2 km below the surface. This magnetic high is associated with a similarly shaped gravity high (Biehler and Rotstein, 1979), the source of which may partly be the magnetic mass but may also be the relatively high density metamorphosed sedimentary rocks associated with the geothermal area (Elders and others, 1972). The Salton Buttes spreading center probably strikes northeast because the row of domes, the local aeromagnetic and gravity anomalies, and the geothermal area all coincide and strike northeast; (2) this proposed position for the center bisects the larger northwest-trending magnetic high into approximately equal parts interpreted to be new "oceanic" crust; and (3), ideally, a spreading center should trend approximately normal to an associated transform fault. In apparent contradiction, the Brawley seismic zone strikes S. 20° E. from the Salton Sea (Johnson and Hill, 1982) and consists of shallow earthquakes (Severson and McEvilly, 1987) located mostly within the valley fill; this seemingly anomalous direction may be due to accommodation of these overlying, partly decoupled materials to a series of short northeast-trending spreading centers between the Salton Sea and Cerro Prieto, Mexico (see fig. 3.6), on strike S. 20° E. and 100 km distant (Fuis and Kohler, 1984; Sibson, 1987). The large, northwest-trending magnetic mass is interpreted to reflect about 30 km of northwestward spreading along its long axis, in which the spreading was

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associated with intrusive activity that built up a 30-km-long strip of magnetic mafic rocks and new crust in the lower section of and below the sedimentary fill. This magnetic feature may not be directly comparable to oceanic-crustal anomalies because slow cooling beneath the fill probably results in weak remanent magnetization, unlike the situation for oceanic crust. This anomaly thus may be predominantly caused by induced magnetization.

The gravity field of the Salton Trough, which is filled with great thicknesses of Cenozoic sedimentary rocks, varies systematically from north to south. An elongate gravity low of −30 to −40 mGal is associated with the sedimentary rocks northwest of the Salton Sea (beyond lat 33°20′ N.). Southward along the axis of the trough, the gravity field increases rapidly until the south end of the Salton Sea, where maximum values of 0 mGal are obtained over the presumed spreading center described above. Farther southeast, to the United States-Mexico border, gravity values range from only –10 to –20 mGal, an initially surprising observation because the 3.5 km or more of young, unmetamorphosed sedimentary deposits in this area might be expected to produce anomalies lower than –40 mGal (Biehler, 1964; Griscom, 1980c, p. 20), similar to the gravity expression northwest of the Salton Sea. Biehler (1964) offered two explanations for the missing low: thinner crust or local high-density basement beneath the trough. Seismic-refraction studies (Fuis and others, 1982, fig. 17A) confirm the second explanation and show a deep "subbasement" (density, 3.1 g/cm^3) in the trough that extends below about 12-km depth. Using this refraction model as a constraint, a gravity model (Fuis and others, 1982, fig. 20) indicates that the crust beneath the trough is no thinner than that of the bordering mountains a few kilometers to the northeast.

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As the Pacific plate slides northward past the North American plate along the San Andreas fault, the frictional stress that resists plate motion there is overcome to cause earthquakes. However, the frictional heating predicted for the process has never been detected. Thus, in spite of its importance to an understanding of both plate motion and earthquakes, the size of this frictional stress is still uncertain, even in order of magnitude.

10. STRESS AND HEAT FLOW

By ARTHUR H. LACHENBRUCH and A. MCGARR

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INTRODUCTION

As one of the best exposed tectonic-plate boundaries in the world, the San Andreas fault provides an excellent opportunity to study the forces causing interplate motion and the associated great earthquakes. Thus, there is considerable motivation, scientific, social, and economic, to understand the thermomechanics of the San Andreas fault system, which has been the subject of intensive studies for the past several decades.

Although substantial progress has been made in unraveling the complex kinematics of the San Andreas fault system (Atwater, 1970; Minster and Jordan, 1984; Weldon and Humphries, 1986), efforts to determine the stresses that give rise to San Andreas fault slip, to date, have not led to anything resembling scientific consensus. The uncertainty results from widespread disagreement over the implications of different methods of assessing the stresses.

The question of how much shear stress acts on the San Andreas fault to cause dextral slip began to acquire definition in 1968, when the first heat-flow data adjacent to the fault zone (fig. 10.1) were gathered and analyzed by Henyey (1968). Because these data did not reveal any anomalous heat flow near the major active faults of the San Andreas system, upper bounds of about 10 to 20 MPa on the average frictional stress resisting fault motion could be calculated (Brune and others, 1969; Henyey and Wasserburg, 1971). These upper bounds were taken as evidence confirming speculation on the low strength of the crust based on earthquake stress drops, almost invariably in the range 0.1–10 MPa (for example, Chinnery, 1964; Brune and Allen, 1967). At the same time, however, laboratory experiments indicated typical frictional strengths for precut rock samples of about 100 MPa under pressure and temperature conditions thought to obtain in the upper crust (Byerlee and Brace, 1968, 1969; Byerlee, 1970).

◀ FIGURE 10.1.—Heat-flow and stress measurements are taken in wells such as this one being drilled by the U.S. Geological Survey at the Crystallaire site, 4 km northeast of the San Andreas fault in the western Mojave Desert. Photograph by M.D. Zoback.

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Over the next several years, new heat-flow measurements supported the absence of any local heat-flow anomaly associated with the San Andreas fault (Lachenbruch and Sass, 1973) and thus augmented the position for low frictional fault strength. The recognition of a broad heat-flow high coincident with the Coast Ranges of California led Lachenbruch and Sass (1973) to suggest that partial decoupling at the base of the seismogenic part of the crust might account for both the weak fault (minimum in shear stress at the fault trace) and the broad thermal anomaly.

Additional laboratory experiments on different rock types, and in conditions of higher temperature and confining pressure than had been obtained previously, continued to support high frictional strength in the top 15 to 20 km of the fault zone (Stesky and Brace, 1973). The experimental results are most simply characterized in terms of a coefficient of friction that varies little with rock type (Byerlee, 1978), slip rate, or slip history (Dieterich, 1979; Ruina, 1983). As emphasized by Brace and Kohlstedt (1980) and Kirby (1980), these results still indicate a high-strength upper crust.

Beginning in the late 1970's, inplace stress measurements have provided another way to assess the stress acting on the San Andreas fault (Zoback and others, 1977), especially with the advent of stress measurements at depths approaching 1 km only a few kilometers distant from the fault (Zoback and others, 1980). If the observed depth gradient for the component of shear stress thought to act on the San Andreas fault could be extrapolated to the base of the seismogenic zone, as argued by McGarr and others (1982), then the corresponding frictional stress resisting fault motion is a factor of 3 greater than the upper bound from the heat-flow analyses, as presented most recently by Lachenbruch and Sass (1980).

The most recent developments, if accepted at face value, could be construed as additional evidence favoring a low-strength San Andreas fault. Specifically, stress-direction indicators on either side of the fault have been interpreted to mean that there is almost no shear stress resolved on the fault plane, thus implying a very weak fault zone (Mount and Suppe, 1987; Zoback and others, 1987). If so, then the question regarding the strength of the fault would be answered, and the outstanding problem would be the equally vexing one of understanding the nature of a remarkably weak fault zone.

This chapter is largely a review and commentary on the different approaches taken to estimate the tractions acting on the San Andreas fault. We restrict our attention to three main methods: (1) inferring stress from the fault's energy budget (thermal and kinetic), (2) inferring fault strength from laboratory measurements of the stresses needed to slide rocks past one another under pressure, and (3) inferring stress on the fault from observations of the crustal state of stress.

ESTIMATES OF AVERAGE STRESS FROM FAULT ENERGETICS

ENERGY BALANCE

In figure 10.2, an earthquake is viewed, according to Reid's (1910) rebound theory, as a strained patch of fault surface of area A that suddenly breaks, permitting points initially in contact to be displaced from one another by an average amount u. The breakage is like the sudden failure of an overloaded leaf spring. We are interested in the average shear stress acting parallel to the wall in the failed section of the fault surface. We denote its initial value by τ_1 and its final value by τ_2. The inclined line in figure 10.3 represents the elastic unloading of the medium as the earthquake displacement increases to its final value u. The area under this line, which represents the total elastic energy released by the earthquake per unit area of faulted surface, can be written as

$$\frac{E}{A} = \bar{\tau} u \,, \tag{1a}$$

where

$$\bar{\tau} = \tfrac{1}{2}(\tau_1 + \tau_2) \,. \tag{1b}$$

The energy E must supply the work E_a of generating seismic waves and the work E_r, converted to heat in overcoming frictional resisting forces. Thus,

$$E = E_a + E_r + ? \,, \tag{2}$$

where the question mark is a reminder (which we shall forget for the moment) that there may be other significant sinks of earthquake energy, such as the surface

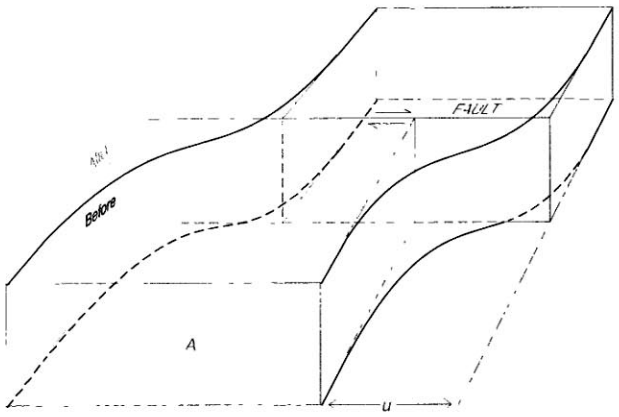

FIGURE 10.2.—Elastic-rebound theory (Reid, 1910), showing displacement near a strike-slip fault segment of area A before and after an earthquake with displacement u. Arrows along fault indicate direction of relative movement.

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energy consumed in creating new fractures. We can now write

$$\frac{E_a}{A} = \tau_a u \tag{3}$$

$$\frac{E_r}{A} = \tau_r u \,, \tag{4}$$

where τ_a, the "apparent stress" of seismology, is the portion of the earthquake stress $\bar{\tau}$ allocated to the production of seismic waves, and τ_r is the average frictional resisting stress allocated to the production of heat. The individual areas represented by equations 3 and 4 are shown in figure 10.3 by contrasting patterns.

This interpretation of the areas in figure 10.3 is fairly general, as long as we define τ_1, τ_2, and τ_r, respectively, as the weighted averages of initial stress, final stress, and friction over the faulted surface, the weighting function being the local fault slip (see Savage and Wood, 1971; Lachenbruch and Sass, 1980). Combining equations 1 through 4 yields

$$\bar{\tau} = \tau_a + \tau_r + ? \,, \tag{5}$$

which states that unless the question mark represents something important that we've neglected, the average earthquake stress $\bar{\tau}$ is the sum of the apparent stress τ_a, to be estimated from seismic measurements of E_a (eq. 3), and the resisting stress τ_r, to be estimated from thermal measurements of frictional heat E_r (eq. 4).

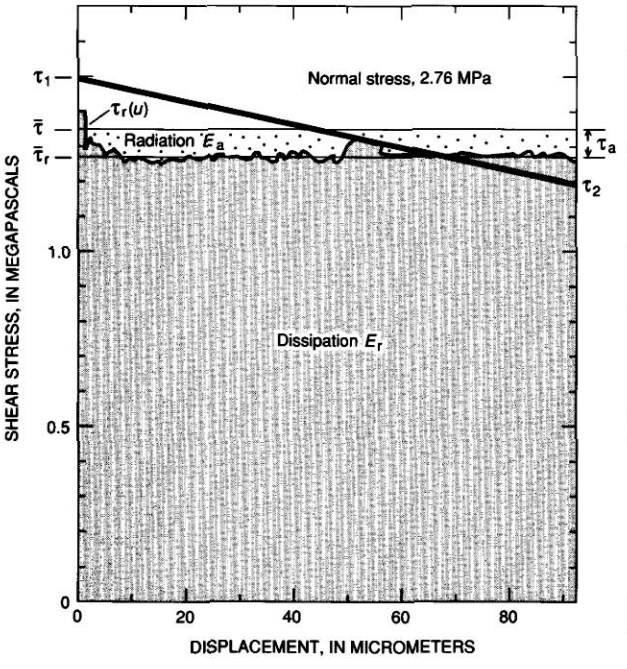

FIGURE 10.3.—Relation between resisting stress and displacement in the unloading elastic medium (inclined line) during an earthquake. As slip (u) increases, stress in the rock diminishes linearly from τ_1 to τ_2, with average value $\bar{\tau}$. Area under this line is total work expended per unit fault area; area (shaded) below curve of resisting stress ($\tau_r(u)$, with average value $\bar{\tau}_r$) is energy dissipated per unit fault area (E_r). Difference between total work expended and dissipated energy is work (done by apparent stress τ_a) that is available for seismic radiation (E_a, stippled area). Modified from a laboratory experiment on a large granite sample by Lockner and Okubo (1983).

APPARENT STRESS: SEISMIC ESTIMATE OF τ_a

Seismologists (for example, Wyss and Brune, 1968; Savage and Wood, 1971; Wyss and Molnar, 1972) have defined apparent stress as

$$\tau_a = \eta\bar{\tau} \,, \tag{6}$$

where η is the seismic efficiency, defined by

$$\eta = \frac{E_a}{E} \tag{7a}$$

$$= \frac{\tau_a}{\bar{\tau}} \,, \tag{7b}$$

where equation 7b follows from 7a according to equations 2 through 5; that is, η is simply the fraction of the total energy release, or the fraction of the average earthquake stress, allocated to seismic radiation.

To estimate τ_a, seismologists first determine the radiated energy E_a and the seismic moment M_0, defined as

$$M_0 = GAu \,, \tag{8}$$

where u is the average slip of an earthquake over a fault-surface area A, and G is the modulus of rigidity (Aki, 1966). Equations 1 and 6 through 8 then yield the simple relation

$$\tau_a = \frac{GE_a}{M_0} \,. \tag{9}$$

A numerical estimate of τ_a can be obtained from equation 9 with the following commonly used formulas relating earthquake magnitude M to E_a or M_0 (Gutenberg and Richter, 1956; Hanks and Kanamori, 1979),

$$\log M_0 = 16 + 1.5M \tag{10a}$$

$$\log E_a = 11.8 + 1.5M \,, \tag{10b}$$

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where M_0 and E_a are in ergs. Substitution of equations 10 in 9 yields

$$\tau_a = 6.3\times10^{-5}G\ . \tag{11}$$

With $G=3\times10^4$ MPa, the value for τ_a is 2 MPa. Almost without exception, estimates of τ_a fall within the range 0–5 MPa, with no indication of any systematic dependence on either earthquake size or tectonic environment (Spottiswoode and McGarr, 1975; Fletcher and others, 1983; Boatwright and Choy, 1986). In short, 5 MPa appears to be a conservative upper bound to τ_a. Thus, the contribution of τ_a is small, and the average fault stress $\bar{\tau}$ can be large only if the frictional resistance τ_r is large (eq. 5).

If laboratory "earthquakes" are proper analogs of crustal earthquakes, which may or may not be the case, then data for such events, including those illustrated in figure 10.3, indicate that τ_a is indeed small, only a tiny fraction of τ_r. By inducing unstable frictional failure (earthquakes) across a 2-m-long fault between slabs of granite 40 cm thick (Dieterich, 1981), Lockner and Okubo (1983) measured seismic efficiencies η for numerous events to conclude that $\eta\approx0.05$. If this result were true also for natural earthquakes—a big "if"—then for a typical value τ_a of 2 MPa, the corresponding value of $\bar{\tau}$, from equation 6, would be 40 MPa, which, as will be seen, is nearly 3 times higher than the limit inferred from an analysis of heat-flow data (Lachenbruch and Sass, 1980).

FRICTION: THERMAL ESTIMATE OF τ_r

Unlike the energy of seismic waves, which permits an estimate of apparent stress τ_a for individual earthquakes from measurements at distant stations, the heat energy of individual earthquakes is not readily analyzable to estimate friction because it causes a measurable temperature rise only within a few meters of the earthquake source, a location inaccessible for measurement. Even for the largest earthquakes, these individual temperature pulses would be indistinguishable from background a few months after the event, and so timely attempts to detect them by drilling would be difficult (McKenzie and Brune, 1972; Lachenbruch, 1986). However, because the frictionally generated heat diffuses quite slowly, it should accumulate in the vicinity of the fault, eventually building up the local thermal gradient until the observable heat loss at the Earth's surface in the fault zone exceeds the normal background heat flow by the rate of heat generation on the fault. Thus, in principle, the measurement of a heat-flow anomaly in the fault zone should permit an estimate of the average frictional contribution τ_r to the earthquake fault stress $\bar{\tau}$ (eq. 5).

The heat-flow anomaly that we seek does not depend on the amount of heat E_r liberated by a single earthquake in a restricted fault area with a displacement u (eq. 4), but on the long-term average rate of heat generation (Q) and the long-term average slip rate (v) from the cumulative effect of successive events. Although most fault displacement probably occurs within a few tens of seconds during large earthquakes every century or so at slip velocities greater than the average ones by a factor of about 10^8, the long-term buildup of the heat-flow anomaly would be indistinguishable from that caused by uniform slip at an equivalent average velocity because the thermal time constant for the buildup (approx 10^6 yr) is large relative to the earthquake-recurrence interval (10^1-10^3 yr). Therefore, we view the slip as a uniform continuous process and introduce

$$Q = \frac{1}{A}\frac{dE_r}{dt} \tag{12a}$$

and

$$v = \frac{du}{dt}\ . \tag{12b}$$

Differentiation of equation 4 yields

$$Q = \tau_r v\ , \tag{13}$$

where v is the long-term average slip velocity, τ_r is the (displacement averaged) frictional resistance, and Q is the long-term average rate of frictional heat production per unit area on the fault surface.

Equation 13 refers to the entire seismogenic (brittle) layer (approx 10–15 km thick), not just a patch as in equation 5. Over this depth, it is reasonable to consider the long-term slip velocity v to be independent of depth, but generally the heat-production rate Q will not be. For example, if the friction τ_r increased linearly with depth (for example, because of increasing gravitational pressure on the fault, as discussed below), the heat production Q on the fault would also increase linearly, as shown in figure 10.4*B*. According to heat-conduction theory, the temperature in the fault plane would then build up over time, as shown in figure 10.4*C*, and a heat-flow anomaly would develop at the surface over the fault, as shown in figure 10.4*A*. For such a distribution, a sharp heat-flow anomaly is seen to build up over the fault in about 1 m.y.; after several million years, it approaches a maximum value somewhat greater than half the average frictional heat production Q on the fault surface (fig. 10.4*B*). This anomaly falls off over a distance from the fault of the same order as the depth of the seismic layer (assumed to be 14 km in fig. 10.4). Other reasonable distributions of

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frictional sources give similar results (see Henyey, 1968; Brune and others, 1969; Henyey and Wasserburg, 1971; Lachenbruch and Sass, 1973, 1980).

The long-term slip rate v, which can be estimated from studies of offset (and dated) geologic features, generally ranges from 2 to 4 cm/yr for motion on the main trace of the San Andreas fault over the past several million years throughout California (see chap. 7; Grantz and Dickinson, 1968). As a useful rule of thumb, if the fault in figure 10.4 were slipping at an average rate (v) of 3 cm/yr and

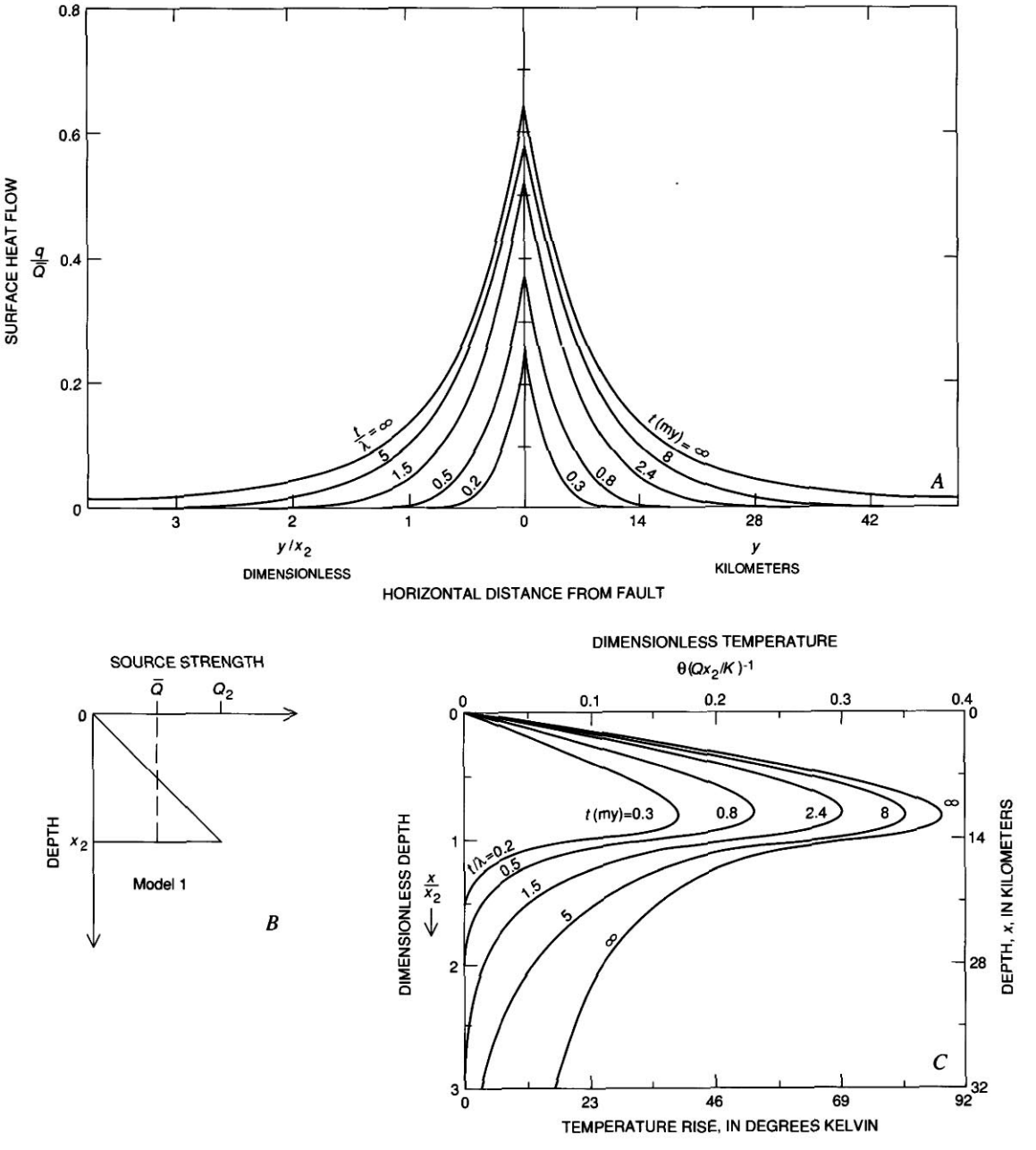

FIGURE 10.4.—Surface heat flow q (A) and fault-plane temperature Θ (C) for a linear increase in source strength from zero at the surface to Q_2 at depth x_2 (B). t, time since initiation of faulting; λ, dimensionless time; Q, average rate of frictional heat generation on fault; K, thermal conductivity. Dimensional results are for x_2=14 km, K=2.5 W/mK, and Q=42 mW/m^2 (equivalent to $2v$≈25 mm/yr, τ_r≈50 MPa) (Lachenbruch and Sass, 1980).

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resisted by an average frictional stress τ_r of 100 MPa, then the average rate of frictional heat production Q (figure 10.4*B*) would be about 0.1 W/m^2; that is,

$$0.1 \text{ W/m}^2 = 100 \text{ MPa} \times 3 \text{ cm/yr}. \quad (14)$$

This quantity is about twice the stable continental heat flow, and so, according to figure 10.4*A*, the corresponding heat-flow anomaly over the fault would be about 100 percent of background after 2 or 3 m.y. of fault slip, whereas if the mean frictional resistance were only 10 MPa, the corresponding heat-flow anomaly would be only about 10 percent of background, close to the limit of detection. Accordingly, if no heat-flow anomaly could be detected over the fault, the mean frictional resistance would be no more than about 10 MPa; if the mean frictional resistance were about 100 MPa, a very conspicuous anomaly should be observed.

An example of heat-flow measurements near the San Andreas fault is shown in figure 10.5 for the Mojave Desert region of southern California (region 7, fig. 10.6). The pattern of anomaly curves from the model in figure 10.4 is scaled for the estimated local slip velocity (25 mm/yr; Weldon and Sieh, 1985) and for a mean frictional resistance of 50 MPa. Clearly, the data are incompatible with such an anomaly; in fact, the average heat flows near the fault and far from the fault ("within 10 km" and "beyond 10 km," figs. 10.7*C*, 10.7*D*) are statistically indistinguishable. Figures 10.7*A* and 10.7*B* show that the same condition prevails in the Coast Ranges of central California (regions 3–6, fig. 10.6). In fact, no local heat-flow anomaly has been confirmed anywhere on the main trace of the San Andreas fault (for possible exceptions, see Lee, 1983; Lachenbruch and Sass, 1988), and so, according to the foregoing simple considerations, the average friction on the fault, τ_r, probably does not exceed 10 MPa.

SUMMARY

In summary, we note that analysis of the kinetic energy of seismic waves suggests that the associated apparent stresses (τ_a) do not exceed 5 MPa. Similarly, analysis of long-term frictional heating and the predicted and observed effects on heat flow from conduction theory

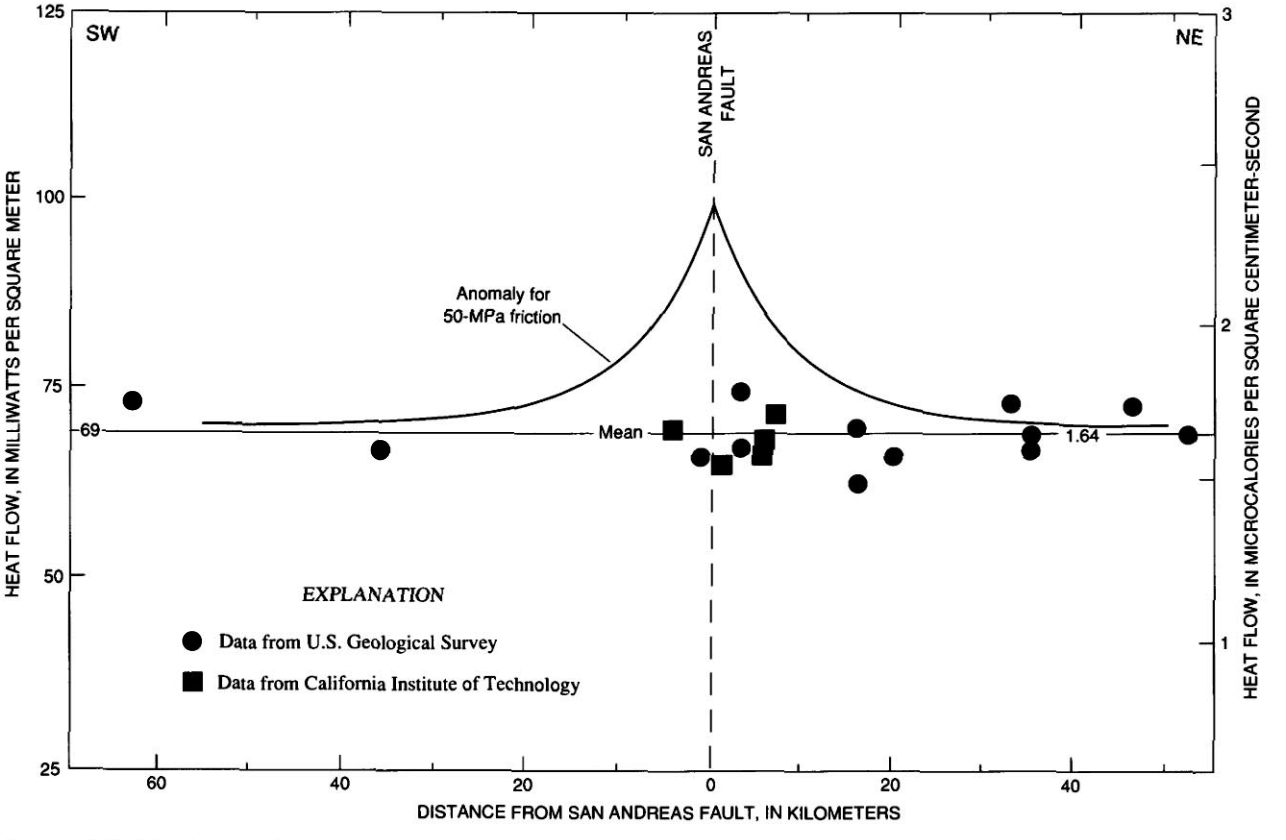

FIGURE 10.5.—Heat flow as a function of distance from the San Andreas fault in the Mojave segment (region 7, fig. 10.6). Theoretical anomaly is for a slip velocity of 25 mm/yr and average friction of 50 MPa (Lachenbruch and Sass, 1988).

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suggest that the average frictional resistance τ_r does not exceed about 10 MPa. Thus, according to equation 5, the long-term average combined earthquake stress $\bar{\tau}$ probably does not exceed about 15 MPa, and, of course, it could be much less. The initial stress τ_1, or "fault strength," would be greater by half the stress drop (fig. 10.2; Lachenbruch and Sass, 1980, eq. 41a), no more than another 5 MPa, for an upper limit of 20 MPa. The major assumptions in this analysis are (1) that heat transfer is exclusively by conduction—that is, no significant heat is transferred by moving ground water; (2) that the fault geometry can be represented by the usual simple conventions (see figs. 10.2, 10.3, and 10.4); and (3) that an earthquake's energy is converted exclusively to seismic waves and heat—that is, no appreciable energy is consumed by creating new surfaces, phases, or chemical combinations (Lachenbruch and Sass, 1973, 1980). We shall discuss these points later.

ESTIMATES OF AVERAGE STRESS FROM LABORATORY MEASUREMENTS OF FRICTION

ROCK FRICTION AND THE STRENGTH OF THE FAULT

We have seen that the average shear stress $\bar{\tau}$ on an earthquake fault can be viewed as the sum of a dynamic part τ_a and a frictional part τ_r. The dynamic part is shown to be small from seismic evidence, and so the earthquake stress must be large or small according to the size of τ_r. We have also seen that τ_r is small according to geothermal evidence. We now consider a second line of evidence from laboratory measurement of friction which suggests to many that, contrary to the geothermal evidence, τ_r must be large.

According to these results, rock surfaces will slide when the shear stress on their surface of contact exceeds the static frictional strength τ_f, given by

$$\tau_f = \mu\sigma_n' , \tag{15a}$$

where

$$\sigma_n' = \sigma_n - P \tag{15b}$$

σ_n is the normal pressure pushing the surfaces together, and P is the fluid pressure in the pores and cracks tending to hold the surfaces apart; σ_n' is called the "effective" normal stress (we generally denote such effective stresses by a prime, " ′ "). The proportionality constant μ in equation 15a is the coefficient of static friction; extensive laboratory experiments show that its value is generally in the range 0.6–0.9 for a remarkably large variety of rock types and surface conditions (Byerlee, 1978), although some studies (for example, Wang and others, 1980), reported substantially lower friction coefficients for some geologic materials, including certain types of fault gouge.

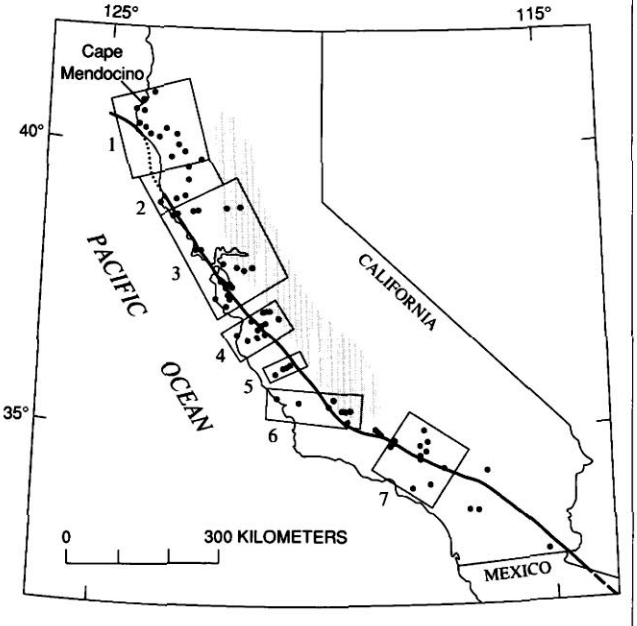

FIGURE 10.6.—Locations of heat-flow measurements near the San Andreas fault and of numbered regions referred to in figure 10.7 (Lachenbruch and Sass, 1980). Heavy line, San Andreas fault, dashed where approximately located, dotted where concealed; stippled area, Great Valley.

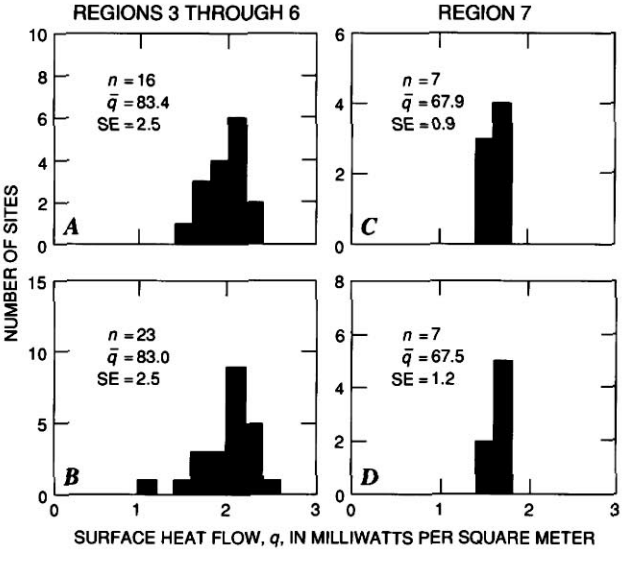

FIGURE 10.7.—Comparison of heat flow within 10 km of main trace of the San Andreas fault (*A*, *C*) and beyond 10 km (*B*, *D*) for regions 3–6 (*A*, *B*) and region 7 (*C*, *D*) (see fig. 10.6 for locations); transitional regions 1 and 2 are not represented. Modified from Lachenbruch and Sass (1980). n, number of samples; $\bar{q}$, mean heat flow; SE, standard error.

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We presume that a fault is a fracture with little cohesive strength that remains inactive until the natural shear stress τ resolved along it exceeds its frictional strength τ_f given by equation 15. This shear stress, which depends on the magnitudes of the principal stresses and on the angular relation between the fault plane and the principal stress directions (fig. 10.8), is given by (Jaeger, 1956, p. 8)

$$\tau = \tfrac{1}{2}(\sigma_1 - \sigma_3) \sin 2\Theta , \qquad (16)$$

where it is assumed for convenience that the intermediate-principal-stress direction (σ_2) lies in the fault plane (true if μ is independent of the orientation of this plane). In figure 10.8, σ_2 is vertical, and σ_1 and σ_3 are the maximum and minimum horizontal principal stresses. Θ is the angle formed by the fault normal and the direction of least compression (σ_3); it is also the angle between the fault trace and the direction of greatest compression (σ_1). To express the failure criterion (eq. 15) in terms of the stress field and fault orientation, we note that the effective normal stress, σ_n', in equation 15 can be written as (Jaeger, 1956, p. 8)

$$\sigma_n' = \tfrac{1}{2}(\sigma_1' + \sigma_3') - \tfrac{1}{2}(\sigma_1' - \sigma_3') \cos 2\Theta . \qquad (17)$$

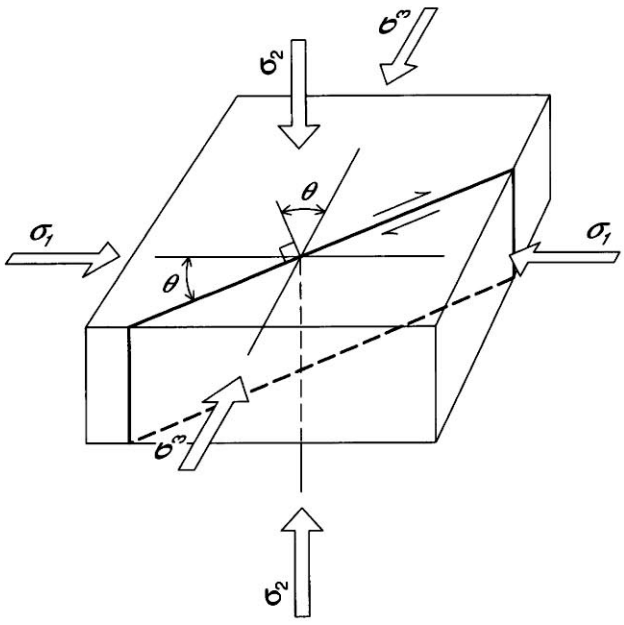

FIGURE 10.8.—Conventions for discussing orientation of fault relative to direction of principal stresses: $\sigma_1 > \sigma_2 > \sigma_3$. Arrows indicate direction of relative movement along fault.

With equations 15 through 17, the friction stress τ_f that must be exceeded on a fault for it to slip can be determined if we know (1) the maximum and minimum principal stresses σ_1 and σ_3, (2) the fluid pressure P, (3) the coefficient of friction μ, and (4) the angle Θ describing the orientation of the fault relative to the principal-stress axes.

As we increase the stress difference, in what direction (Θ) will the Earth ultimately break, and what will be the stress on the failure plane? Clearly, the answer could be influenced by the existence of planes of weakness (McKenzie, 1969); for example, major preexisting faults or foliated country rock might result in directions with anomalously low μ.

THE CASE OF EQUAL STRENGTH IN ALL DIRECTIONS

We first assume that no such directional strength variation exists, that the rock is fractured in all directions, and that all potential shear surfaces have the same coefficient of friction μ. In this case, the foregoing equations show that the trace of the favored fault plane will depart from the direction of maximum compression by an angle Θ_0, dependent only on the coefficient of friction, as follows:

$$\Theta_0 = 45° - \tfrac{1}{2}\tan^{-1}\mu . \qquad (18)$$

Note that generally $\Theta_0 < 45°$ (the direction of the surface of maximum resolved elastic shear stress, eq. 16) because of the effects of normal stress on friction (Jaeger, 1956). With this additional relation (eq. 18), we can express the frictional strength τ_f of a plane of orientation Θ in terms of the coefficient of friction and the effective-principal-stress components as follows:

$$\frac{\tau_f}{\sigma_1'} = \frac{\mu}{1 + \mu \cot \Theta} = \frac{\mu}{1 + \mu^2}\left(1 + \frac{\mu}{\sqrt{1 + \mu^2}}\right)^{-1} , \qquad \Theta = \Theta_0 \qquad (19a)$$

$$\frac{\tau_f}{\sigma_3'} = \frac{\mu}{1 - \mu \tan \Theta} = \frac{\mu}{1 + \mu^2}\left(1 + \frac{\mu}{\sqrt{1 + \mu^2}}\right)^{-1} , \qquad \Theta = \Theta_0 \qquad (19b)$$

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$$\frac{\tau_f}{\frac{1}{2}(\sigma_1' + \sigma_3')} = \frac{\mu}{1 + \mu \cot 2\Theta}$$

$$= \frac{\mu}{1 + \mu^2}, \qquad \Theta = \Theta_0 \qquad (19c)$$

To evaluate the frictional strength, the vertical stress is generally assumed to be a principal stress (reasonable because the Earth's surface supports no traction) equal to the rock column's weight, ρgz, an assumption supported by inplace stress measurements (McGarr and Gay, 1978). In this case, the vertical effective stress σ_v' will be

$$\sigma_v' = \rho gz - P, \qquad (20a)$$

where ρ is the rock density, and the fluid pressure P is given by

$$P = \lambda \rho gz\,. \qquad (20b)$$

The value $\lambda=0$ represents conditions in dry rock. For a typical open ("hydrostatic") hydrologic system, we have $\lambda \sim 0.37$ ($= \rho_w/\rho_{rock}$, where ρ_w is the density of water). As $\lambda \to 1$, the fluid pressure approaches the weight of overburden, and the vertical effective stress σ_v' vanishes (as discussed below, this limit probably occurs only in the thrusting regime, where σ_3 is vertical).

The curves in figure 10.9 (referred to ordinate scale at left margin) give the frictional strength normalized by the effective vertical principal stress for those cases in which the vertical stress is the maximum (dashed curve), average (solid curve), or minimum (dotted curve) principal stress, respectively. The first right-hand ordinate scale gives the increase in frictional strength with depth (τ_f/z) for the usual assumption of hydrostatic fluid pressure ($P=\rho_w gz$). For typical values of μ from Byerlee's results (for example, 0.6–0.9), the frictional strength for normal and thrust faults increases with depth at rates of about 5 and 20 MPa/km, respectively (fig. 10.9). The rate of increase for strike-slip faults lies between these limits; a commonly used value, 8 MPa/km, is shown by the solid curve in figure 10.9. For an upper-crustal fault extending to 14 km depth, these increases would result in average friction (the value at a 7-km depth) of 35, 56, and 140 MPa for normal, strike-slip, and thrust faults, respectively (see second ordinate scale on right, fig. 10.9). Such calculations provide the basis for the expectation of high fault stress from the analysis of laboratory results: These values are substantially greater than the 20 MPa upper limit for initial stress suggested from the analysis of heat-flow data in strike-slip tectonic regimes (horizontal dashed line, fig. 10.9). Note that the heat-flow limit would require $\mu \lesssim 0.2$ for the assumed conditions.

THE CASE OF A WEAK DIRECTION

The estimates of large friction from the fault model of figure 10.9 depend on three principal assumptions: (1) that the average coefficient of friction on real faults is comparable to typical laboratory values ($\mu \sim 0.6$–0.9), (2) that the average fluid pressure throughout the depth of the fault is comparable to the weight of the overlying column of water ($\lambda \sim 0.37$, eq. 20), and (3) that the coefficient of friction (μ) is the same in all directions, so that the fault direction (Θ_0) is determined by the applied stress (eq. 18) and not by the orientation of a special plane of weakness. Partly in response to recent reports that the maximum horizontal principal stress is oriented nearly perpendicular to the San Andreas fault (Mount and Suppe, 1987; Zoback and others, 1987), we drop the last assumption and suppose that the fault occupies a very weak plane (which is assumed to contain the intermediate principal stress). Because of the anomalous weakness of this plane, the friction along it could be very low, consistent with the heat-flow data, and faulting could persist there irrespective of the ambient stress field.

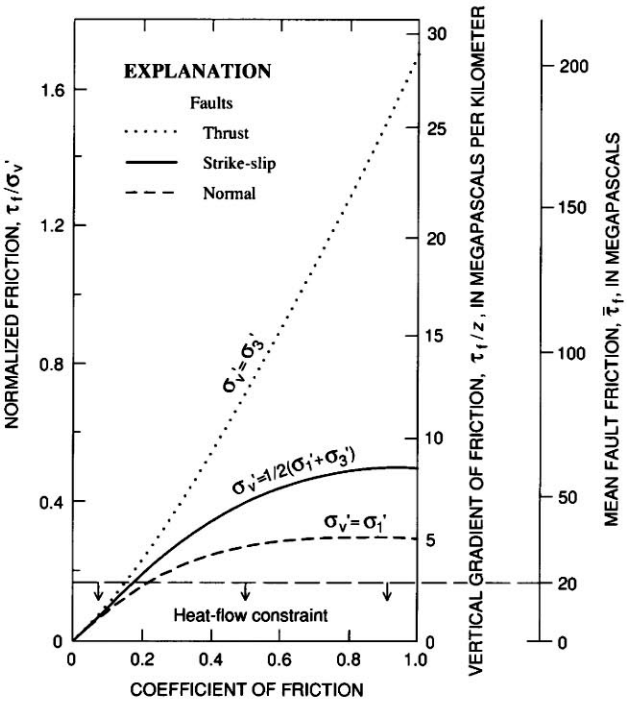

FIGURE 10.9.—Variation of normalized fault friction (left-hand ordinate scale) with coefficient of friction under three conditions for vertical effective stress (σ_v') for failure at optimum angle Θ_0. Increase in fault friction τ_f with depth z under hydrostatic fluid pressure is given by right-hand ordinate scale, and mean friction $\bar{\tau}_f$ on a fault 14 km deep by scale on far right. Horizontal dashed line is upper limit of mean friction suggested by heat-flow constraint. σ_1' and σ_3', maximum and minimum horizontal effective principal stress, respectively.

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According to the friction model (eq. 15), the two factors that might weaken the plane are either an abnormally low coefficient of friction or unusually high pore pressure. For now, we assume that each of these conditions can exist regardless of laboratory or hydrologic evidence.

The first question we consider is whether a very weak fault can coexist with stronger faults such that both types are active, as may be the case along the San Andreas fault (for a closely related discussion, see Sibson, 1985). To address this question, it is convenient to express the crustal strength in terms of the ratio σ_1'/σ_3' (Brace and Kohlstedt, 1980). From equations 19a and 19b, the condition at failure (eq. 15a) for a weak plane oriented at an angle Θ to the direction of σ_1 (fig. 10.8) is

$$\frac{\sigma_1'}{\sigma_3'} = \frac{1 + \mu \cot \Theta}{1 - \mu \tan \Theta}. \qquad (21a)$$

For isotropic strength, failure occurs at Θ_0 (eq. 18), the direction in which σ_1'/σ_3' is a minimum for a given μ:

$$\frac{\sigma_1'}{\sigma_3'} = (\sqrt{1 + \mu^2} + \mu)^2, \qquad \Theta = \Theta_0. \qquad (21b)$$

Faults at angles other than Θ_0 support greater deviatoric stresses and the higher values of σ_1'/σ_3' given by equation 21a.

The conditions necessary for the coexistence of active faults with different coefficients of friction are illustrated in figure 10.10, where the ratio of effective principal stresses at the point of failure is plotted as a function of the fault angle for various values of the coefficient of friction (eq. 21a). Suppose, for example, that the coefficient of friction is only 0.1 in the direction of the San Andreas fault, whereas in all other directions it is 0.6. Because σ_1'/σ_3' must be at least 3.1 to cause faulting in the crustal environs, the low-strength San Andreas fault must be oriented at $\Theta \leq 3.5°$ or $\Theta \geq 81.5°$ (fig. 10.10); otherwise, σ_1'/σ_3' would be too low to cause slip in the stronger directions. In this example, then, the weak fault must be oriented either nearly parallel or nearly perpendicular to the direction of σ_1.

In the context of the notion that the San Andreas fault is nearly perpendicular to the direction of σ_1', or at $\Theta \sim 90°$ in figure 10.10, we note that a very low coefficient of fault friction is required. The strength curves for each value of μ have two asymptotes where $\sigma_1'/\sigma_3' \to \infty$. These asymptotes occur where the denominator of equation 21a vanishes; one asymptote is at $\Theta = 0$, or σ_1 parallel to the fault, for any value of μ, and the other is at $\Theta = 2\Theta_0$ (eq. 8), or $\Theta = 90 - \tan^{-1} \mu$. Thus, the normal to any fault that fails in shear must be oriented at an angle of at least $\tan_{-1}$ μ from the direction of σ_1. For the four curves in figure 10.10, the right-hand asymptotes are at $\Theta = 84.3$, 73.3, 59.0, and 48.0, respectively, for $\mu = 0.1$, 0.3, 0.6, and 0.9. Thus, if the fault trace makes an angle greater than 59°, then μ must be less than 0.6 as long as the fluid pressure is less than the least principal stress.

More generally, enhanced pore pressure alone cannot lead to active faults nearly normal to σ_1 unless $P > \sigma_3$, in which case $\sigma_3' < 0$ and failure is likely to manifest itself as hydraulic fracturing rather than fault slip.

SUMMARY

To recapitulate, the simplest interpretation of earthquakes in terms of the frictional fault model and laboratory measurements of rock friction leads to fault stresses many times larger than the limits suggested from heat-flow and fault energetics. This interpretation depends on three assumptions: (1) that the average coefficient of friction on real faults is comparable to typical laboratory values ($\mu \sim 0.6$–0.9), (2) that the pore-fluid pressure throughout the depth of faulting is comparable to the weight of the overlying column of water, and (3) that the intrinsic resistance of the Earth to sliding is isotropic—that is, no weak directions exist. To reduce the high estimates of friction obtained from rock mechanics to the low ones obtained from heat flow, we must assume either smaller values of the coefficient of friction μ or larger

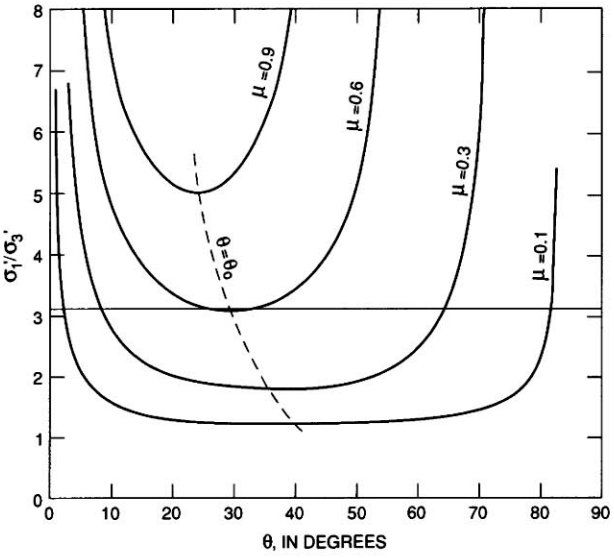

FIGURE 10.10.—Failure criteria for various coefficients of friction as functions of fault angle Θ. For fixed σ_1', σ_3', and μ, slip will occur for all Θ between points where horizontal line defined by σ_1'/σ_3' intersects curve defined by μ. For example shown, if $\sigma_1'/\sigma_3' = 3.1$, then for $\mu = 0.1$, slip can occur at all angles between 3° and 82° but only at optimum angle 29.5° if $\mu = 0.6$. Dashed curve, optimal failure angle $\Theta_0(\mu)$ (eq. 18). σ_1' and σ_3', maximum and minimum horizontal effective principal stress, respectively.

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values of fluid pressure P (see eq. 15). Of particular interest in this connection is reported evidence that the trend of the San Andreas fault in California might occupy an anomalous weak direction. According to Mount and Suppe (1987) and Zoback and others (1987), the fault plane is nearly perpendicular to the direction of maximum compression ($\Theta \sim \pi/2$, fig. 10.10), a direction in which the resolved shear stress is very small. Such a condition could be consistent with the low friction required by heat flow, while permitting high stresses to accommodate the subsidiary faulting observed on more favorably situated planes. This model, however, raises some basic questions regarding the mechanics of faulting; for the fault to slip, it must have a low shear strength, as well as the low shear stress suggested by its orientation. If conventional friction theory applies, anomalously high fluid pressure along the fault cannot readily account for the required low friction because, unless μ is unusually low, the fault becomes exceedingly resistant to shear failure as Θ begins to approach $\pi/2$ (fig. 10.10).

ESTIMATION OF FAULT STRENGTH FROM INPLACE STRESS MEASUREMENTS

In principle, measurements of the magnitude and orientation of crustal stress in the vicinity of the San Andreas fault should provide the most direct evidence of the forces acting to cause interplate motion there. However, some essential problems exist with this approach. Because we have little understanding of the mechanics of the system, it is difficult to interpret the data. We are not dealing with a laboratory experiment in which a sample is loaded in a testing machine whose characteristics are well known; in such a situation, it is straightforward to use gages to estimate the magnitude of the load. In contrast to the well-controlled laboratory situation, we have little idea of the nature of the forces applied to the Earth's crust to cause a deviatoric state of stress and, in the case of tectonically active areas, slip across major throughgoing faults. We know neither where the forces are applied nor what is applying them; moreover, there is even debate about what the state of stress would be if only gravity were acting (McGarr, 1988).

In addition to the absence of a conceptual framework, there are numerous experimental difficulties in determining the state of stress, that is, the magnitudes and orientations of the three principal stresses as functions of position within the crust. Data must be obtained from depths below the zone of weathering, in rock that is sufficiently strong to support deviatoric stresses. In granitic rocks, this requirement, in effect, necessitates stress measurements at depths of about 50 m or more, thus limiting the measurement technique to hydraulic fracturing, the only common procedure that can be used at such depths (Haimson and Fairhurst, 1970).

The hydraulic-fracturing, or "hydrofrac," method involves isolating a section of a borehole and then pressurizing this cylinder by pumping in fluid until a tensile crack forms and propagates into the previously unfractured rock. By monitoring the pressure-time history of the fluid in the isolated section, both the maximum and minimum horizontal stresses can be estimated (Hubbert and Willis, 1957; Zoback and Haimson, 1983). This approach assumes that one of the principal stresses σ_v is oriented vertically and can be calculated from the weight of overburden (eq. 20). The other two principal stresses are the maximum, σ_H, and minimum, σ_h, horizontal stresses. In contrast to engineering usage, the convention adopted here is for compressional stresses to be positive because, in the Earth's crust, tensional stresses are rarely encountered, even at the surface.

Although the uppermost crust near the San Andreas fault system has not been sampled as much for stress as for heat flow, enough inplace stresses have been measured to provide an indication of the state of stress there and how it compares with crustal stresses in other tectonic settings. To date, 41 successful hydrofrac measurements have been made in the 12 wells shown in figure 10.11 at depths of as much as 850 m. A total of 29 of these data, in wells along the Mojave reach of the fault (fig. 10.11*C*), were analyzed by McGarr and others (1982). Since that study, four stress measurements have been made at Black Butte (BB, fig. 10.11*C*) in the Mojave Desert (Stock and Healy, 1988), the data from the Hi Vista well have been reanalyzed by Hickman and others (1988), and additional measurements have been made in central California (Zoback and others, 1980). Currently, stress measurements are being made at the Cajon Pass well near the southeast end of the Mojave reach of the San Andreas fault, with some observations at depths below 3 km. Because no clear picture has yet emerged (see Healy and Zoback, 1988), we have not incorporated the Cajon Pass results into this review.

The state of horizontal deviatoric stress can be characterized in terms of two parameters: the maximum horizontal shear stress τ_m given by

$$\tau_m = \tfrac{1}{2}(\sigma_H - \sigma_h) , \qquad (22)$$

and the angle Θ between the trace of the fault and the direction of maximum horizontal compressive stress σ_H. Under favorable conditions, both parameters can be determined by the hydrofrac technique. We have shown that if $\Theta \sim 45°$, then τ_m is entirely resolved onto the plane of the fault to produce its slip; as Θ approaches 0° or 90°,

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the resolved stress on the fault becomes arbitrarily small irrespective of the magnitude of τ_m (eq. 16).

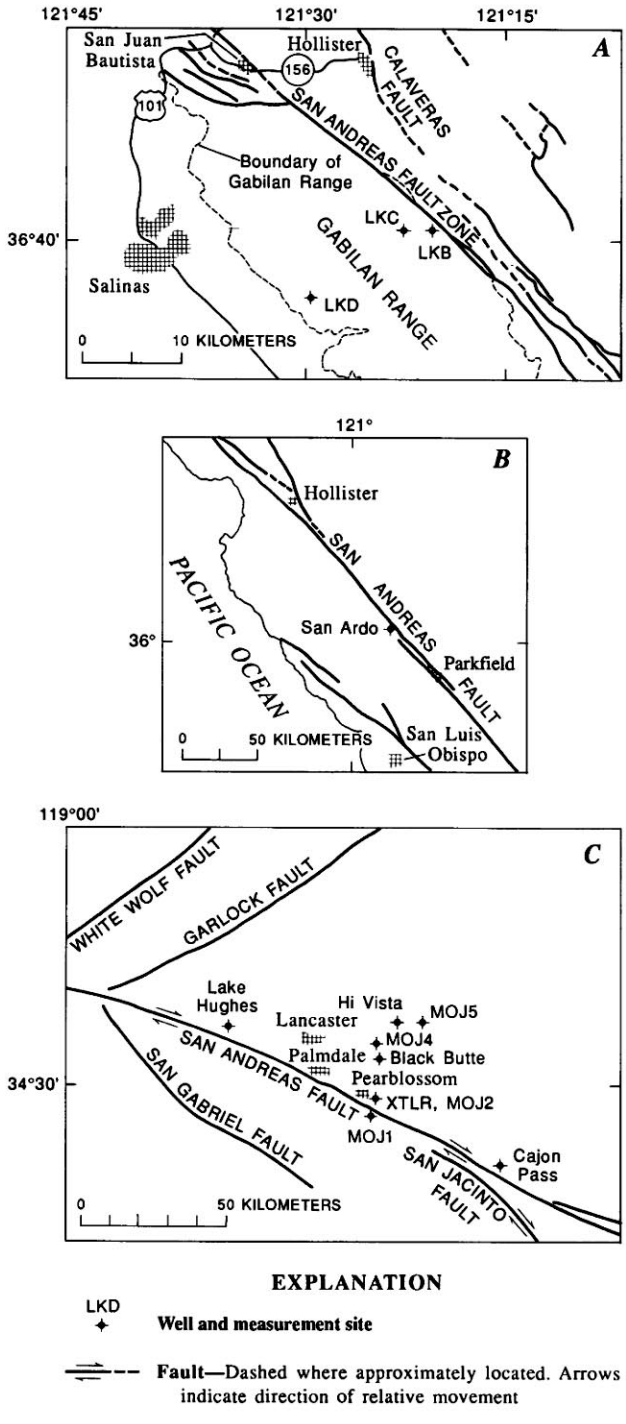

FIGURE 10.11.—Sketch maps of the Gabilan Range (*A*), central California coast (*B*), and western Mojave Desert (*C*), showing locations of wells where stress measurements have been taken along the San Andreas fault using the hydrofracturing technique.

Evidence regarding the actual orientation of σ_H relative to the strike of the San Andreas fault is contradictory. Observations favoring Θ distributed about 45°, so as to cause dextral fault slip, were presented by McNalley and others (1978), Zoback and others (1980), Zoback and Zoback (1980), and Hickman and others (1988); however, these data, from the Mojave Desert, show considerable scatter. In contrast, Mount and Suppe (1987) and Zoback and others (1987) reviewed a broad set of data, including many borehole breakout orientations, that suggest $\Theta \approx 90°$; Oppenheimer and others (1988) came to a similar conclusion. An intermediate result was obtained by Jones (1988), who stated that σ_H is oriented at 65° to the local strike of the San Andreas fault in southern California. Thus, currently, we know neither the preferred value of Θ nor whether such a value even exists. For the foregoing values of Θ (45°, 65°, or 90°), the shear stress resolved on the fault (eq. 16) would be τ_m, $0.77\tau_m$, or 0, respectively. In view of this uncertainty, we leave Θ unspecified and describe what is known of τ_m the upper limit to the shear stress that can be resolved on the fault.

The first-order feature seen in data from the San Andreas fault zone (fig. 10.12) is a marked tendency for τ_m to increase with depth. The solid line, a regression fit to all of the data, indicates a depth gradient of 8.3 MPa/km, not significantly greater than the gradient of 7.9 MPa/km reported by McGarr and others (1982) on the basis of 29 of the 41 data plotted in figure 10.12. We note that the observed depth gradient of τ_m also agrees well with the curves for strike-slip faults (solid curves, fig. 10.9) for a coefficient of friction of 0.6 or greater. In addition to the general increase in τ_m with depth, considerable variation from one well to another and within individual wells is suggested by figure 10.12.

Figure 10.13 shows that the departure of the measured values of τ_m from the regression line in figure 10.12 does not vary systematically with distance from the San Andreas fault. The principal conclusion to be drawn from figure 10.13 seems to be that the magnitude of deviatoric stress is not measurably affected by proximity to the San Andreas fault. Thus, whatever effect the fault may have on the magnitude of the shear stress, it is either too subtle, too localized, or too deep to be recognized in the current data set.

We note that there is no detectable difference between the Mojave Desert residuals, measured near a locked section of the San Andreas fault, and those in central California (fig. 10.11*A*), where the fault is creeping and presumably does not produce great earthquakes. If measurements were made to greater depths, some differences might appear, but at least in the topmost several hundred meters, the magnitude of shear stress seems to be largely independent of position along the strike of the San Andreas fault.

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Having failed to discover any spatial relation between the San Andreas fault and deviatoric-stress magnitudes, we now consider the question of whether or not any detectable differences exist between the stress states measured near the San Andreas fault (fig. 10.12) and those measured elsewhere in different tectonic settings. A review of crustal shear stress by McGarr (1980) considered a large suite of stress data in "hard" rocks measured at depths extending to 3.6 km. The resulting regression line of

$$\tau_m \text{ (MPa)} = 5.0 + 6.59z \text{ (km)} \quad (23)$$

has a greater surface intercept but a similar depth gradient to the San Andreas regression

$$\tau_m \text{ (MPa)} = 1.58 + 7.51z \text{ (km)} \quad (24)$$

fitted to the crystalline-rock data in figure 10.12. The comparison between equations 23 and 24 is not entirely appropriate because the data used to develop equation 23 represent all three stress states; stresses measured in regions of strike-slip tectonics were not considered separately by McGarr (1980) (see fig. 10.9). More recently, however, data measured in a 2,000-m-deep well in Cornwall, U.K. (Pine and others, 1983), permit quite an interesting comparison. For both the San Andreas and the Cornwall data sets, most of the stress observations are compatible with strike-slip tectonics; that is, σ_v is the intermediate principal stress. For most of the San Andreas and all of the Cornwall measurements, the rock is granitic. In contrast to the San Andreas system, however, the tectonic setting in Cornwall is presently inactive. The deviatoric stresses at Cornwall are believed to be a consequence of the Alpine orogeny, which apparently has caused the maximum horizontal stress to be oriented northwestward throughout much of Europe (for example, McGarr and Gay, 1978).

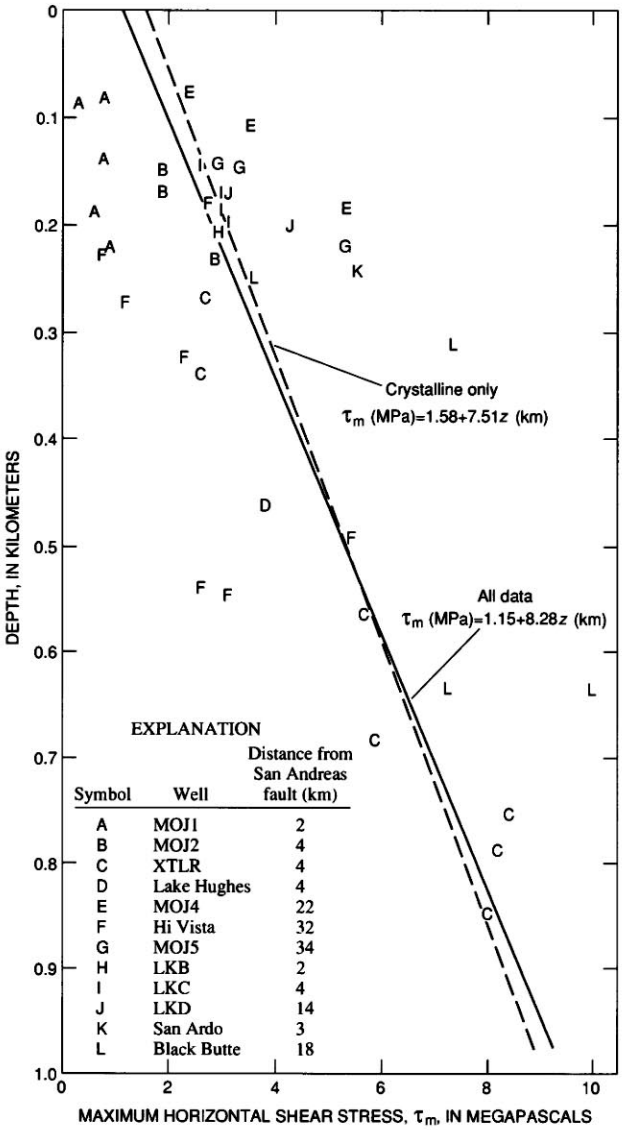

FIGURE 10.12.—Maximum horizontal shear stress as a function of depth z. Solid regression line has been fitted to all data, and dashed line to measurements in crystalline rock only. See figure 10.11 for locations of wells.

The 12 data sets obtained by Pine and others (1983) indicate a stress state (fig. 10.14) surprisingly similar to that of the San Andreas fault (fig. 10.12). For the maximum shear stress, the depth gradient of 7.52 MPa/km is indistinguishable from its counterpart in the crystalline San Andreas crust of 7.46 MPa/km; however, the surface intercept at Cornwall is larger. If the state of deviatoric stress is much the same in Cornwall as along the San Andreas system, then we must conclude that the plate-tectonic motion in California along the San Andreas fault has no expression in the shallow (1–2 km deep) stress field. Accordingly, much of what has been discovered about continental-crustal stress in general may apply to the crust adjacent to the San Andreas fault.

This generalization implies that the applied forces which give rise to τ_m in the vicinity of the San Andreas fault are not specific to the Pacific-North American plate boundary. In terms of observed shear stress, a major active plate-boundary fault would be at least as likely in Cornwall, U.K., as in California from what we currently know of stress magnitudes, at depths down to a few kilometers.

DISCUSSION

From what we currently know of crustal stress and heat flow, neither is influenced by proximity to the San Andreas fault, the most conspicuous and best studied

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plate-boundary fault on the continents. The measured horizontal shear stress increases rapidly with depth (approx 8 MPa/km), essentially as would be predicted from laboratory measurements of friction and the assumption that crustal stress is limited by the frictional resistance of fractures forced together by the weight of overlying rocks. From this consistency of independent observations, two large "if's" lead to what seems to be a physical contradiction: (1) if these vertical stress gradients persist throughout the depth of the seismogenic faulting layer (approx 12–15 km), then the average of the maximum horizontal shear stresses throughout the layer is quite large (approx 50 MPa); and (2) if the direction of the San Andreas fault is aligned with this maximum-horizontal-shear-stress direction, then the frictional heat generated by such stress during the documented fault motion (tens of kilometers per million years) should cause the background heat flow to double as the fault is approached. In 100 heat-flow measurements over a 1,000-km span of the San Andreas fault, no such heat-flow anomaly has been observed.

The contradiction stems from two separate lines of argument: (1) inplace and laboratory measurements of rock stress imply average fault stresses of about 50 MPa or more, and (2) the absence of a local heat-flow anomaly and the energy balance of the fault imply an average fault stress of about 15 MPa or less. At least one of these arguments must be wrong. We have outlined the major factors in each argument, and we shall now point out some possible loopholes and areas for further study.

The energy-balance argument leading to the heat-flow constraint on fault stress could be invalidated if the neglected energy sinks turn out to be important, or if the heat-conduction model is unrealistic or inappropriate. The general energy argument assumes that fault slip produces only seismic radiation and heat. It supposes that the energy consumed by the grinding of rocks into fault gouge (Lachenbruch and Sass, 1980) or the heat absorbed by possible phase changes or chemical reactions is negligible, and that the energy of seismic radiation does not grossly differ from the estimates made by seismologists. The heat-conduction model assumes that the frictional heat production occurs in a near-vertical fault zone (whose width is small relative to its depth) extending throughout the seismogenic layer. Systematic nonconductive removal of frictional heat by circulating ground water could invalidate this model (see O'Neill and Hanks, 1980; Williams and Narasimhan, 1989), as could a grossly different fault geometry—for example, a fault whose lower half was continually being rejuvenated because of migration of the upper half away from it along an upper-crustal detachment surface (Namson and Davis, 1988). All of these effects probably deserve further study.

The mechanical argument leading to large fault stress is based on observations of inplace stress (to maximum depths of approx 1 km in the San Andreas fault zone and of approx 4 km elsewhere on the continents), on laboratory measurements of rock friction and the efficiency of simulated earthquakes, and on downward extrapolation of these results through the seismic layer, on the assumption that fluid pressure is normal and frictional properties are uniform and isotropic. The consistency between the most frequently measured friction coefficients and the inplace determinations of the vertical gradient of maximum shear stress is reassuring (solid curves, fig. 10.9; fig. 10.12); however, the downward extrapolation of these results to depths of 10 or 15 km is an uncertain step, with loopholes that could invalidate the high-fault-stress conclusion.

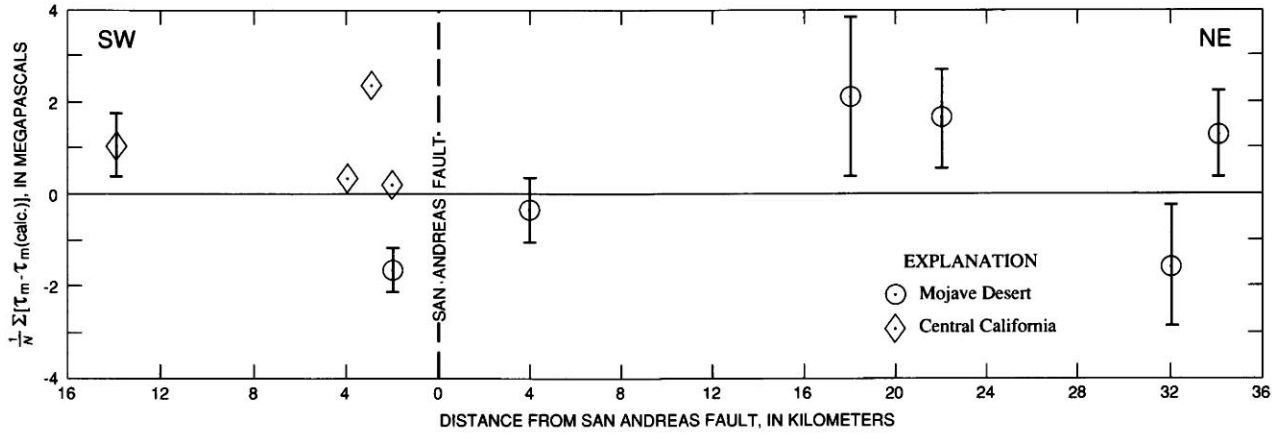

FIGURE 10.13.—Averages of N maximum-shear-stress (τ_m) residuals as functions of distance from the San Andreas fault. In calculating residual at a particular distance, effect of depth z is removed by using solid-line regression fit to data of figure 10.12 [τ_m (MPa)=1.15+8.28z (km)]. Error bars, 1σ.

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There are at least three such loopholes. First, the fluid pressure might increase with depth, as it is known to do in some sedimentary basins, approaching the minimum principal stress (Berry, 1973). Second, the friction coefficient at depth might be lower than average laboratory values; such lower values have been reported in some studies of gouge and other clay-size aggregates (Wang and others, 1980). Each of these effects could substantially lower the maximum stress at depth. Third, the frictional strength properties might be anisotropic, with the main trace of the fault occupying a weak direction. If so, the maximum stress at depth might be high, as maintained in the mechanical argument, but the shear stress resolved on the fault might be very low, as maintained in the thermal argument. Under these circumstances, the fault must be nearly parallel to a principal axis, as suggested by Mount and Suppe (1987) and Zoback and others (1987). Such a condition could be consistent with the low friction on the main fault required by heat flow, while permitting high stresses to accommodate subsidiary faulting on more favorably situated planes with normal frictional properties.

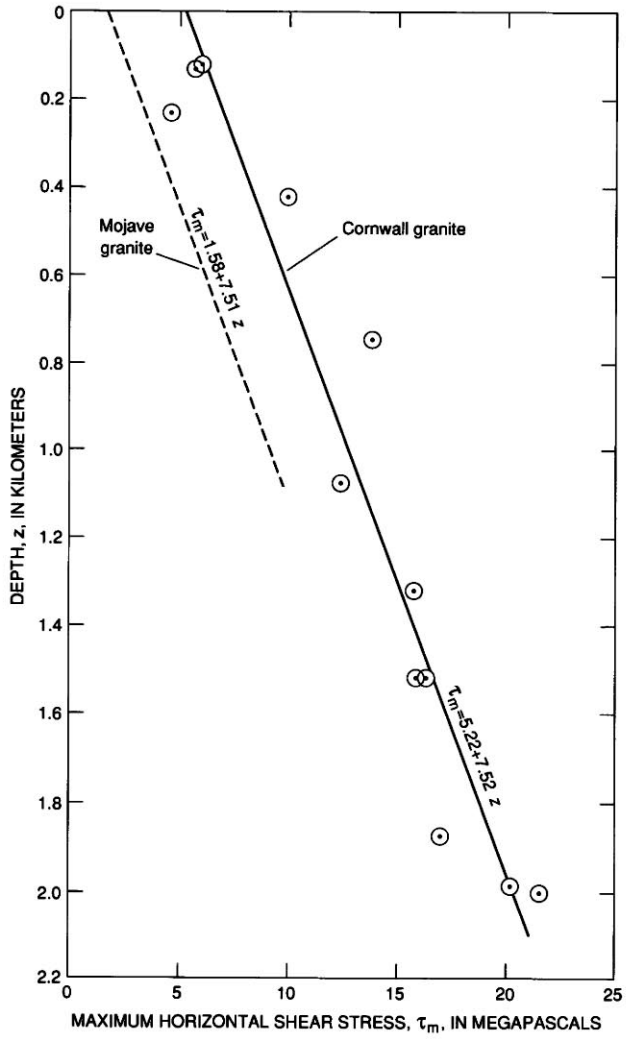

FIGURE 10.14.—Maximum horizontal shear stress τ_m as a function of depth z in granite near Cornwall, U.K. Data from Pine and others (1983).

As mentioned above in the section entitled "Introduction," geothermal studies of the San Andreas fault have provided evidence for a very weak fault for two decades; the meaning of this result depends heavily on the direction of principal stresses in the fault zone and the magnitude of the stress differences there. As we have shown, existing evidence is contradictory, especially in the Mojave Desert region. Many measurements of stress near the San Andreas fault suggest that the fault trace is inclined at an intermediate azimuth (approx 45°) to the principal-stress directions, and thereby imply that the fault coincides approximately with the direction of maximum shear stress and that the heat-flow constraint could not be satisfied unless horizontal shear stress (and stress differences) were low everywhere. In this case, both the San Andreas fault and active subsidiary faults with other orientations would have to be weak. If, however, the horizontal-stress differences are large, the weak fault required by heat flow is a "zero shear stress" boundary condition on the adjacent fault blocks that requires the fault to be almost normal to a principal-stress direction. In this case, the heat-flow constraint could be honored on an anomalously weak main trace, whereas subsidiary faults with other orientations and normal strength could also be active.

Thus, the occurrence of a weak direction may reconcile observations of rock mechanics with the longstanding implications of thermomechanical studies. It does, however, raise several questions:

1. Does the maximum-horizontal-principal-stress direction form an intermediate angle with the trace of the San Andreas fault (as was formerly accepted and as is required by isotropic frictional properties), or is the maximum compression nearly fault normal, as suggested by more recent observations (Mount and Suppe, 1987; Zoback and others, 1987)? As we have pointed out, there is conflicting observational evidence on this issue.
2. If the horizontal compressive stress is nearly fault-normal, what is the physical mechanism that permits the fault to slip under the small shear stress resolved on its direction? We have shown that the mechanism commonly invoked to explain a weak fault—namely, locally elevated fluid pressure—is not likely; however, anomalously low coefficients of friction could

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account for slip under near fault-normal compression if the frictional fault model is valid.

3. How would such a weak plate-boundary fault evolve, and would its existence imply that the resistance to relative motion between the Pacific and North American plates is negligible? What is the role of decoupling and basal resistance? Lachenbruch and Sass (1973) pointed out that strong shear stresses in the far field which might drive dextral slip between the plates cannot be balanced by a weak fault without invoking unexpected strength in the lower crust and drag (and possible decoupling or "detachment") beneath the horizontal base of the faulting layers. If the faulted plate boundary should weaken as it evolves, then either such basal drag must develop near the fault, or the far-field stress must diminish to maintain the equilibrium condition. The best way to learn whether such basal tractions exist is to determine whether the shear stress resolved parallel to the fault diminishes as the fault is approached (Lachenbruch and Sass, 1973; McGarr and others, 1982). We have shown here that a transect normal to the San Andreas fault shows no such diminution, although the observations were much shallower (approx 1 km deep or above) than the depth of earthquakes; direct stress measurements at seismogenic depths (below 5 km) are needed. Whether or not such basal decoupling and drag exist near the San Andreas fault is fundamental to our understanding of its earthquakes and of the nature of continental transform plate boundaries and their resistance to plate motion.

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Reid, H.F., 1910, The mechanics of the earthquake, v. 2 of The California earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission: Carnegie Institution of Washington Publication 87, 192 p.

Ruina, A.L., 1983, Slip instability and state variable friction laws: Journal of Geophysical Research, v. 88, no. B12, p. 10359–10370.

Savage, J.C., and Wood, M.D., 1971, The relationship between apparent stress and stress drop: Seismological Society of America Bulletin, v. 61, no. 5, p. 1381–1388.

Sibson, R.H., 1985, A note on fault reactivation: Journal of Structural Geology, v. 7, no. 6, p.751–754.

Spottiswoode, S.M., and McGarr, Arthur, 1975, Source parameters of tremors in a deep-level gold mine: Seismological Society of America Bulletin, v. 65, no. 1, p. 93–112.

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Stock, J.M., and Healy, J.H., 1988, Continuation of a deep borehole stress measurement profile near the San Andreas fault zone, 2, Hydraulic fracturing stress measurements at Black Butte, Mojave Desert, California: Journal of Geophysical Research, v. 93, no. B12, p. 15196–15206.

Wang, C.-Y., Mao, N.-H., and Wu, F.T., 1980, Mechanical properties of clays at high pressure: Journal of Geophysical Research, v. 85, no. B3, p. 1462–1468.

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Williams, C.F., and Narasimhan, T.N., 1989, Hydrogeologic constraints on heat flow along the San Andreas fault—a testing of hypotheses: Earth and Planetary Science Letters, v. 92, p. 131–143.

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Wyss, Max, and Molnar, Peter, 1972, Efficiency, stress drop, apparent stress, effective stress, and frictional stress of Denver, Colorado, earthquakes: Journal of Geophysical Research, v. 77, no. 8, p. 1433–1438.

Zoback, M.D., and Haimson, B.C., eds., 1983, Hydraulic fracturing stress measurements: Washington, D.C., National Academy Press, 270 p.

Zoback, M.D., Healy, J.H., and Roller, J.C., 1977, Preliminary stress measurements in central California using the hydraulic fracturing technique: Pure and Applied Geophysics, v. 115, p. 135–152

Zoback, M.D., Tsukahara, Hiroaki, and Hickman, S.H., 1980, Stress measurements at depth in the vicinity of the San Andreas fault: Implications for the magnitude of shear stress at depth: Journal of Geophysical Research, v. 85, no. B11, p. 6157–6173.

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Zoback, M.L., and Zoback, M.D., 1980, State of stress in the conterminous United States: Journal of Geophysical Research, v. 85, no B11, p. 6113–6156.

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SUPPLEMENT: ADDITIONAL READING AND SOURCE MATERIAL

ROBERT E. WALLACE, Compiler

To help the reader find avenues into the voluminous literature about the San Andreas fault system, the following selected references are grouped into four sets: (1) maps, (2) review and reference publications, (3) publications of historical interest, and (4) publications of general interest. Many of these selected references have been included because they themselves have extensive bibliographies. The references in section 3 are limited to those pre-1965, except for Hill's review (1981) on the history of concepts. The references in section 4 are directed especially toward the layman or specialists in disciplines other than earth science. These suggested additional readings should be available in most earth-science libraries or from the publisher; many can also be found in larger public libraries.

MAPS

Bond, K.R., and Zietz, Isidore, 1987, Composite magnetic anomaly map of the conterminous United States: U.S. Geological Survey Geophysical Investigations Map GP–977, scale 1:2,500,000.

Dibblee, T.W., Jr., 1973, Regional geologic map of San Andreas and related faults in Carrizo Plain, Temblor, Caliente, and La Panza Ranges and vicinity, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–757, 9 p., scale 1:125,000.

Drummond, K.J., chairman, 1981, Pacific Basin sheet *of* Plate-tectonic map of the circum-Pacific region: Tulsa, Okla., American Association of Petroleum Geologists, scale 1:10,000,000.

Engdahl, E.R., and Rinehart, W.A., 1988, Seismicity map of North America: Boulder, Colo., Geological Society of America: scale 1:5,000,000, 4 sheets.

Geological Society of America, 1987, Gravity anomaly map of North America: Boulder, Colo., scale 1:5,000,000, 4 sheets.

—— 1987, Magnetic anomaly map of North America: Boulder, Colo., scale 1:5,000,000, 4 sheets.

Goter, S.K., 1988, Seismicity of California 1808–1987: U.S. Geological Survey Open-File Report 88–286, scale 1:1,000,000.

Shaded relief map in color with earthquake epicenters in red.

Jennings, C.W., compiler, 1958–66, Geologic atlas of California: Sacramento, California Division of Mines and Geology, scale 1:250,000, 27 sheets.

This atlas contains 27 geologic map sheets that together constitute the "Geologic Map of California" at a scale of 1:250,000. Information sheets accompany each geologic map. As of 1989, the map series is being brought up to date, and the Santa Rosa Regional Geologic map series 2A (1982, 5 sheets) and San Bernardino Regional Geologic map series 3A (1987, 5 sheets) have been completed.

—— compiler, 1975, Fault map of California with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology Geologic Data Map 1, scale 1:750,000.

This is the principal map representation of faults in California on a single map sheet. It contains a wealth of information and is indispensable to anyone interested in the San Andreas fault. An updated edition is in preparation.

—— compiler, 1977, Geologic map of California: California Division of Mines and Geology Geologic Data Map 2, scale 1:750,000.

—— 1985, An explanatory text to accompany the 1:750,000 scale fault and geologic maps of California: California Division of Mines and Geology Bulletin 201, 197 p.

A significant review of data. For example, plate 2 includes four maps: (1) structural provinces of California, (2) parallelism between major Quaternary faults, (3) relation of earthquake epicenters to faults, and (4) earthquake epicenters.

King, P.B., compiler, 1969, Tectonic map of North America: Washington, U.S. Geological Survey, scale 1:5,000,000, 2 sheets.

King, P.B., and Beikman, H.M., compilers, 1974, Geologic map of the United States (exclusive of Alaska and Hawaii): Washington, U.S. Geological Survey, scale 1:2,500,000, 3 sheets.

Real, C.R., Toppozada, T.R., and Parke, D.L., 1978, Earthquake epicenter map of California: California Division of Mines and Geology Map sheet 39, scale 1:1,000,000. A map and tabulation of earthquakes of

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magnitude 5 and greater, 1900–74.

Simpson, R.W., Hildenbrand, T.G., Godson, R.H., and Kane, M.F., 1987, Digital colored Bouguer gravity, free-air gravity, station location, and terrain maps for the conterminous United States: U.S. Geological Survey Geophysical Investigations Map GP–953-B, scale 1:7,500,000, 2 sheets.

Simpson, R.W., Jachens, R.C., Saltus, R.W., and Blakely, R.J., 1986, Isostatic residual gravity, topographic, and first-vertical-derivative gravity maps of the conterminous United States: U.S. Geological Survey Geophysical Investigations Map GP–975, scale 1:7,500,000, 2 sheets.

Stover, C.W., 1986, Seismicity map of the conterminous United States and adjacent areas, 1975–1984: U.S. Geological Survey Geophysical Investigations Map GP–984, scale 1:5,000,000.

A standard reference depicting seismicity in the United States.

REVIEW AND REFERENCE PUBLICATIONS

Atwater, Tanya, 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, no. 12, p. 3513–3536.

Develops the concept of the Pacific system of plates converging with and underriding the North American plate.

Crowell, J.C., ed., 1975, San Andreas fault in southern California: California Division of Mines and Geology Special Report 118, 272 p.

A guidebook containing 29 papers and a useful preliminary fault and geologic map of southern California at a scale of 1:750,000.

Dibblee, T.W., 1967, Areal geology of the western Mojave Desert, California: U.S. Geological Survey Professional Paper 522, 153 p.

Documents many of the bedrock features that characterize the San Andreas fault system.

Dickinson, W.R., and Grantz, Arthur, eds., 1968, Proceedings of conference on geologic problems of San Andreas fault system: Stanford, Calif., Stanford University Publications in the Geological Sciences, v. 11, 374 p.

An important collection of 47 papers, representing the prevailing state of knowledge about the San Andreas fault system at the time of its publication.

Eaton, J.P., O'Neill, M.E., and Murdock, J.N., 1970, Aftershocks of the 1966 Parkfield-Cholame, California, earthquake: A detailed study: Seismological Society of America Bulletin, v. 60, no. 4, p. 1151–1197.

Ernst, W.G., ed., 1981, The geotectonic development of California (Rubey volume 1): Englewood Cliffs, N.J., Prentice-Hall, 706 p.

Possibly the best general review in one volume of the geologic and tectonics relations pertinent to the San Andreas fault system. More than 1,300 references listed in the back of the volume provide an invaluable source for further study.

Hart, E.W., Hirschfeld, S.E., and Schulz, S.S., eds., 1982, Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Hayward, Calif., 1982, Proceedings: California Division of Mines and Geology Special Publication 62, 447 p.

A collection of 61 papers in which the Hayward and Calaveras faults, and other smaller branches of the San Andreas fault system, receive considerable attention.

Hinze, W.J., Kane, M.F., O'Hara, N.W., Redford, M.S., Tanner, James, and Weber, Christian, eds., 1985, The utility of regional gravity and magnetic anomaly maps: Tulsa, Okla., Society of Exploration Geophysicists, 454 p.

A set of 34 papers providing information and guidance on the use and interpretation of gravity and magnetic-anomaly data, as well as regional maps.

Kovach, R.L., and Nur, Amos, eds., 1973, Proceedings of the conference on tectonic problems of the San Andreas fault system: Stanford, Calif., Stanford University Publications in the Geological Sciences, v. 13, 494 p.

An important collection of 53 papers, representing the prevailing state of knowledge about the San Andreas fault system at the time of its publication.

Oliver, H.W., 1980, Interpretation of the gravity map of California and its continental margin: California Division of Mines and Geology Bulletin 205, 52 p.

A general reference and bibliographic source of gravity data.

Pakiser, L.C., Jr., and Mooney, W.D., eds., in press, Geophysical framework of the continental United States: Geological Society of America Memoir 172.

A collection of 34 papers covering a broad range of subjects, including stress, tectonics, regional summaries, and methods.

Ross, D.C., 1984, Possible correlations of basement rocks across the San Andreas, San Gregorio-Hosgri and Rinconada-Reliz-King City faults, California: U.S. Geological Survey Professional Paper 1317, 37 p.

An insight into the longer term history of the San Andreas fault system as indicated by the disruption of older rocks.

Scholl, D.W., Grantz, Arthur, and Vedder, J.G., eds.

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1987, Geology and resource potential of the continental margin of western North America and adjacent ocean basins—Beaufort Sea to Baja California (Earth Science Series, v. 6): Houston, Tex., Circum-Pacific Council for Energy and Mineral Resources.

A major source volume about the continental margin of North America. Includes 33 chapters concerned with topics ranging from tectonic and basin evolution to hydrocarbon and metallic-mineral occurrence and potential.

Sharp, R.V., 1967, San Jacinto fault zone in the Peninsular Ranges of southern California: Geological Society of America Bulletin, v. 78, no. 6, p. 705–729.

Stewart, J.H., and Crowell, J.C., in press, Strike-slip tectonics in the Cordilleran region, western United States in Burchfiel, B.C., Libman, P.W., and Zoback, M.L., eds., The Cordilleran orogen: Boulder, Colo., Geological Society of America.

A review of strike-slip faults, including the San Andreas fault, in the Western United States.

Streitz, Robert, and Sherburne, R.W., eds., 1980, Studies of the San Andreas fault zone in northern California: California Division of Mines and Geology Special Report 140, 187 p.

A valuable set of 16 papers on subjects including geology, geophysics, seismology, and engineering.

Sylvester, A.G., 1988, Strike-slip faults: Geological Society of America Bulletin, v. 100, no. 11, p. 1666–1703.

An excellent review of the concept, recognition, mechanics, and behavior of strike-slip faults, with numerous references to the San Andreas fault. Includes an extensive bibliography.

Ziony, J.I., ed., 1985, Evaluating earthquake hazards in the Los Angeles region—an earth-science perspective: U.S. Geological Survey Professional Paper 1360, 505 p.

A valuable collection of 16 papers that review the state of the art about geologic hazards, ranging from predicting earthquake faulting and ground motion to landslides, tsunamis, and the use of earth-science information.

PUBLICATIONS OF HISTORICAL INTEREST

Allen, C.R., 1957, San Andreas fault in San Gorgonio Pass, southern California: Geological Society of America Bulletin, v. 68, no. 3, p. 315–349.

Anderson, F.M., 1899, The Geology of Point Reyes peninsula: Berkeley, University of California Publications, Department of Geology Bulletin, v. 2, no. 5, p. 119–153.

Bailey, E.H., Irwin, W.P., and Jones, D.L., 1964, Franciscan and related rocks, and their significance in the geology of western California: California Division of Mines and Geology Bulletin 183, 177 p.

A classic paper in which the San Andreas fault receives considerable attention and early tectonic models are presented.

Branner, J.C., 1906, An authoritative opinion: Mining and Scientific Press, v. 92, p. 347.

Crowell, J.C., 1952, Probable large lateral displacement on the San Gabriel fault, southern California: American Association of Petroleum Geologists Bulletin, v. 36, no. 10, p. 2026–2035.

—— 1962, Displacement along the San Andreas fault, California: Geological Society of America Special Paper 71, 59 p.

Documents large-scale strike slip on the San Andreas fault system.

Eaton, J.E., 1939, Geology and oil possibilities of Caliente Range, Cuyama Valley and Carrizo Plain, California: California Journal of Mines and Geology, v. 35, no. 3, p. 255–274.

Suggests 25 miles of strike slip on the San Andreas fault.

Gilbert, G.K., 1907, The earthquake as a natural phenomenon, *in* The San Francisco earthquake and fire of April 18, 1906, and their effects on structures and structural materials: U.S. Geological Survey Bulletin 324, p. 1–13.

This paper provided the first overview of the San Andreas fault in northern California. From Gilbert's field notes, he appears to have been the first to appreciate the true significance of the fault.

Hill, M.L., 1981, San Andreas fault: History of concepts: Geological Society of America Bulletin, pt. 1, v. 92, no. 3, p. 112–131.

A review of the early development of concepts about the significance of the San Andreas fault, especially the amount of strike slip.

Hill, M.L., and Dibblee, T.W., Jr., 1953, San Andreas, Garlock, and Big Pine faults, California: A study of the character, history, and tectonic significance of their displacements: Geological Society of America Bulletin, v. 64, no. 4, p. 443–458.

This classic paper was the first to provide data indicative of hundreds of miles of strike slip on the San Andreas fault.

Hill, R.T., 1928, Southern California geology and Los Angeles earthquakes: Los Angeles, Southern California Academy of Sciences, 232 p.

Lawson, A.C., 1895, Sketch of the geology of the San Francisco peninsula: U. S. Geological Survey Annual Report 15, p. 439–473.

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First use of the name "San Andreas fault."

—— chairman, 1908, The California earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission: Carnegie Institution of Washington Publication 87, 2 v.
This treatise on the 1906 earthquake contains an abundance of important data about the San Andreas fault.

Noble, L.F., 1926, The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Institution of Washington Year Book 25, p. 415–422..

—— 1933, Excursion to the San Andreas fault and Cajon Pass: International Geological Congress, 16th, Washington, 1933, Guidebook 15, p. 10–21.

—— 1954, The San Andreas fault zone from Soledad Pass to Cajon Pass, California, [pt] 5 *off* Structural features, chap. 4 *of* Jahns, R.H., ed., Geology of southern California: California Division of Mines Bulletin 170, v. 1, p. 37–48.

Oakeshott, G.B., 1959, The San Andreas fault in Marin and San Mateo Counties, *in* Oakeshott, G.B., ed., San Francisco earthquakes of March 1957: California Division of Mines Special Report 57, 127 p.

Pack, R.W., 1920, The Sunset-Midway oil field, California, part 1, Geology and oil resources: U.S. Geological Survey Professional Paper 116, 179 p.

Pack, R.W., and English, W.A., 1915, Geology and oil prospects of Waltham, Priest, Bitterwater, and Peachtree Valleys, California: U.S. Geological Survey Bulletin 581, p. 119–160.

Reed, R.D., 1933, Geology of California: Tulsa, Okla., American Association of Petroleum Geologists, 355 p.

—— 1943, California's record in the geologic history of the world, *in* Geologic formations and economic development of the oil and gas fields of California: California Division of Mines Bulletin 118, p. 99–118.
Does not mention strike slip on the San Andreas fault.

Reed, R.D., and Hollister, J.S., 1936, Structural evolution of southern California: American Association of Petroleum Geologists Bulletin, v. 20, no. 12, p. 1529–1704.

Reid, H.F., 1910, The mechanics of the earthquake, v. 2 of The California earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission: Carnegie Institution of Washington Publication 87, 192 p.
Develops elastic-rebound theory.

Schuyler, J.D., 1896, Reservoirs for irrigation: U.S. Geological Survey Annual Report 18, p. 617–740.

Steinbrugge, K.V., Zacher, E.G., Tocher, Don, Whitten, C.A., and Claire, C.N., 1960, Creep on the San Andreas fault: Seismological Society of America Bulletin, v. 50, no. 3, p. 389–415.
This paper was the first to report slow, continuous slip (creep) on the San Andreas fault.

Taliaferro, N.L., 1938, San Andreas fault in central California [abs.]: Geological Society of America Proceedings, 1937, p. 254–255.
Concludes that horizontal slip on the San Andreas fault is less than a mile.

Vaughan, F.E., 1922, Geology of San Bernardino Mountains north of San Gorgonio Pass: Berkeley, University of California Publications, Department of Geological Sciences Bulletin, v. 13, no. 9, p. 319–411.

Vickery, F.P., 1925, The structural dynamics of the Livermore [California] region: Journal of Geology, v. 33, no. 6, p. 608–628.

Wallace, R.E., 1949, Structure of a portion of the San Andreas rift in southern California: Geological Society of America Bulletin, v. 60, no. 4, p. 781–806.

Wilson, J.T., 1965, A new class of faults and their bearing on continental drift: Nature, v. 207, no. 4995, p. 343–347.
Develops the concept of a transform fault.

Wood, H.O., and Buwalda, J.P., 1930, Horizontal displacement along the San Andreas fault in Carrizo Plain, California [abs.] : Pan-American Geologist, v. 54, no. 1, p. 75.

PUBLICATIONS OF GENERAL INTEREST

Dewey, J.F., 1972, Plate tectonics: Scientific American, v. 226, no. 5, p. 56–68.
A brief introduction to the concepts of plate tectonics, including excellent diagrams of the geometry of the global plates.

Iacopi, Robert, 1971, Earthquake country: Menio Park, Calif., Lane, 160 p.
A review and guidebook about the San Andreas fault, written for the layman, but includes useful maps and photographs of interest

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to the scientist and layman alike.

Jones, D.L., Cox, Allan, Coney, Peter, and Beck, Myrl, 1982, The growth of western North America: Scientific American, v. 247, no. 5, p. 70–84.

Refines the concept of plate tectonics has been refined to include the accretion of smaller blocks to the main continental masses. The San Andreas fault system is involved with the motions of both larger and smaller plates.

Jordan, T.H., and Minster, J.B., 1988, Measuring crustal deformation in the American West: Scientific American, v. 259, no. 2, p. 48–58.

Provides some ideas and data about how western North America is being deformed.

Schulz, S.S., and Wallace, R.E., 1987, The San Andreas fault: Washington, U.S. Geological Survey, 17 p.

Pamphlet providing a brief review for the layman.

Wesson, R.L., and Wallace, R.E., 1985, Predicting the next great earthquake in California: Scientific American, v. 252, no. 2, p. 35–43.

The science of earthquake prediction has been evolving, and the San Andreas fault system has been a target of major interest. This paper reviews some progress that has been made.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1991-586-938

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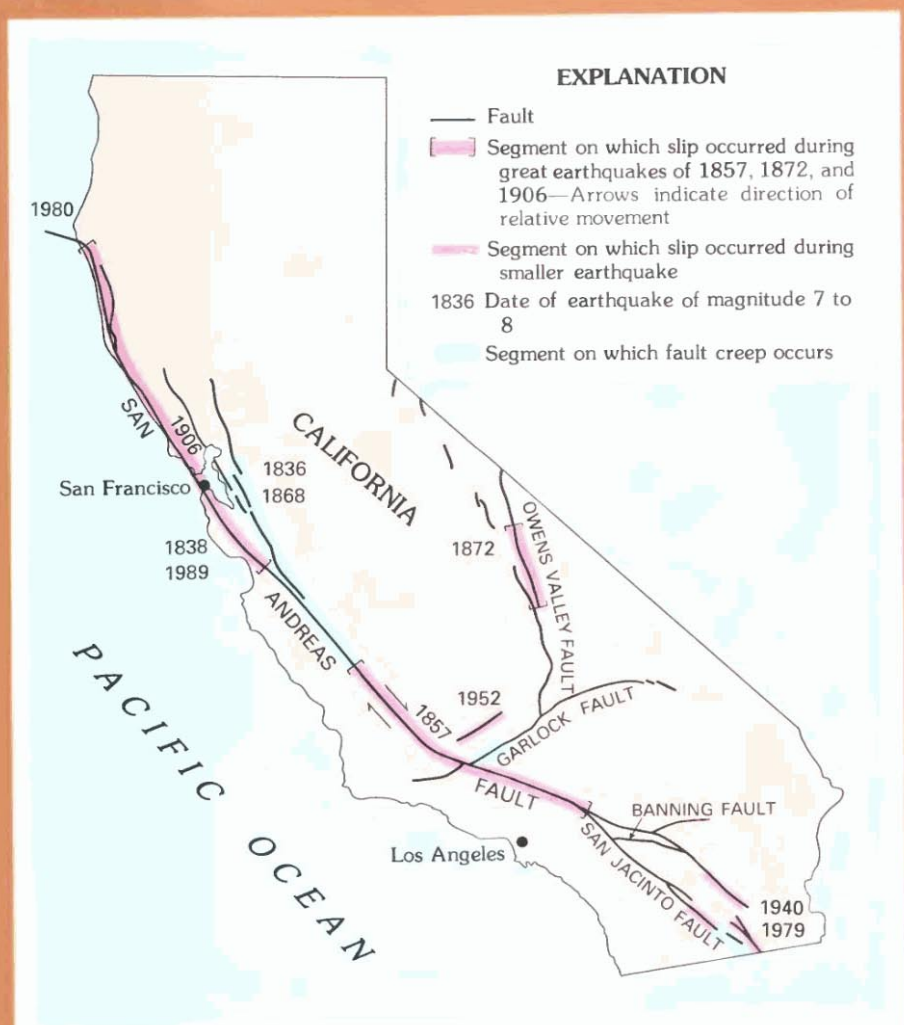

SAN ANDREAS FAULT SYSTEM AND OTHER LARGE FAULTS IN CALIFORNIA

Different segments of fault display different behavior.

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Memorandum

Date:	July 6, 2020
From:	Catalyst Environmental Solutions Inc.
RE:	Heber 2 Project Description Information

This information was copied directly from the Conditional Use Permit Amendment Application. None of the information provided in this memorandum is new or revised.

Construction Schedule

The proposed Project facilities are anticipated to take up to eight months to install, test, and become fully integrated with the existing system. Construction will begin immediately after all permits are secured.

Construction Equipment

Heavy construction equipment, including semi-truck trailers, flatbed trucks, excavators/bulldozers, forklifts, roller, and cranes would be used to deliver and place the proposed facilities on the Heber 2 Project Site. Smaller powered hand tools, such as drills, compressors, and welding equipment would also be used. Employee vehicles would be used to transport workers to the Project Site and parked at the designated parking locations.

Workforce

The Project would require a temporary increase in labor force (15 workers) during the short-term construction period (approximately eight months). The workforce is assumed to be from southern California and would likely not require accommodations.

Site Preparation

The Project Site was developed and graded during the original construction of the Heber 2 Complex in 1992, and its current condition is exposed soil and gravel. To ensure the proposed facilities are situated on safe and stable surfaces, minor excavation and compaction activities would be performed. The top 18 inches of the Project Site's exposed soil would be removed, extending approximately 5 feet beyond the proposed facilities. A minimum of 18 inches of CalTrans Class 2 aggregate based will be placed and compacted to the appropriate density (ASTM D1557). On-site soil that has been piled during excavation will be used as backfill material, as necessary. Only those soils free of debris and deleterious matter would be used as backfill material. The proposed facilities would be placed on shallow-spread footers and wall footers to support the structures. All site preparation and fill placement activities will be monitored by a qualified geotechnical engineer to detect undesirable materials and/or site conditions that may arise during site preparation.

Demolition and Disposal

As provided in the CUP application, the Application would apply the following demolition and disposal measures:

- Workers would be required to properly dispose of all refuse and trash to prevent any litter on the site.

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- During construction, portable chemical sanitary facilities would be used by all construction personnel. These facilities would be serviced by a local contractor.
- All construction wastes, liquid or solid, would be disposed of in compliance with all appropriate local, state, and federal disposal regulations.
- Solid wastes would be disposed of in an approved solid waste disposal site in accordance with Imperial County Environmental Health Department requirements. Waste would be routinely collected and disposed of at an authorized landfill by a licensed disposal contractor.
- All hazardous materials would be used, transported, and disposed of in accordance with applicable safe handling and disposal regulations.

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Records Index

Date:	July 8, 2020
From:	Catalyst Environmental Solutions Inc.
RE:	Requested Documents for Heber 2 Repower Project Initial Study & Negative Declaration

The index below provides an identification number for each document requested in support of the Heber 2 Repower Project Initial Study and Negative Declaration (IS/ND). The document number provided in the index table correlates to the file name for each requested document.

Requested Document	Document No.
Conditional Use Permit (CUP No. 06-0006) under which the Project must obtain an amendment.	H2RP-1
The Permit to Operate, issued to the Heber 2 Complex by the Imperial County Air Pollution Control District ("ICAPCD").	H2RP-2
The California Historical Resources Information System (CHRIS), managed by the California Office of Historic Preservation.	H2RP-3 (CONFIDENTIAL – NOT FOR PUBLIC RELEASE)
Bryant, William A. and Earl W. Hart. 2007. Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Studies Zoning Act with Index to Earthquake Fault Zones Maps, Department of Conservation, California Geological Survey, Special Publication 42.	H2RP-4
Olive, WW., et al. 1989. Swelling Clays Map of the Conterminous United States	H2RP-5
Existing Water Permit	H2RP-6
Imperial County 2018 PM10 Plan and Imperial County 2018 PM2.5 Plan.	H2RP-7
ASTM International. 2019. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (DM1557).	H2RP-8
California Air Resources Board (CARB). 2017. Ambient Air Quality Standards.	H2RP-9
California Department of Fish and Wildlife. 2019. CNDDB Maps and Data	H2RP-10 (1 PDF, 2 Excel files)
California Department of Industrial Relations (DIR). 2016. Safety and Health Protocol on the Job	H2RP-11
California Department of Resources Recycling and Recovery (CalRecycle). 2017. Integrated Waste Management Plans	H2RP-12
California Department of Toxic Substances Control (DTSC). 2010. Certified Union Program Agencies (CUPA).	H2RP-13
California Department of Transportation (Caltrans). 2013. Technical Noise Supplement to the Traffic Noise Analysis Protocol.	H2RP-14
California Department of Transportation. 2017. California Scenic Highway Mapping System.	H2RP-15
California Department of Water Resources. 2003. California's Groundwater.	H2RP-16
California Office of Planning and Research. 2003. General Plan	H2RP-17

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Guidelines.	
United States Environmental Protection Agency (EPA). 2015. National Ambient Air Quality Standards.	H2RP-18
United States Geological Survey (USGS). 1990. The San Andreas Fault System, California, Robert E. Wallace, editor, U.S. Geological Survey Professional Paper 1515.	H2RP-19
Detailed construction schedule.	H2RP-20
List of all construction equipment.	H2RP-20
Description of construction equipment: hp, engine tier, hours of operation per day over the duration of construction.	H2RP-20
Number of workers and commute distance.	H2RP-20
Amount of demolition debris and its disposal location	H2RP-20
Amount of imported fill.	H2RP-20
Acres of grading	H2RP-20

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HEBER 2

UPDATED PROJECT DESCRIPTION

(AND RESPONSES TO COMMENTS)

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APPENDIX A

Site Photographs

(Collected on June 1, 2019 and June 13, 2019)

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Photo 1 – western portion of development site.



Photo 2 – southwest portion of development site.

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Photo 3 – northwestern portion of development site.



Photo 4 – northern portion of development site.

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Photo 5 – central portion of development site.



Photo 6 – central portion of development site.

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Photo 7 – northern portion of development site.

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Biological Resources Clearance Memorandum

Date:	June 3, 2019
From:	Catalyst Environmental Solutions
RE:	**Biological Resources Clearance Survey for the Heber 2 Geothermal Repower Project**

INTRODUCTION

The Second Imperial Geothermal Company (SIGC), a wholly owned subsidiary of ORMAT Nevada, Inc (ORMAT), owns and operates the Heber 2 Geothermal Energy Complex, which was originally constructed in 1992 and expanded in 2006. SIGC proposes to amend the existing Conditional Use Permit (CUP; No. 06-0006) to install two water-cooled ORMAT Energy Converters (OECs) to replace six old units from 1992; three 10,000 gallon isopentane above ground storage tanks; and, additional pipeline to connect the proposed facilities with the existing Heber 2 Complex (hereinafter, "Project"). All proposed facilities would be developed within the existing Heber 2 Complex and fence line. The proposed action also includes the extension of the permitted life of the entire Heber 2 facility (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049). The objective of the Project is to improve the efficiency of geothermal energy generation and refurbish the Heber 2 Complex to the original net generation of 33 megawatts (MW) gross. The total project footprint from developing the proposed facilities is approximately 4 acres, with all disturbances occurring within the existing power plant fence line.

Th purpose of this technical memorandum is to verify the absence of any sensitive biological resources occurring on/near the proposed development site at the Heber 2 Complex in Imperial County and to demonstrate the proposed project's compliance with applicable federal and state regulations.

Project Location

The Heber 2 Complex is located on private lands owned by ORMAT in southern Imperial County (**Figure 1)**. The proposed development would occur entirely on Assessor's Parcel Number (APN) 054-250-031, which is a 39.99-acre property. The address for Heber 2 is 855 Dogwood Road, Heber, CA 92249.

Project Description

Existing Facilities

The existing Heber 2 Geothermal Energy Power Plant (Heber 2) was permitted for development under CUP No. 06-0006 in 1996 and consists of the following facilities:

- The Heber 2 Complex currently generates less than the 33 MW net generation capacity, the proposed improvements will restore the facility's generation capacity to 33 MW of renewable energy.

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- The Heber 2 Complex currently includes two injection wells, two six-cell cooling towers, an electrical substation, emergency fire water pump, evacuation skid system-vapor recovery maintenance unit, control room, office space, maintenance facilities, two 10,000 gallons isopentane storage tanks, piping, and ancillary equipment/facilities.
- The parcel where the Heber 2 Complex site is located is approximately 40 acres and is enclosed by security fencing.
- Operations personnel are present at the Heber 2 Complex during routine working hours (8am-5pm), and the facility is monitored 24 hours per day from the control room at the Heber 1 geothermal power plant, approximately 1 mile to the east.

Proposed Facilities

SIGC proposes to install two new water-cooled ORMAT Energy Converters (OECs); three 10,000 gallon above ground storage tanks; and, additional pipeline to connect the proposed facilities with the existing Heber 2 Complex (hereinafter, "Project"). This application also proposes to extend the permitted life of the entire Heber 2 Complex (including the related Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049). The objective of the Project is to improve the efficiency of geothermal energy generation and refurbish the Heber 2 Complex to the original nameplate generation of 33 megawatts (MW). The total project disturbance from developing the new OECs is approximately 4 acres, all within the existing power plant footprint and fencing. Figure 2 provides a site plan of the proposed and existing facilities.

The existing OEC units would be shut down, disassembled, and removed from the Heber 2 site likely immediately after the completion of the development of the proposed facilities, and no later than 5 years after issuance of the CUP.

The development site is completely devoid of any vegetation and is actively disturbed as part of ongoing energy generation operations at Heber 2. Appendix A provides photographs of the development site. Considering its current condition, site preparation for the installation of the proposed facilities would be limited to minor excavation and soil/gravel compaction.

ORMAT Energy Converter-1 (OEC-1)

The proposed OEC-1 unit is a two-turbine combined cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, turbines, vaporizer, water cooled condensers, preheaters and recuperators, with the OEC served by the existing evacuation skid/vapor recovery maintenance unit (VRMU) for purging and maintenance events. The design capacity for the unit is 25.43 MW Gross.

ORMAT Energy Converter-2 (OEC-2)

The proposed OEC-2 unit is a two-cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, turbines, vaporizers, water cooled condensers and preheaters, with the OEC served by the existing portable evacuation skid/vapor recovery maintenance unit (VRMU) for purging and maintenance events. The design capacity for the unit is 14.01 MW Gross.

Three Additional Isopentane Above Ground Storage Tanks

To support the new OEC units, three new ABSTs for additional isopentane supply would be installed. There are two existing ABSTs, and the new ABSTs would be sited adjacent to the existing tanks. Each ABST has a capacity of 10,000 gallons.

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Construction Schedule

The proposed developments are anticipated to take up to eight months to install, test, and become fully integrated with the existing system. Construction will initiate immediately after all permits are secured.

REGULATORY FRAMEWORK

Federal

Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531-1544) protects federal listed threatened and endangered species from unlawful take (harass, harm, pursue, hunt, shoot, kill ,wound, collect, capture, trap or attempt to do so) or significantly modify habitat. If a proposed project would jeopardize a threatened or endangered species, then a Section 7 consultation with a federal agency could be required.

Migratory Bird Treaty Act (50 Code Federal Regulations (CFR) 10.13) is a federal statute with several foreign countries to protect species that migrate between countries. Over 1000 species are listed and may not be disrupted during nesting activities. It is illegal to collect any part (nest, feather, eggs, etc.) of a listed species, disturb species while nesting or offer for trade or barter any listed species or parts thereof.

Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c) protects bald and golden eagles from take (harass, harm, pursue, hunt, shoot, kill, wound, collect, capture, trap or attempt to do so) or interference with breeding, feeding or sheltering activities.

Clean Water Act, 1972 (CWA 33 U.S.C. 1251 et seq.) regulates discharges into waters of the U.S. EPA is given the responsibility to implement programs to prevent pollution.

State of California

California Environmental Quality Act (CEQA) Title 14 CA Code of Regulations 15380 requires that endangered, rare or threatened species or subspecies of animals or plants be identified within the influence of the project. If any such species are found, appropriate measures should be identified to avoid, minimize or mitigate to the extent possible the effects of the project.

Native Plant Protection Act CDFG Code Section 1900-1913 prohibits the taking, possessing, or sale within the stare of any plant listed by CDFG as rare, threatened or endangered. Landowners may be allowed to take these species if CDFW is notified at least 10 days prior to plant removal or if these plants are found within public right of ways.

California Fish and Game Codes 3503, 3503.5. 3513 protect migratory birds, bird nests, and eggs including raptors (birds of prey) and raptor nests from take unless authorized by CDFW.

California Fish and Game Code Section 1600 (as amended) regulates activities that substantially diverts or obstructs the natural flow of any river, stream or lake or uses materials from a streambed. This can include riparian habitat associated with watercourses.

State of CA Fully Protected Species identifies and provides additional protection to species that are rare or face possible extinction. These species may not be taken or possessed at any time except for scientific research or relocation for protection of livestock.

Porter-Cologne Water Quality Control Act (as amended) is administered by the State Water Resource Control Board (SWRCB) to protect water quality and is an avenue to implement California

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responsibilities under the federal Clean Water Act. This act regulates discharge of waste into a water resource.

EXISTING CONDITIONS

Topography and Soils

The entire Heber 2 project site contains Holtville silty clay, wet (63.2%) and Imperial-Glenbar silty clay loams, wet, 0-2 percent slopes (36.8%) (NRCS 2019). The proposed 4 acres of disturbance contains Imperial-Glenbar silty clay loams, wet, 0-2 percent slopes. The project site is relatively flat and located at approximately -5 below sea level.

Vegetation

No vegetation is present on the project site. The site is classified as "Agricultural and Developed Vegetation" and "Developed and Other Human Use" (USGS 2011). The project site is surrounded on all sides by farmland (Agricultural and Developed Vegetation).

Jurisdictional Waters

No wetlands or jurisdictional waters are located on the project site. Man-made channels are located along the southern (Central Main Canal - classified as R2UBHx), northern and eastern (both classified as R4SBCx) property line of the project site (USFWS 2019c).

Wildlife

The project site is developed with an active geothermal plant. Due to lack of vegetation and water, no amphibians, fish, or reptiles are expected to occur onsite. Due to the developed and active nature of the site, no mammals or birds are expected to inhabit the site. Mammals including coyote (*Canis latrans*) and pocket gopher (*Thomomys* spp.) have been observed in the vicinity of the project but are not likely to occur onsite due to security fencing. Common bird species including red tailed hawk (*Buteo jamaicensis*), crow (*Corvus* spp.) pigeon (*Columbia livia*) have been observed in the vicinity of the project and could be transient visitors to the site.

SENSITIVE AND SPECIAL STATUS SPECIES

The potential for sensitive species to occur in the vicinity of the project site was evaluated using information from the U.S. Fish and Wildlife (USFWS) Information, Planning, and Consultation System (IPaC System); California Natural Diversity Database (CNDDB); and California Native Plant Society (CNPS) Rare Plant Program.

Special Status Plants

No federally listed threatened or endangered plant species have the potential to occur on or near the project site (USFWS 2019a).

Five plant species listed by the CNPS have the potential to occur in the Heber quandrangle in which Heber 2 Complex is located (CNPS 2019):

- Watson's amaranth (*Amaranthus watsonii*)
- Abrams' spurge (*Euphorbia abramsiana)*
- California satintail (*Imperata brevifolia*)
- ribbed cryptantha (*Johnstonella costata*)

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- winged cryptantha (*Johnstonella holoptera*)

Special Status Wildlife Species

No federally listed threatened or endangered wildlife species have the potential to occur on the project site and no critical habitat exists on or near the project site (USFWS 2019a, b). The following six migratory bird species are listed by IPaC as having the potential to occur on or near the project site:

- Burrowing owl (*Athene cunicularia*)
- Costa's hummingbird (*Calypte costae*)
- Gila woodpecker (*Melanerpes uropygialis*)
- Long-billed curlew (*Numenius americanus*)
- Rufous hummingbird (*Selasphorus rufus*)
- Whimbrel (*Numenius phaeopus*)

No California special status species are known to occur on the project site (CDFW 2019).

BIOLOGICAL RESOURCES CLEARANCE SURVEY

Methodology

On Saturday, June 1, 2019, biologist Amy Plesetz conducted a biological compliance clearance survey of the ORMAT Heber Site 2 via pedestrian survey.

Findings

The area to be disturbed for the Heber 2 project is completely void of any vegetation. There is no suitable habitat for special-status plant species. There are no tall trees that would encourage raptor nesting, no suitable habitat for burrowing owl, and no food source for hummingbirds. No wildlife or traces of wildlife, including nesting birds, were observed.

The area immediately to the west of the proposed disturbed area is developed with solar panels with scarce disturbed-like vegetation that does not provide suitable habitat for any special-status or common species. Areas north and south of the proposed disturbed area contain geothermal plant facilities. Active farmland surrounds the entire project site.

There may be suitable habitat for burrowing owl in the project vicinity, but this habitat is off-site and more than 500 feet away.

POTENTIAL PROJECTS IMPACTS

No impacts to biological resources from the proposed project are expected due to the developed nature of the site, small project footprint, lack of vegetation and suitable habitat for wildlife, and lack of wildlife traces observed during the biological site visit (June 1, 2019).

No canals or drain structures will be removed or impacted; therefore, there will be no impacts to jurisdictional waters.

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RECOMMENDED AVOIDANCE, MINIMIZATION, AND MITIGATION MEASURES

- Speed limits of 10 mph would be observed on the project site in order to minimize dust and avoid collision and incidental mortality of transient wildlife.
- The site is void of vegetation; however, vegetation control, including invasive species eradication, will be controlled to prevent growth under/near the proposed facilities.

BIBLIOGRAPHY

California Department of Fish and Wildlife (CDFW). 2019. California Natural Diversity Database. Accessed 13 June 2019.

California Native Plant Society (CNPS). 2019. Inventory of Rare and Endangered Plants of California (online edition, v8-03 0.39). Website http://www.rareplants.cnps.org. Accessed 12 June 2019.

Natural Resource Conservation Service (NRCS). 2019. SUGGO Database.

U.S. Geological Survey (USGS). 2011. GAP/LANDFIRE National Terrestrial Ecosystems 2011. Website: https://maps.usgs.gov/terrestrial-ecosystems-2011/. Accessed 13 June 2019.

U.S. Fish and Wildlife Service (USFWS). 2019a. IPac Resource List.

USFWS 2019b. Critical Habitat for Threatened & Endangered Species Website. Website: https://fws.maps.arcgis.com/home/webmap/viewer.html. Accessed 12 June 1029.

USFWS. 2019c. National Wetlands Inventory, Wetlands Mapper. Website: https://www.fws.gov/wetlands/data/Mapper.html. Accessed 12 June 2019.

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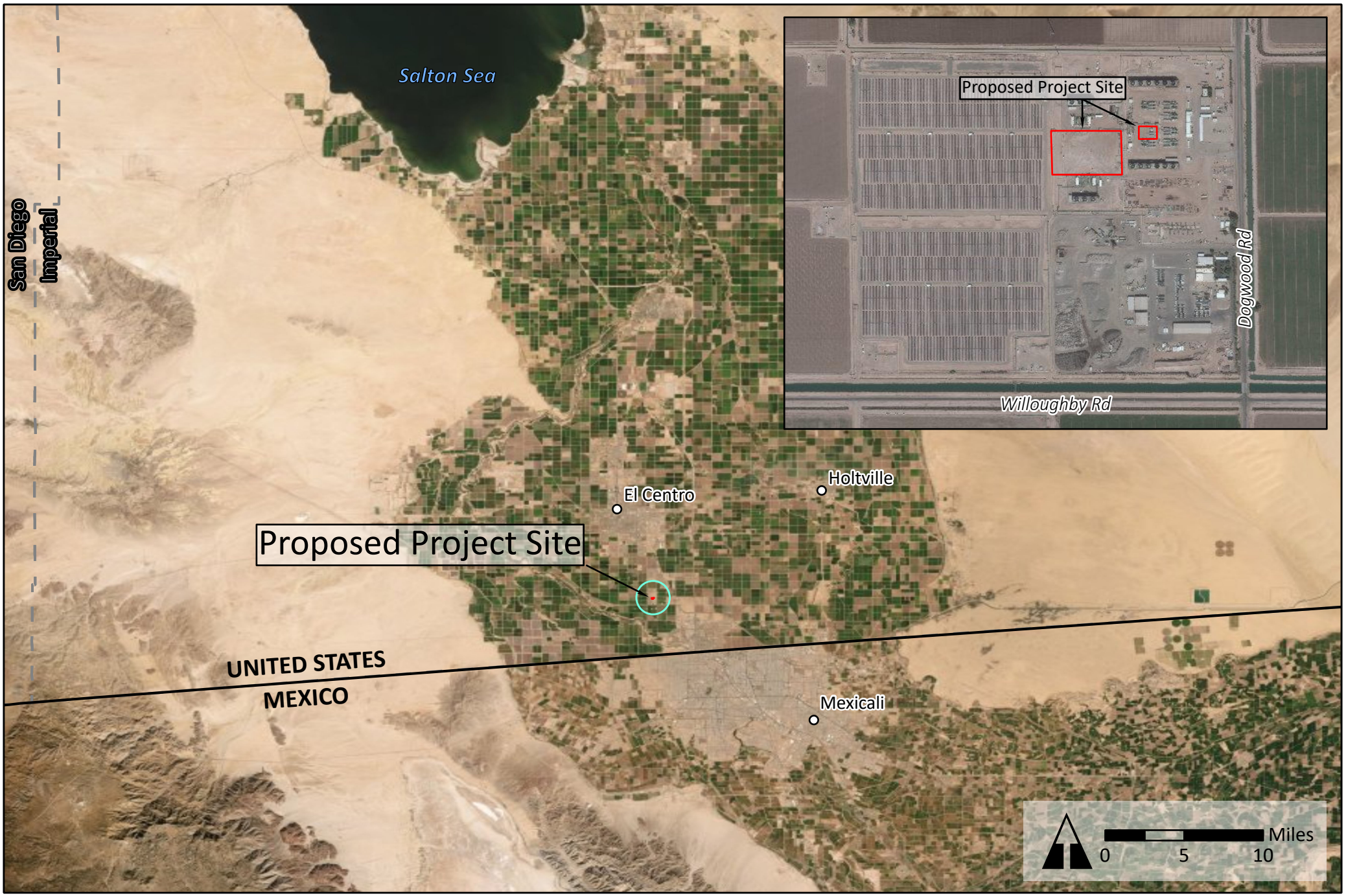

Legend

- United States/Mexico Border
- County Line
- Project Site
- 1-Mile Radius

PROPOSED PROJECT SITE - HEBER 2

Figure 1

ORMAT

Date: July 2019

Catalyst ENVIRONMENTAL SOLUTIONS

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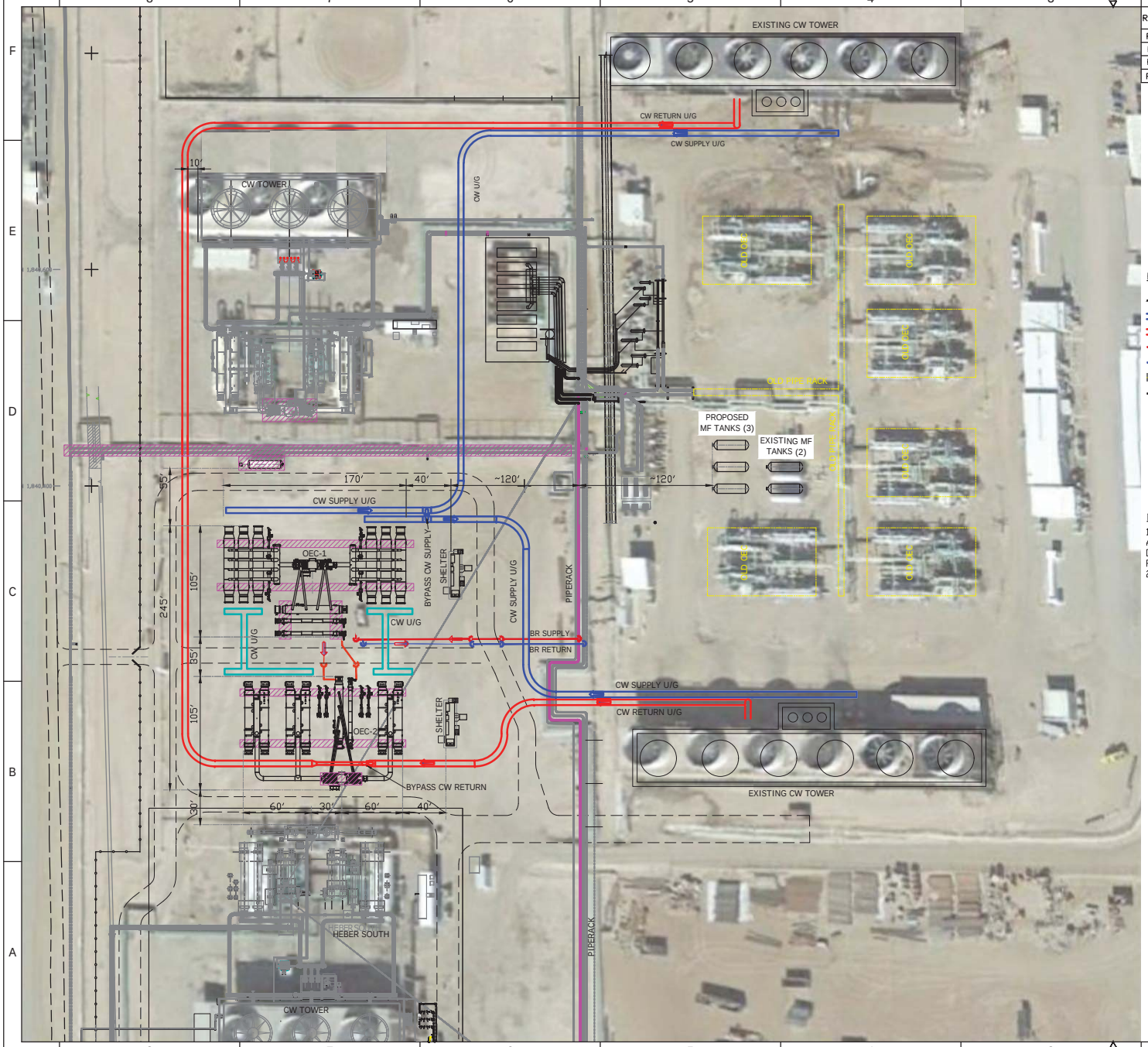
REV	DESCRIPTION	DATE	BY	CHK	ENG	PRJ
P6	UPDATE MODELS OES-1 & OEC-2	5.APR.2019	A.S.	A.N.		S.H.
P7	UPDATE MODELS OES-1	17.APR.2019	A.S.	A.N.		S.H.
P8	UPDATE OEC-1 & OEC-2	27.MAY.2019	A.S.	A.N.		S.H.
P9	UPDATE LOCATION OEC-1	18.JULY.2019	A.S.	A.N.		S.H.



KEY:

- EXISTING FENCE LINE
- PROPOSED UNDERGROUND CW SUPPLY LINE
- PROPOSED UNDERGROUND CW RETURN LINE
- PROPOSED BR SUPPLY LINE
- PROPOSED BR RETURN LINE
- EQUIPMENT TO BE DECOMMISSIONED
- EXISTING EQUIPMENT TO REMAIN

CW	COOLING WATER
U/G	UNDERGROUND
BR	GEOTHERMAL BRINE
OEC	ORMAT ENERGY CONVERTOR
MF	MOTIVE FLUID

NOTE:

1. THE ARRANGEMENT AND SIZES PRESENTED ARE PRELIMINARY AND INDICATIVE ONLY AND SUBJECT TO CHANGED ON DESIGN OPTIMIZATION , DETAILED DESIGN AND ACTUAL EQUIPMENT PURCHASED (MANUFACTURED).
2. DIMENSIONS ARE IN MM [FEET], ELEVATIONS ARE IN MM FEET]

0 20' 100' 200'

GRAPHIC SCALE (FEET)

PREPARED BY:

Stantec

PHONE: FAX:

FOR:

Second Imperial Geothermal Company
855 B Dogwood Road
Heber CA 92249

TITLE:

HEBER2 REPOWER
GENERAL ARRANGEMENT
POWER PLANT ON MAP

DRAWN BY: KAM	DESIGNED BY:
CHECKED BY:	APPROVED BY:
PROJECT NUMBER: 01OT.01234.01.0123	SCALE: AS SHOWN
DATE: 04/01/04	FILE PATH: K:/(CLIENT) OR JOB #

SHEET:

1 OF 1

APPENDIX A

Site Photographs

(Collected on June 1, 2019 and June 13, 2019)

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Photo 1 – western portion of development site.



Photo 2 – southwest portion of development site.

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Photo 3 – northwestern portion of development site.



Photo 4 – northern portion of development site.

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Photo 5 – central portion of development site.



Photo 6 – central portion of development site.

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Photo 7 – northern portion of development site.

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Technical Memorandum

Cardno

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Date June 28, 2019

To: Ben Pogue, PMP, AICP
Director of Environmental Planning & Natural Resource Management
Catalyst Environmental Solutions
315 Montana Avenue, Suite 311
Santa Monica, California 90403

From: Jennifer M. Ferris, MA, RPA

RE **Cultural Resources Records Review for the Heber 2 Geothermal Optimization Project**
Confidential – Not for Public Disclosure

Dear Mr. Pogue:

This technical memorandum describes the results of the cultural resources records review completed in June 2019 for the Heber 2 Geothermal Optimization Project. The project is located at 855 Dogwood Road, Heber, Imperial County, California. The project is in Section 33 of Township 16 South, Range 14 East of the San Bernardino Base & Meridian.

The cultural resources records review was completed by Cardno, who requested a records search at the South Central Coastal Information Center (SCCIC) of the California Historical Resources Information System (CHRIS). The SCCIC records search included a review of archives containing archaeological site records and reports of cultural resource studies previously conducted near the project area. Other resources reviewed include the National Register of Historic Places (NRHP), the California Register of Historical Resources (CRHR), the California Inventory of Historic Resources, California Historical Landmarks, California Points of Historical Interest, and the Historic Property Data File.

1.0 Review Results

There are no previously recorded cultural resources (archaeological or historic) within the project area. One previously recorded cultural resource (CA-IMP-008166, Niland to Calexico Railroad) lies within 1.0 mile of the project area (Figure 1). The railroad, which is still in use today, was constructed between 1902 and 1904 by the Southern Pacific Company and runs 65 miles from Niland to Calexico. The railroad has not been evaluated for listing in the NRHP.

There have been 23 surveys, records searches, and environmental impact reports completed within 1.0 mile of the project area. These are shown in Table 1 and Figure 2. Two of the studies

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(SCCIC report numbers IM-00115 and IM-00235) partially covered the current project area. None of these studies resulted in the discovery of cultural resources.

Table 1. Previously Conducted Studies within 1.0 mile of the Project Area.

SCCIC Report Number	Authors/ Association	Year	Title	Associated Cultural Resources
IM-00063	Von Werlhof, Jay, and Shrilee Von Werlhof/ Imperial Valley College Museum	1976	Archaeological Examination of a Proposed Geothermal Testing Site near Heber, California	None
IM-00066	Von Werlhof, Jay, and Sherilee Von Werlhof/ Imperial Valley College Museum	1976	Archaeological Record Search of the Heber, California, Region	None
IM-00075	Von Werlhof, Jay, and Sherilee Von Werlhof/ Imperial Valley College Museum	1976	Archaeological Examinations of Certain Geothermal Well Test-Site Areas in the Heber, California, District	None
IM-00115	Von Werlhof, Jay, and Sherilee Von Werlhof/ Imperial Valley College Museum	1977	Archaeological Examination of the Heber Anomaly Report Prepared For VTN Consolidated, Inc.	None
IM-00123	VTN Consolidated, Inc.	1977	Draft Environmental Impact Report for the Heber Geothermal Demonstration Project	None
IM-00185	Von Werlhof, Jay, and George E. Collins/ Imperial Valley College Museum	1979	Archaeological Examinations of Proposed Geothermal Facilities near Heber, CA	None
IM-00192	VTN Consolidated, Inc.	1979	Draft Master Environmental Impact Report for a 500-Megawatt Geothermal Development at Heber, Imperial County, California	None
IM-00199	Walker, Carol, Charles Bull, and Jay Von Werlhof/ Recon	1979	Cultural Resource Study of a Proposed Electric Transmission Line From Jade to the Sand Hills, Imperial County, California	None
IM-00233	Walker, Carol, Charles Bull, and Jay Von Werlhof/ Recon	1981	Cultural Resource Study of a Proposed Electric Transmission Line From Jade to the Sand Hills, Imperial County, California	None
IM-00235	Bureau of Land Management	1981	APS/SDG&E Interconnection Project - Supplement to the Draft Environmental Document	None
IM-00272	Sanchez, Miguel/ PBS & Associates	1982	Draft Environmental Impact Report - Current Land Use Plan, Heber Planning Unit	None
IM-00301	Welch, Patrick/ Bureau of Land Management	1983	Cultural Resource Inventory for Thirty Proposed Asset Management Parcels in Imperial County, California	None
IM-00368	Imperial County Planning Department	1987	Chevron Geothermal Company Of California Supplemental Project Information for the Auxiliary Production Facility Heber Geothermal Unit, Imperial County	None

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SCCIC Report Number	Authors/ Association	Year	Title	Associated Cultural Resources
IM-00441	ENSR Consulting and Engineering	1990	Environmental Assessment/Initial Study for the Placement of Fiber Optic Facilities Between Salton Microwave Station And Calexico California	None
IM-00536	Burkenroad, David	1979	Phase One Regional Studies APS/SDG&E Interconnection Project Transmission System Environmental Study Cultural Resources: History	None
IM-00537	Wirth Associates, Inc.	1979	Phase One Regional Studies APS/SDG&E Interconnection Project Transmission System Environmental Study Cultural Resources: Archaeology	None
IM-00538	Imperial County	1979	Proposed Workscope Phase II Cultural Resources Studies APS-SDG&E Transmission Interconnect Project, Miguel to Sand Hills, Sand Hills to Pvngs	None
IM-00547	Cultural Systems Research, Inc.	1982	Draft Archaeological Research Design and Data Recovery Program for Cultural Resources Within the Mountain Springs (Jade) to Sand Hills Portion of the APS/SDG&E Interconnection Project 500kv Transmission Line	None
IM-00595	Cultural Systems Research, Inc.	1982	Mountain Springs (Jade) to Sand Hills Data Recovery Preliminary Report	None
IM-01080	Von Werlhof, Jay/ Imperial Valley College Desert Museum	1999	Archaeological Examinations Of The Heber Facilities Sewer And Water Improvements Project	None
IM-01095	Garnsey, Michael/ ASM Affiliates	2007	Cultural Resources Study For The Proposed Mosaic Project, Imperial County, California	None
IM-01306	Wirth Associates, Inc.	1980	APS/SDG&E Interconnection Project Environmental Study Phase Ii Corridor Studies - Native American Cultural Resources Appendices	None
IM-01313	Wirth Associates, Inc.	1980	APS/SDG&E Interconnection Project (Phase II Corridor Studies) - Cultural Resources: Archaeology	None

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Attachment A
Figures

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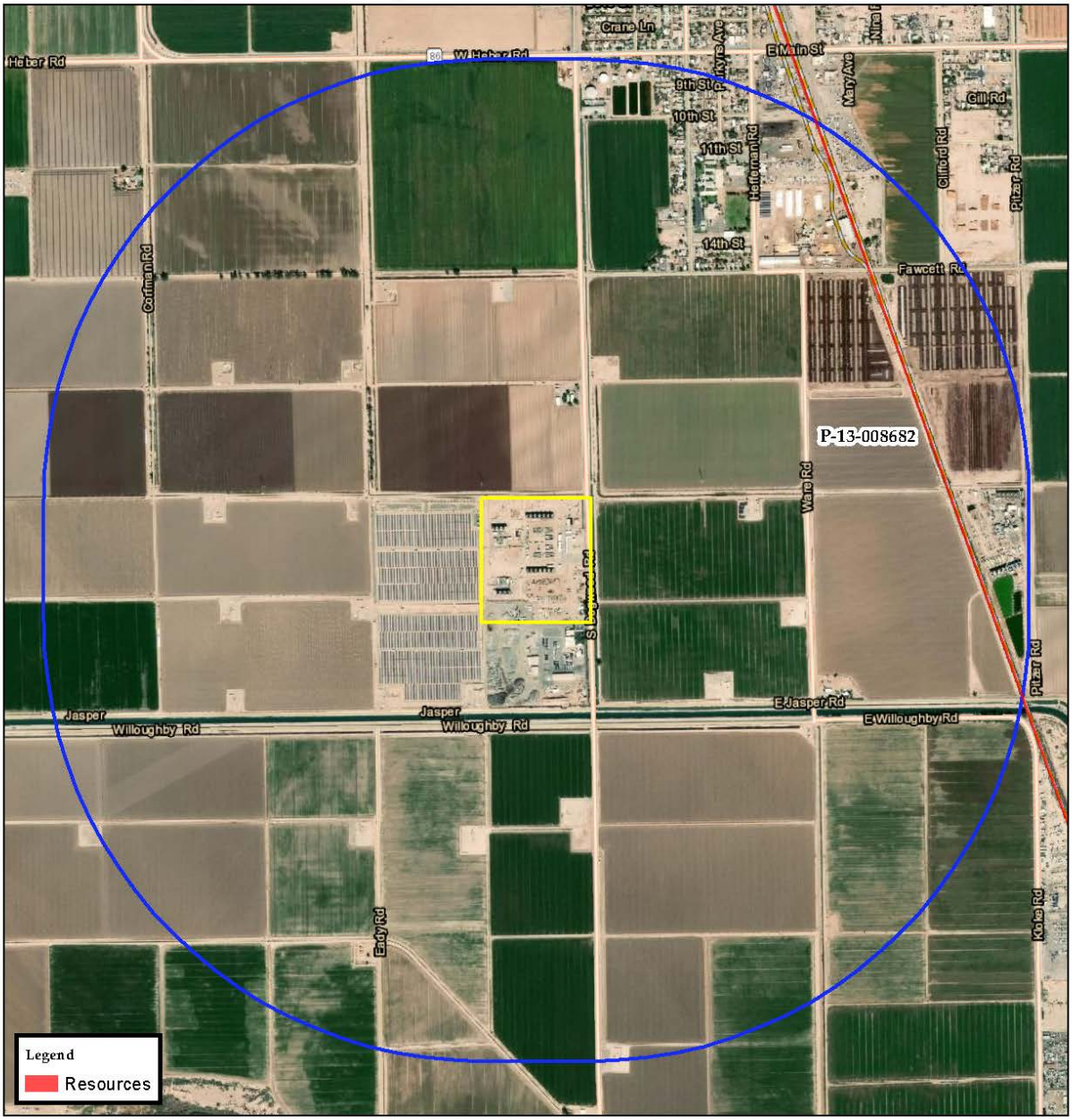
CONFIDENTIAL. This document is confidential under California Government Code 6254.10 and the National Historic Preservation Act, Section 304, and other applicable federal, state, and local laws and regulations prohibiting public and unauthorized disclosure of records related to cultural resources.



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Historical Resources with Primary and Trinomial Designations

0 250 500 1,000 Meters

Nick Doose, Jun 23, 2019

Aerial © ESRI 2017

Figure 1 Cultural resources located within search radius.

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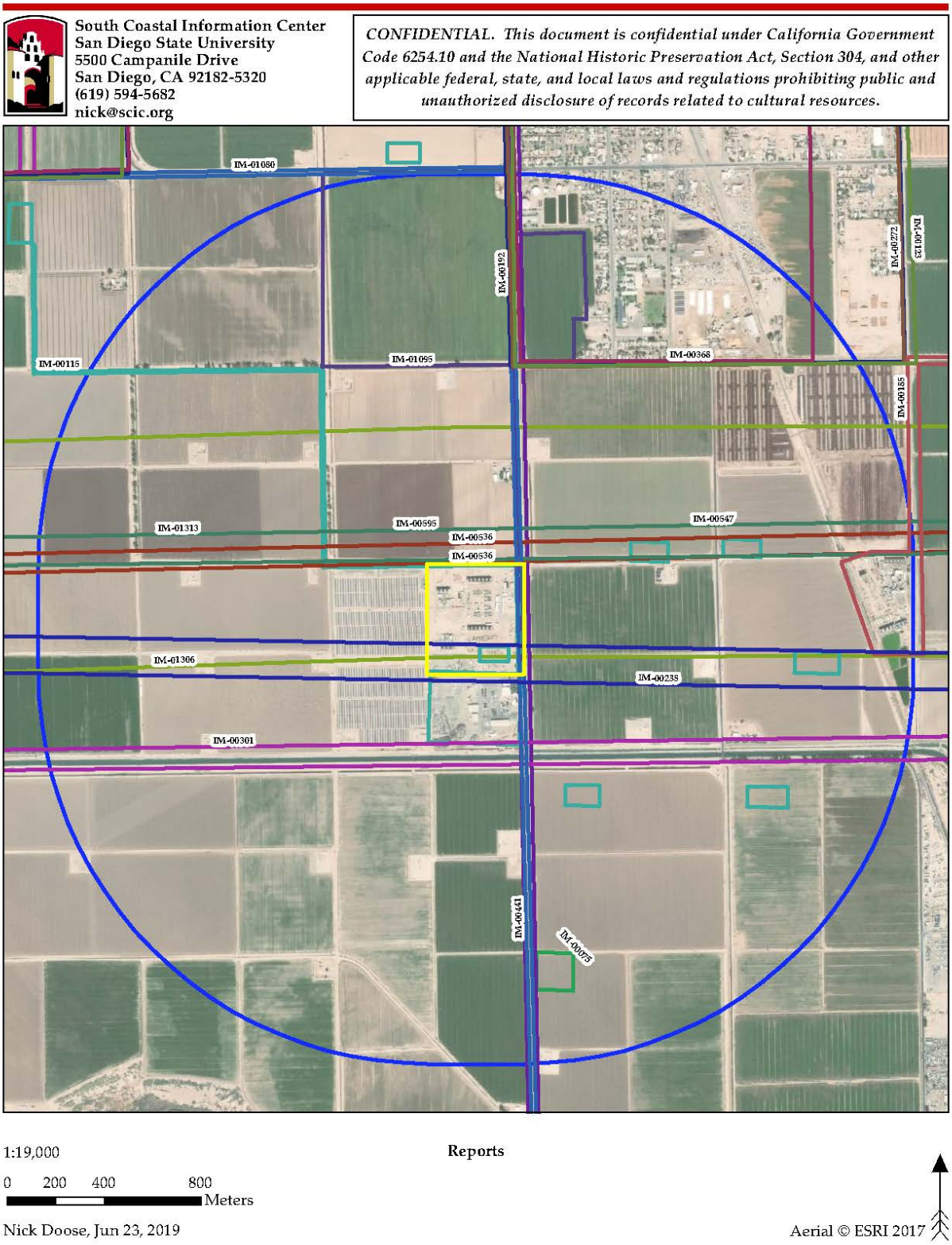

Figure 2 Previously conducted cultural resources studies within search radius.

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Water Quality Management Plan
Heber 2 Geothermal Repower Project

(855 Dogwood Road, Heber, California)

July 2019







Prepared By:

Catalyst Environnemental Solutions
315 Montana Avenue, Suite 311
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Prepared For:

Second Imperial Geothermal Company (ORMAT Nevada Inc.)
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Heber, CA 92249

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Document Information

Prepared for	Second Imperial Geothermal Company (ORMAT Nevada Inc.)
Project Name	Heber 2 Geothermal Repower Project 855 Dogwood Road, Heber, California
Address	Second Imperial Geothermal Company 947 Dogwood Road Heber, CA 92249
Project Manager	Ben Pogue bpogue@ce.solutions
Project Engineer	Paden Voget, P.E. pvoget@ce.solutions State of California Professional Engineer #69238
Date	July 19, 2019

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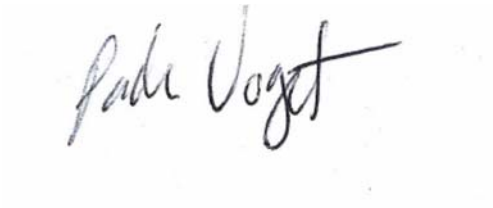
Professional Certification

Water Quality Management Plan

Heber 2 Geothermal Repower Project

This report has been prepared by Catalyst Environmental Solutions Corporation under the professional supervision of the Principal(s) and/or staff whose signature(s) appear hereon.

The scope of work and specifications are presented in accordance with generally accepted professional engineering practice and those of the California State Water Resources Control Board Order No. 20013-001-DWQ. There is no other warranty either expressed or implied.





Paden Voget, PE
State of California Professional Engineer #69238

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Project Owner's Certification

This Water Quality Management Plan (WQMP) has been prepared for Second Imperial Geothermal Company (ORMAT Nevada Inc.) by Catalyst Environmental solutions. The WQMP is intended to comply with the requirements of the County of Imperial and the Phase II Small MS4 General Permit Imperial Valley Watershed. The undersigned, while it owns the subject property, is responsible for the implementation of the provisions of the site consistent with the Phase II Small MS4 Permit and the intent of the County of Imperial and the unincorporated community of Heber. Once the undersigned transfers its interest in the property, its successors in interest and the city/county/town shall be notified of the transfer. The new owner will be informed of its responsibility under this WQMP. A copy of the approved WQMP shall be available on the subject site in perpetuity.

"I certify under a penalty of law that the provisions (implementation, operation, maintenance, and funding) of the WQMP have been accepted and that the plan will be transferred to future successors."

Project Data			
Permit/Application Number(s):	CUP No. 06-0006	Grading Permit Number(s)	N/A
Tract/Parcel Map Number(s):	APN 054-250-031	Building Permit Number(s)	N/A
CUP, SUP, and/or APN:			06-0006
Owner's Signature			
Owner Name:	Connie Stechman		
Title:	VP, Finance		
Company:	Ormat Nevada Inc.		
Address:	6140 Plumas Street, Reno, NV 89519		
Email:	cstechman@ormat.com		
Telephone:	775-356-9029		
Signature:	Connie Stechman	Date:	8/12/19

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SECTION 1 Project Description

The Second Imperial Geothermal Company, a wholly owned subsidiary of ORMAT Nevada Inc (ORMAT), owns and operates the Heber 2 Geothermal Energy Complex. The proposed Heber 2 Geothermal Repower Project (Project) is located at 855 Dogwood Road, Heber, California within unincorporated Imperial County. The Project includes the installation of two water-cooled ORMAT Energy Converters (OECs) to replace six old units from 1992; three 10,000 gallon isopentane above ground storage tanks; and, additional pipeline to connect the proposed facilities with the existing Heber 2 Complex (Site). The total project disturbance from developing the new OECs is approximately 4 acres, all within the existing power plant complex and fence line. A vicinity map of the Project Site is included in **Figure 1**.

The Project includes the replacement of six air-cooled OECs with two water-cooled OECs. The pre-Project pervious area is roughly 4 acres. The Project will result in less than 200 square feet of area converted in impervious surface area resulting from installation of equipment footings/foundations. In addition, no grading is proposed for the Project. Accordingly, the Project will not result in a change to the existing grade and stormwater flows and drainage will not be altered from existing conditions. **Figure 2** illustrates the existing drainage facilities in the vicinity of the Project. **Figure 3** provides a site plan of the proposed facilities.

1.1 SITE LOCATION

The Site includes approximately 4 acres within the Heber quadrangle of the U.S. Geological Survey (USGS) 7.5" topographic map, and sits within Township 16 South, Range 14 East of the San Bernardino Base and Meridian in Imperial County, California.

1.2 LAND USE AND TOPOGRAPHY

The Project is located on private lands owned by ORMAT in southern Imperial County as shown in **Figure 1**. The Project site includes approximately 4 acres entirely within the Assessor's Parcel Number (APN) 054-250-031, which is a 39.99-acre property. APN 054-250-031 is zoned as A-2-G SPA, for General Agriculture (A-2), Geothermal Overlay Zone (G), and in the Heber Specific Plan Area (SPA). The Project Site lies at an elevation approximately 15 feet below mean sea level (msl) in the Imperial Valley region of the California low desert. The surrounding properties lie on terrain which is flat, part of a large agricultural valley.is The Site is currently vacant and unimproved. The Site is also devoid of vegetation and is actively disturbed as part of ongoing energy generation operations at Heber 2. Adjacent properties outside of the fenced operations yard consists of agricultural land to the north and a solar farm to the west.

1.3 SITE GEOLOGY, HYDROGEOLOGY, AND SOILS

The part of Imperial County containing Heber lies within the Pliocene to Holocene, Q Geologic Unit (McCrink et al. 2011). Three natural geomorphic provinces underlay Imperial County, including the Peninsular Ranges, the Colorado Desert, and the Mojave Desert. The Colorado Desert geomorphic province spans central Imperial County and contains the Salton Sea and the Imperial valley. This Basin and Range province, sometimes referred to as the Salton Trough, is composed of a low-lying barren

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desert basin located between alluvium-covered, active branches of the San Andreas Fault containing Cenozoic sedimentary rocks and alluvial, lacustrine, and eolian deposits. The surface of sediments in the middle of the trough are about 275 feet below sea-level (bsl) (Digital Desert, 2019).

Surface water in the area of the Site consists of canals and agricultural drains operated and maintained by the Imperial Irrigation District. Canals adjacent to the Project Site include Date Drain No. 3, Date Drain No. 3a, Date Drain No. 3b, and Date Drain No. 3c as illustrated in **Figure 2**. These canals ultimately drain to the Alamo River, a tributary to the Salton Sea. Surface runoff within the Project Site occurs primarily as sheetflow across the lot generally to the north, eventually flowing into the adjoining ditches.

The regional groundwater flow direction within the Imperial Valley is toward the Salton Sea, a closed basin with a surface elevation of approximately 225 feet below sea level. Groundwater flow in the Project area flows in a general northwest direction.

Dry lean silty clays dominate the project site surface extending to approximately 4 to 5 feet below ground surface (bgs). These silty clays are underlain by moist stiff clays from approximately 6 ft to 38-40 ft bgs. Silty clay to clayey silt dominate 40-50 ft bgs to the extent of geotechnical exploration (Landmark 2019).

1.4 HYDROMODIFICAITON APPLICABILITY

As discussed above, the Project would result in less than 50 square feet of impervious area from pre-Project conditions. In addition, no grading is proposed for the Project or changes to the permeability of the Site. As such, the post-development runoff volume, time of concentration, and peak flow velocity would not be altered from that of the pre-development condition.

1.5 POTENTIAL STORMWATER POLLUTANTS

Table 1 summarizes expected stormwater pollutants of concern based on land use and site activities.

Table 1. Pollutants of Concern

Pollutant	Potential to Impact Stormwater (Y/N)	Additional Information and Comments
Pathogens (Bacterial/Virus)	N	--
Nutrients – Phosphorous	N	--
Nutrients - Nitrogen	N	--
Noxious Aquatic Plants	N	--
Sediment	Y	Overland flows over unpaved surface may result in sediment in stormwater runoff
Metals	Y	Leaks/spills in Project area may result in metals in stormwater runoff
Oil and Grease	Y	Leaks/spills in Project area may result in oil and grease in stormwater runoff

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Trash/Debris	Y	Improperly disposed of trash/debris may result in trash in stormwater runoff
Pesticides/Herbicides	N	--
Other	N	--

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SECTION 2 Best Management Practices

This section describes the Best Management Practices (BMPs) that will be implemented and maintained throughout the life of the project. The BMPs will be used to prevent and minimize water pollution that can be caused by stormwater runoff. **Table 2** details the BMPs selected to be implemented at the Site based on the potential pollutants. Note that the Site is within the existing operational footprint and is subject to the existing policies and programs implemented by ORMAT for the facility. Because the Project does not propose any changes to the existing stormwater volume, peak flow velocity, time of concentration or drainage patterns, no structural BMPs are proposed.

Table 2. Non-Structural Source Control BMPs

Pollutant Source	Pollutant	BMP	Existing?	New/Revised?
Stormwater run-on and runoff	Erosion, sediment, contaminated stormwater	• Stabilize drainage with rocks, gravel, vegetation, or riprap • Provide perimeter control to isolate sediment (loose dirt). Includes earthen berms, fiber rolls, silt fence, etc.	X	
Vehicle Track Out	Sediment, Dust	• Provide tracking control devise • Conduct street sweeping	X	
Work Areas	Trash	• Regularly monitor and clean trash • Provide employee training for good housekeeping	X	
Equipment Areas (OECs, ITLUs, pipes)	Isopentane, sediment	• Control drainage patterns with berms • Use water truck for dust control • Conduct routine inspections	X	X
Stored materials and equipment maintenance	Oil, grease, hydraulic fluid, anti-freeze, metals	• Provide good housekeeping training • Store materials in secondary containment • Spill kit and response training	X	

In addition to the activities listed above, ORMAT follows all approved operational guidelines that are currently in place. Temporary and permanent soil erosion control BMPs will be implemented in conformance with the BMP Fact Sheets provided in the CASQA Stormwater Best Management Practice Handbook – Industrial and Commercial (2014).

2.1 NON-STRUCTURAL BMPS

The following are prevention practices utilized to minimize the probability of pollution of stormwater discharge.

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2.1.1 Good Housekeeping

As a component of this program, good housekeeping practices are performed so that facility is kept in a clean and orderly condition. Proper housekeeping practices include:

- Periodic cleanup of equipment, as needed, based upon facility inspections,
- Sweeping impervious surfaces, as needed, based upon facility inspections,
- Proper waste disposal practices and covering of waste storage areas at all times,
- Proper storage and covering of materials at all times,
- Removal of any oil-stained soil/gravel, especially around equipment locations and loading areas,
- Cleaning of significant oil and grease stains on surfaces that drain to the stormwater drainage areas, and
- Cleaning the exterior of oil containers on hydraulic machinery upon discovery of an accumulation of hydraulic fluid.

2.1.2 Preventative Maintenance

As a component of this program, operations and maintenance staff perform preventative maintenance of stormwater management devices to assure their proper operation. Preventative maintenance of stormwater management devices includes the following:

- Cleaning of accumulated sediment, potential contaminants, and debris from the Site;
- Inspection of secondary containment structures as part of the regular daily visual inspections;
- Maintenance and inspection of secondary containment structures, as needed, based upon inspections;
- Daily inspection and maintenance of equipment and associated piping and valves as required by preventive maintenance procedures;
- Inspection and maintenance of rainfall protection coverings for waste storage bins and receptacles on a periodic basis; and
- A comprehensive preventive maintenance schedule is performed on all facility operations equipment as part of routine procedures.

2.1.3 Spill Response

Spill prevention and response is performed according to the facility's SPCC Plan . Copies of this plan are located in the on-site ORMAT office.

A limited amount of spill cleanup equipment is stored onsite. This equipment is found within hazardous material storage areas. Detailed information concerning spill cleanup equipment and resources is included in the SPCC Plan.

The volume of containment areas surrounding each potential source is designed to hold the contents of a spill from the largest vessel / container. The SPCC Plan summarizes the capacity of potential sources and volume of the respective secondary containment areas.

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2.1.4 Material Handling and Storage

The primary hazardous material to be stored on-site is isopentane. The additional isopentane will be stored in the appropriately designed (3x) 10,000 gallon above ground storage tanks, as well as the existing (2x) 10,000 gallon tanks. The isopentane is used as a motive fluid for geothermal energy generation and is not directly discharged, rather is released as an air emission. Therefore, the isopentane would not be directly exposed to stormwater. All other hazardous waste would be stored in 55-gallon drums and other Department of Transportation (DOT) approved packaging within a contained area located on the Site. Stormwater that accumulates within the hazardous material and hazardous waste containment area is collected via vacuum truck and disposed of off-site or recycled back into the production system. A bill of lading, non-hazardous waste manifest or uniform hazardous waste manifest is used to document all such shipments.

2.1.5 Employee Training

A combined annual Storm Water Compliance / SPCC Plan training program is conducted for the Pollution Prevention Team members and operations personnel. Participants undergo stormwater management training for all areas and operations at this facility, as well as reviewing the spill response, control and countermeasure procedures. Other stormwater training is done on an as-needed basis.

2.1.6 Waste Handling/Recycling

At times, product or oily waste streams are transferred from the facility in 55-gallon drums. A bill of lading, non-hazardous waste manifest or uniform hazardous waste manifest is used to document all such shipments. Operations or contractor personnel closely monitor loading of transport vehicles. Collection and satellite accumulation containers for hazardous and non-hazardous waste are kept covered to prevent contact with stormwater. Appropriate spill control equipment and supplies are kept readily available in case of a spill.

2.1.7 Record Keeping and Internal Reporting

All inspection, sampling, maintenance, corrective action records, and any other information that is a part of this plan are maintained at the facility office. All records are maintained for a period of at least three (3) years.

2.1.8 Erosion Control and Site Stabilization

Permanent BMPs used at the facility to prevent soil erosion include routing runoff along earthen swales or drainage areas, and preventing run-off with berms along certain sections of the property line. Temporary BMPs used at the Site to prevent soil erosion include the use of sandbags, crushed rock, and silt fence. These BMPs are used as and where needed, especially in areas that are undeveloped or in the process of being developed.

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SECTION 3 Operation and Maintenance Plan

The Heber 2 Geothermal Repower Project is located at 855 Dogwood Road, Heber, California. The following non-structural water quality best management practices (BMPs) are proposed for the Project:

- Good Housekeeping
- Preventative Maintenance
- Spill Response
- Material Handling and Storage
- Employee Training
- Waste Handling/Recycling
- Record Keeping and Internal Reporting
- Erosion Control and Site Stabilization

3.1 MAINTENANCE RESPONSIBILITY

The Second Imperial Geothermal Company, a wholly owned subsidiary of ORMAT Nevada Inc (ORMAT) is the property owner and is responsible for BMP maintenance. Since ORMAT is the owner, no access agreement or easement is necessary to maintain the BMPs. ORMAT funds will be used to support Operation and Maintenance (O&M) activities to maintain BMP functionality. ORMAT maintenance staff are expected to perform the maintenance.

3.2 MAINTENANCE ACTIONS AND FREQUENCY

Maintenance actions are generally grouped into two categories: routine and intermittent.

Routine Maintenance

Routine inspections of the Project facilities and grounds will be performed annually. During these inspections staff evaluate if there is significant accumulation of trash, debris, or sediment that would need to be removed. Cleaning is done as needed based on the results of the inspections. The inspection frequency may be adjusted based on experience at the site (e.g., if inspections rarely find any material that needs to be cleaned out, then the inspection frequency can be reduced).

Intermittent Maintenance

Intermittent maintenance activities include more substantial maintenance that is not required as frequently as routine maintenance. The most likely form of intermediate maintenance is removal of sediment from existing drainage infrastructure and detention basins where necessary to maintain the capacity of the basins. Given that the Project Site is pervious and will not be graded or significantly altered and that rain is infrequent in Heber, this type of maintenance is expected to be required approximately once every year.

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3.3 MAINTENANCE PROCEDURES

During each maintenance visit, the maintenance crew will evaluate existing drainage paths and infrastructure by inspecting for the maintenance indicators in **Table 3**. When a maintenance indicator is observed, the action described in the "Maintenance Actions" column will be taken.

Note that regardless of the projected maintenance type (routine or intermittent) described in the previous section, when a maintenance indicator is observed, the required maintenance action will be taken. For example, if significant sediment accumulation is observed in year three instead, then the accumulated sediment will still be cleaned out, even though the estimated frequency was once every year.

Table 3-1. Maintenance Indicators and Actions for BMPs

Typical Maintenance Indicator	Maintenance Action
Erosion due to concentrated stormwater runoff flow	Repair eroded areas and make appropriate corrective measures such as adding berm or stone at flow entry points, or re-grading as necessary.
Accumulated sediment, litter, or debris	Remove and properly dispose of accumulated materials, without damage to stormwater drainage structures.
Standing water	Remove any obstructions or debris or invasive vegetation, loosing or replace top-soil to allow for better infiltration, or minor re-grading for proper drainage.
Obstructed inlet or outlet structures	Clear obstructions.
Damage to structural components such as inlet or outlet structures	Repair or replace as applicable.

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Figures





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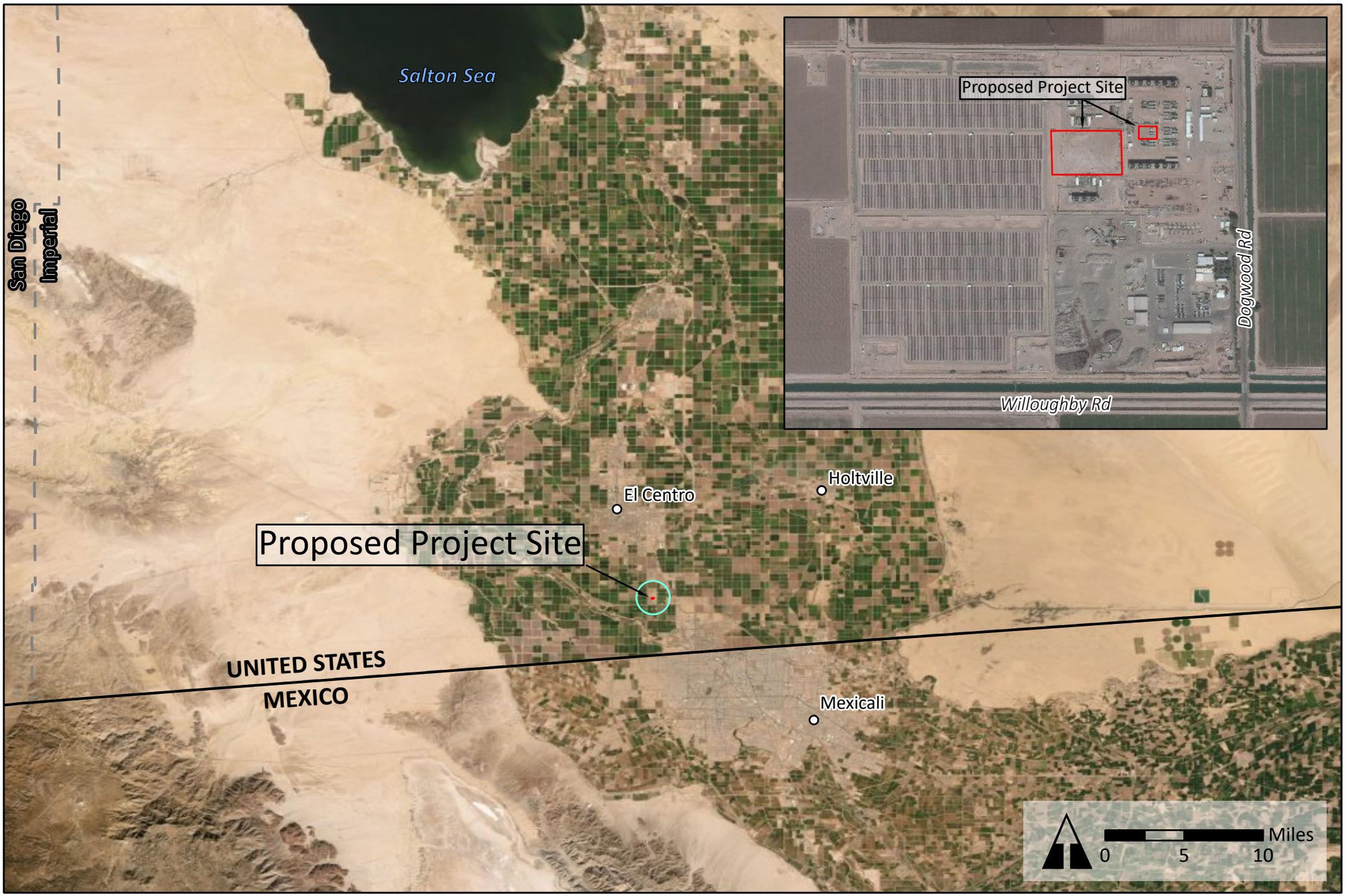

Legend

- United States/Mexico Border
- County Line
- Project Site
- 1-Mile Radius

PROPOSED PROJECT SITE - HEBER 2

Figure 1

ORMAT

Date: July 2019

Catalyst ENVIRONMENTAL SOLUTIONS

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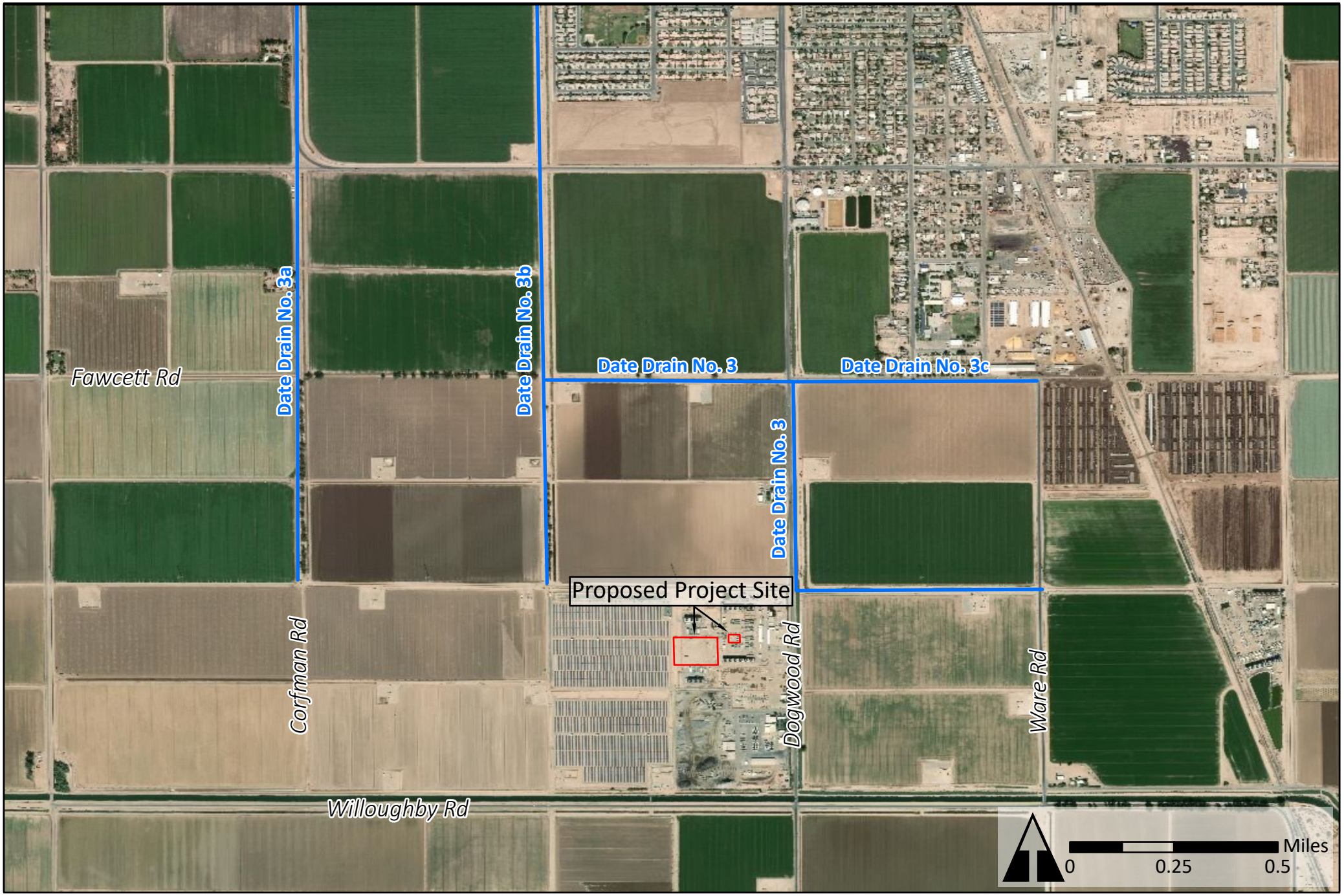

Legend

- Drainage Canal
- Project Site

DRAINAGE CANALS

Figure 2

ORMAT

Date: July 2019

Catalyst ENVIRONMENTAL SOLUTIONS

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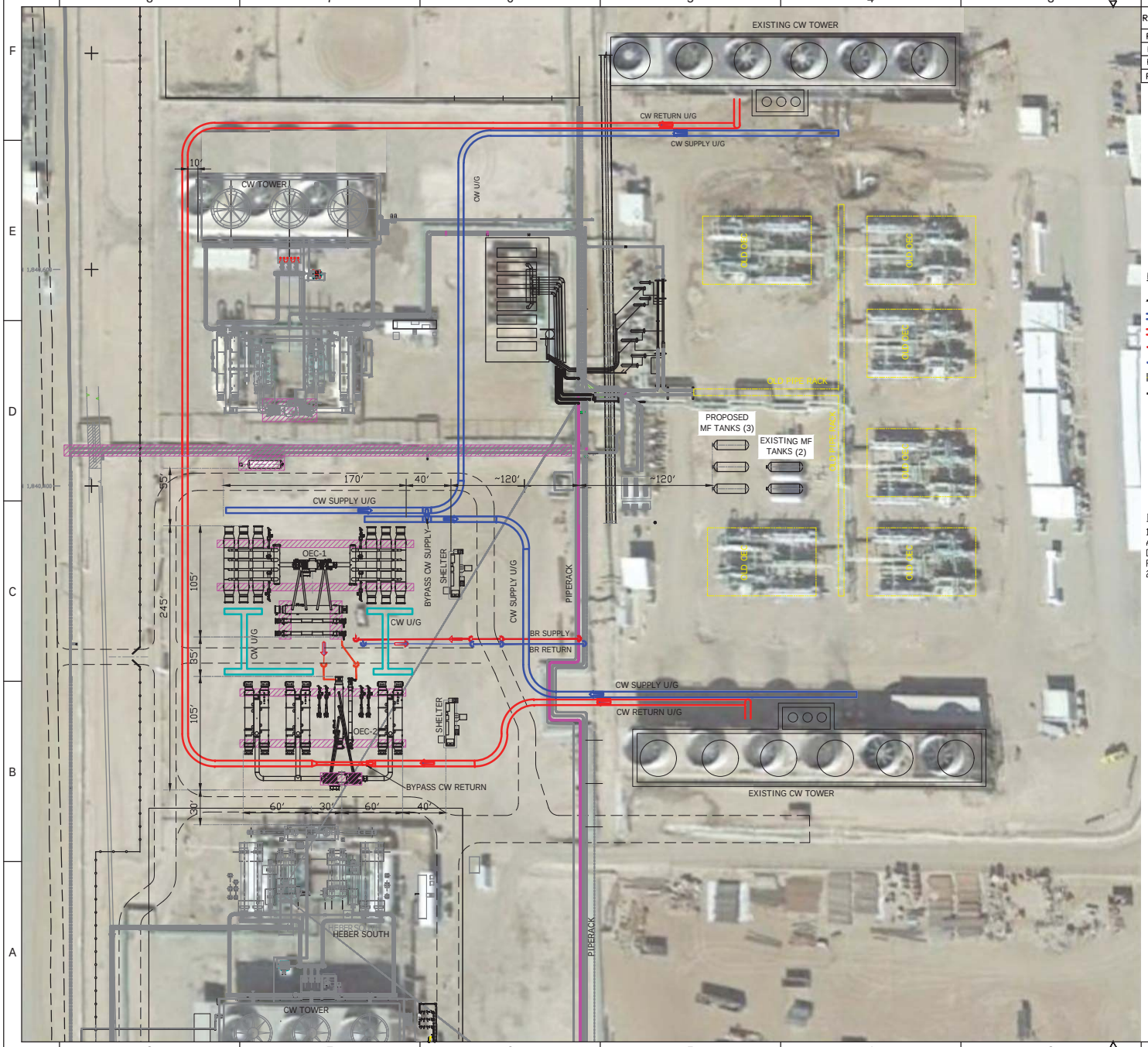

REV	DESCRIPTION	DATE	BY	CHK	ENG	PRJ
P6	UPDATE MODELS OES-1 & OEC-2	5.APR.2019	A.S.	A.N.		S.H.
P7	UPDATE MODELS OES-1	17.APR.2019	A.S.	A.N.		S.H.
P8	UPDATE OEC-1 & OEC-2	27.MAY.2019	A.S.	A.N.		S.H.
P9	UPDATE LOCATION OEC-1	18.JULY.2019	A.S.	A.N.		S.H.

N

KEY:

- EXISTING FENCE LINE
- PROPOSED UNDERGROUND CW SUPPLY LINE
- PROPOSED UNDERGROUND CW RETURN LINE
- PROPOSED BR SUPPLY LINE
- PROPOSED BR RETURN LINE
- EQUIPMENT TO BE DECOMMISSIONED
- EXISTING EQUIPMENT TO REMAIN
- CW — COOLING WATER
- U/G — UNDERGROUND
- BR — GEOTHERMAL BRINE
- OEC — ORMAT ENERGY CONVERTOR
- MF — MOTIVE FLUID

NOTE:

1. THE ARRANGEMENT AND SIZES PRESENTED ARE PRELIMINARY AND INDICATIVE ONLY AND SUBJECT TO CHANGED ON DESIGN OPTIMIZATION , DETAILED DESIGN AND ACTUAL EQUIPMENT PURCHASED (MANUFACTURED).
2. DIMENSIONS ARE IN MM [FEET], ELEVATIONS ARE IN MM FEET]

0 20' 100' 200'

GRAPHIC SCALE (FEET)

PREPARED BY:

Stantec

PHONE: FAX:

FOR:

Second Imperial Geothermal Company
855 B Dogwood Road
Heber CA 92249

TITLE:

HEBER2 REPOWER
GENERAL ARRANGEMENT
POWER PLANT ON MAP

DRAWN BY: KAM	DESIGNED BY:
CHECKED BY:	APPROVED BY:
PROJECT NUMBER: 01OT.01234.01.0123	SCALE: AS SHOWN
DATE: 04/01/04	FILE PATH: K:/(CLIENT) OR JOB #

SHEET:

1 OF 1

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Geotechnical Site Summary Memorandum

Date: July 2019

From: Catalyst Environmental Solutions - Dan Tormey, P.G., Ph.D; Ben Pogue, M.P.A., P.M.P., A.I.C.P.

RE: Heber 2 Geothermal Repower Project – Geotechnical Site Assessment

---

This technical memorandum provides a summary of the geotechnical conditions for the Heber 2 project site, located at the Second Imperial Geothermal Company's (a wholly owned subsidiary of ORMAT Nevada, Inc.) existing Heber 2 Geothermal Energy Complex at 855 Dogwood Road, Heber, California, in Imperial County. Site-specific information was gathered from available online resources and extrapolated from the *Geotechnical Report Update* prepared by Landmark Consultants (Landmark, 2019). Landmark's report provides an update to previous geotechnical reports conducted at the site (Landmark 2005, 2007) and reflects the adoption of the 2016 California Building Code (CBC) and Imperial County's geotechnical engineering standard of practice.

Desktop reconnaissance was conducted to gather information on the geological-geotechnical site conditions, soil conditions, seismic conditions, liquefaction potential, site stability, and stormwater infiltration potential. Collectively, this memorandum provides a comprehensive review of the project site's geotechnical conditions to support the development of a California Environmental Quality Act (CEQA) Initial Study/Negative Declaration (IS/ND), as opposed to an as-graded, or as-built geotechnical report.

1.0 Geological/Geotechnical Site Conditions

The part of Imperial County containing Heber lies within the Pliocene to Holocene, Q Geologic Unit (McCrink et al. 2011). Three natural geomorphic provinces underlay Imperial County, including the Peninsular Ranges, the Colorado Desert, and the Mojave Desert. The Colorado Desert geomorphic province spans central Imperial County and contains the Salton Sea and the Imperial valley. This Basin and Range province, sometimes referred to as the Salton Trough, is composed of a low-lying barren desert basin located between alluvium-covered, active branches of the San Andreas Fault containing Cenozoic sedimentary rocks and alluvial, lacustrine, and eolian deposits. The surface of sediments in the middle of the trough are about 275 feet below sea-level (bsl) (Digital Desert, 2019).

2.0 Soil Conditions

There are approximately 28 soil types found in the region of the project area (Aco, Antho, Carrizo, Carsitas, Chuckwalla, Cibola, Coachella, Fluvaquents, Gadsden, Gilman, Glenbar, Holtville, Imperial, Indio, Kofa, Lagunita, Laposa, Laveen, Mecca, Meloland, Niland, Orita, Ripley, Rositas, Salorthids, Superstition, Torriorthents, and Vint). Glenbar, Holtville, and Imperial parent

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spoils are formed from fine-textured, stratified alluvial basin deposits (ICPDS 2015). The clay material deposited during the formation of the Colorado River delta terrace is the original source of Holtville and Imperial parent soils. Many of the other soils were formed from fan sediment originating from large gullies created by runoff into the Salton Sea. Imperial County soils are characterized by hyperthermic soil temperature and aridic soil moisture regimes (Digital Desert, 2019).

Dry lean silty clays dominate the project site surface extending to approximately 4 to 5 feet below ground surface (bgs). These silty clays are underlain by moist stiff clays from approximately 6 ft to 38-40 ft bgs. Silty clay to clayey silt dominate 40-50 ft bgs to the extent of geotechnical exploration (Landmark 2019).

3.0 Seismic Conditions/Liquefaction Potential

There are several active faults in the Imperial Valley, including the Brawley Fault Zone, San Jacinto Fault Zone (contains the Coyote Creek Fault, the Elmore Ranch Fault, and the Wienert Fault), the Elsinore Fault (contains the Laguna Salada Fault), the Imperial Fault, the San Andreas Fault Zone, and the Superstitions Hills Fault (ICPDS 2015). There are several mapped faults of the San Andreas Fault System across the valley, which is comprised of the San Andreas, San Jacinto, and Elsinore Fault Zones. Landmark (2019) employed a computer-aided search approach to assess known faults and seismic zones within 36 miles of the project site. The Imperial Fault located 9.4 miles southwest of the project site was the closest mapped Earthquake Fault Zone.

Earthquake hazard zones are characterized by areas susceptible to fault ruptures (ground surface breaks/cracks along a fault), liquefaction, and landslides. Ground shaking can occur during an earthquake, and its intensity is related to the proximity of the area to the fault, the focal depth, soil types, the location of the epicenter, and the size (magnitude) of the earthquake. Soils formed from alluvial deposits are more prone to ground shaking than dense materials such as bedrock. Moderate to strong ground motion could be expected in the project area; however, ground motions could vary considerably due to potential attenuation by rock and soil deposits, as well as the type of fault and direction of rupture (Landmark 2019). Soils in the project area were classified as Site Class D, which is characterized by a stiff soil profile. Further, Landmark determined a Seismic Design Category of D based on a Risk Category III.

Liquefaction occurs when loosely packed, saturated soil or sediment at or near the ground surface loses its strength, which can lead to excessive settlement, ground rupture, lateral spreading, or failure of shallow bearing foundations (Imperial County 2015). Landslide and liquefaction zones have not been mapped in this area (ICPDS 2015); however, the Colorado River Delta region of southern Imperial County (including Heber) is a seismically active area. Landmark (2019) evaluated liquefaction potential at the project site using the 1997 NCEER Liquefaction Workshop methods. Due to the cohesive nature of the subsurface soils, liquefaction is not anticipated at the project site, and mitigation is not recommended.

Several significant earthquakes have occurred in the vicinity with corresponding surface fault ruptures and liquefaction events (McCrink et al. 2011). Four earthquakes greater than

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magnitude 5 were recorded near Heber, between 1915 and 1979. The El Mayor-Cucapah earthquake (magnitude 7.2) that occurred throughout southern Imperial valley in 2010 caused widespread liquefaction near the towns of Calexico (immediately south of Heber) and El Centro (immediately north of Heber).

4.0 Stormwater Infiltration Potential

Encouraging stormwater infiltration by means of a stormwater management plan (SWMP) can improve water conservation by reducing evaporation and increasing groundwater recharge, as well avoiding erosion and potential damage to concrete foundations and slabs. Beneficial water quality of streams and rivers can also be maintained by preventing discharge of stormwater containing sediments and other materials. The City of El Centro and City of Imperial SMP provide best management practices (BMPs) for stormwater management by commercial businesses and industrial operations (City of El Centro and Imperial County 2013).

Heber also has a Master Drainage Plan (established in 2006), although the town's management of stormwater defers to the Imperial County Planning and Development guidelines and the county Public Works Department. The Imperial Irrigation District board adopted the Imperial Integrated Regional Water Management Plan (IRWMP) in 2012 (GEI 2012). The plan was developed to support the efforts to meet the County's future water resource demands while conforming to California Department of Water Resources guidelines.

Groundwater is encountered approximately 8 to 10 feet bgs at the project site (Landmark 2019). Onsite infiltration potential (capacity of the most limiting layer to transmit water [Ksat]) ranges from very low to moderately low (0.00 to 0.06 inches per hour) (Holtville silty clay, wet; approximately 71% of the project site) to moderately high (0.20 to 0.57 inches per hour) (Imperial-Glenbar silty clay loams, wet; approximately 29% of the project site). These soil types are also considered to be moderately well drained (NRCS 2019). Evaporation potential is considered poor at the project site.

5.0 Site Stability

The project site is located within the seismically active Imperial Valley and has the potential for ground disturbance based on soil and subsurface characteristics. Recommendations for the expansion project, including engineered design and earthquake-resistant construction complying with the latest edition of the CBC for Site Class D are provided in Landmark's updated geotechnical report (2019).

6.0 References

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Geotechnical Report Update

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Prepared for:

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Geotechnical Report Update
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855 Dogwood Road
Heber, California
LCI Report No. LE19075

Dear Mr. Huberman:

Landmark Consultants, Inc. is providing this geotechnical report for the project at the Heber 2 Repower geothermal power plant. This report updates Landmark's 2004 and 2007 Geotechnical Reports for the power plant located at 855 Dogwood Road southwest of Heber, California. The update addresses changes made due to the adoption of the 2016 California Building Code (CBC) and geotechnical engineering standard of practice in Imperial County. The original reports (LCI Report No. LE04354, dated January 10, 2005 and LCI Report No. LE07178, dated May 9, 2007) are provided in Appendix D and Appendix E, respectively.

This update report presents selected elements of our findings and professional opinions only. It does not present all details that may be needed for the proper application of our findings and professional opinions. Our findings, professional opinions, and application options are best related through reading the full Geotechnical Report Update, and with the active participation of the engineer of record who developed them during design and construction of the project.

Seismic Parameters

Seismic Risk: The project site is located in the seismically active Imperial Valley of southern California with numerous mapped faults of the San Andreas Fault System traversing the region. The San Andreas Fault System is comprised of the San Andreas, San Jacinto, and Elsinore Fault Zones in southern California. The Imperial fault represents a transition from the more continuous San Andreas fault to a more nearly echelon pattern characteristic of the faults under the Gulf of California (USGS 1990). We have performed a computer-aided search of known faults or seismic zones that lie within a 36 mile (57 kilometer) radius of the project site as provided in Table 1.

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A fault map illustrating known active faults relative to the site is presented on Figure 1, *Regional Fault Map*. A legend for the regional fault map is presented on Figure 2. The criterion for fault classification adopted by the California Geological Survey defines Earthquake Fault Zones along active or potentially active faults. An active fault is one that has ruptured during Holocene time (roughly within the last 11,000 years). A fault that has ruptured during the last 1.8 million years (Quaternary time), but has not been proven by direct evidence to have not moved within Holocene time is considered to be potentially active. A fault that has not moved during both Pleistocene and Holocene time (that is no movement within the last 1.8 million years) is considered to be inactive. Review of the current Alquist-Priolo Earthquake Fault Zone maps (CGS, 2000a) indicates that the nearest mapped Earthquake Fault Zones are the Imperial fault located approximately 9.4 miles southwest of the project site.

Site Acceleration: The project site is considered likely to be subjected to moderate to strong ground motion from earthquakes in the region. Ground motions are dependent primarily on the earthquake magnitude and distance to the seismogenic (rupture) zone. Accelerations also are dependent upon attenuation by rock and soil deposits, direction of rupture and type of fault; therefore, ground motions may vary considerably in the same general area.

CBC General Ground Motion Parameters: The 2016 CBC general ground motion parameters are based on the Risk-Targeted Maximum Considered Earthquake (MCE_R). The Structural Engineers Association of California (SEAOC) and Office of Statewide Health Planning and Development (OSHPD) Seismic Design Maps Web Application (SEAOC, 2019) was used to obtain the site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters. **The site soils have been classified as Site Class D (stiff soil profile).**

Design spectral response acceleration parameters are defined as the earthquake ground motions that are two-thirds (2/3) of the corresponding MCE_R ground motions. Design earthquake ground motion parameters are provided in Table 2. **A Risk Category III was determined using Table 1604.5 and the Seismic Design Category is D since S_1 is less than 0.75**.

The Maximum Considered Earthquake Geometric Mean (MCE_G) peak ground acceleration (PGA_M) value was determined from the "U.S. Seismic Design Maps Web Application" (SEAOC, 2019) for liquefaction and seismic settlement analysis in accordance with 2016 CBC Section 1803.5.12 and CGS Note 48 ($PGA_M = F_{PGA}*PGA$). **A PGA_M value of 0.50g is used for liquefaction settlement analysis.**

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Subsurface Soil and Groundwater

Subsurface soils encountered during Landmark's 2004 and 2007 geotechnical studies consist of surficial dry very stiff lean silty clays to a depth of 4 to 5 feet. Stiff clays extend from about 6 feet to a depth of 38 to 40 feet. Silty clay to clayey silt was encountered from 40 to 50 feet, the maximum depth of exploration. The subsurface logs (Plates B-1 through B-5 in Appendix B) depict the stratigraphic relationships of the various soil types. Groundwater was not noted in the CPT soundings, but is typically encountered at a depth of about 8 to 10 feet below ground surface at the plant site.

Liquefaction Potential

Liquefaction potential at the project site was evaluated using the 1997 NCEER Liquefaction Workshop methods. The 1997 NCEER methods utilize direct SPT blow counts or CPT cone readings from site exploration and earthquake magnitude/PGA estimates from the seismic hazard analysis. The resistance to liquefaction is plotted on a chart of cyclic shear stress ratio (CSR) versus a corrected blow count $N_{1(60)}$ or Qc_{1N}. A PGA_M value of 0.50g was used in the analysis with a 15-foot groundwater depth and a threshold factor of safety (FS) of 1.3.

The computer program CLiq (Version 2.2.0.32, Geologismiki, 2017) was utilized for liquefaction assessment at the project site. The estimated settlements have been adjusted for transition zones between layers and the post liquefaction volumetric strain has been weighed with depth (Robertson, 2014 and Cetin et al., 2009). Computer printouts of the liquefaction analyses are provided in Appendix C.

Liquefaction is not expected occur at the project site due to the cohesive nature of the subsurface soils. No mitigation is required for liquefaction induced settlements at this project site.

Site Preparation

Structure Subgrade Preparation: The exposed surface soil within foundation areas should be removed to 18 inches below the foundation elevation or existing grade (whichever is lower) extending five feet beyond all foundation lines. Exposed subgrade should be neat cut (flat blade on bucket).

A minimum of 18 inches of Caltrans Class 2 aggregate base shall be placed and compacted in 6 inch maximum lifts to 95% of ASTM D1557 maximum dry density below each foundation or mat slab.

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Imported fill soil (if required) should have a Plasticity Index less than 15 and sulfates (SO_4) less than 1,000 ppm or non-expansive, granular soil meeting the USCS classifications of SM, SP-SM, or SW-SM with a maximum rock size of 3 inches and 5 to 35% passing the No. 200 sieve. The geotechnical engineer should approve imported fill soil sources before hauling material to the site. Imported granular fill should be placed in lifts no greater than 8 inches in loose thickness and compacted to at least 95% of ASTM D1557 maximum dry density at optimum moisture ±2%.

Trench Backfill: On-site soil free of debris, vegetation, and other deleterious matter may be suitable for use as utility trench backfill. Backfill soil within paved areas should be placed in layers not more than 6 inches in thickness and mechanically compacted to a minimum of 90% of the ASTM D1557 maximum dry density except for the top 12 inches of the trench which shall be compacted to at least 95%. Native backfill should only be placed and compacted after encapsulating buried pipes with suitable bedding and pipe envelope material. Pipe envelope/bedding should either be clean sand (Sand Equivalent SE>30). Precautions should be taken in the compaction of the backfill to avoid damage to the pipes and structures.

Observation and Density Testing: All site preparation and fill placement should be continuously observed and tested by a representative of a qualified geotechnical engineering firm. Full-time observation services during the excavation and scarification process is necessary to detect undesirable materials or conditions and soft areas that may be encountered in the construction area. The geotechnical firm that provides observation and testing during construction shall assume the responsibility of "*geotechnical engineer of record*" and, as such, shall perform additional tests and investigation as necessary to satisfy themselves as to the site conditions and the geotechnical parameters for site development.

Auxiliary Structures Foundation Preparation: Auxiliary structures such as free standing or retaining walls should have footings extended to a minimum of 24 inches below grade. The existing soil beneath the structure foundation prepared in the manner described for foundations except the preparation needed only to extend 12 inches below and beyond the footing.

Foundations and Settlements

Shallow spread footings and continuous wall footings are suitable to support the structures associated with the plant upgrades. Footings shall be founded on a layer of properly prepared and compacted soil as described in Section 4.1. The foundations may be designed using an allowable soil bearing pressure of 2,000 psf at 18-inch embedment depth when foundations are supported on compacted Caltrans Class 2 aggregate base (extending a minimum of 1.5 feet below footings).

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The allowable soil pressure may be increased by 20% for each foot of embedment depth in excess of 18 inches and by one-third for short term loads induced by winds or seismic events. The maximum allowable soil pressure at increased embedment depths shall not exceed 4,000 psf.

Flat Plate Structural Mats: Structural mats may be designed for a modulus of subgrade reaction (Ks) of 100 pci when placed on compacted clay or a subgrade modulus of 250 pci when placed on 2.5 feet of granular fill. Mats shall overlay 2 inches of sand and a 10-mil polyethylene vapor retarder. The structure support pad shall be moisture conditioned and recompacted as specified in Section 4.1 of this report.

Resistance to horizontal loads will be developed by passive earth pressure on the sides of footings and frictional resistance developed along the bases of footings and concrete slabs. Passive resistance to lateral earth pressure may be calculated using an equivalent fluid pressure of 300 pcf to resist lateral loadings. The top one foot of embedment should not be considered in computing passive resistance unless the adjacent area is confined by a slab or pavement. An allowable friction coefficient of 0.35 may also be used at the base of the footings to resist lateral loading. Foundation movement under the estimated loadings are estimated to not exceed ½ inch with differential movement of about two-thirds of total movement for the loading assumptions stated above when the subgrade preparation guidelines given above are followed.

Note: The entire plant area overlays a geothermal fluids reservoir that geothermal fluids extraction and reinjection is causing annual ground surface settlement of 1 to 2 inches per year. The settlement is not uniform.

Drilled Piers: New foundations may be supported on cast-in-place, drilled piers. Design criteria are provided below.

Vertical Capacity: Vertical capacity for 24 and 36-inch diameter shafts are presented in Figure 3. Capacities for other shaft sizes can be determined in direct proportion to shaft diameters. Point bearing and skin friction parameters have been used to determine the allowable shaft capacity. The allowable capacities include a factor of safety of 2.5. The allowable vertical compression capacities may be increased by 33 percent to accommodate temporary loads such as from wind or seismic forces. The allowable vertical shaft capacities are based on the supporting capacity of the soil.

Lateral Capacity: The allowable lateral capacities for 24 and 36-inch diameter shafts are given in the table shown below. The allowable horizontal deflection has been assumed to be one-half inch (0.50 inch).

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Table 3 – Lateral Capacities

Shaft Diameter (in.)	24		36	
Head Condition	Free	(*) Fixed	Free	(*) Fixed
Allowable Head Deflection (in.)	0.5	0.5	0.5	0.5
Minimum Length (ft.)	10	10	10	10
Lateral Capacity (kips)	15.6	50.8	20.0	65.0
Maximum Moment (foot-kips)	42.2	-293.3	53.7	-362.4
@Depth from Pier Head (ft.)	4.2	0	4.2	0
Minimum Length (ft.)	20	20	20	20
Lateral Capacity (kips)	32.0	70.5	52.0	124.0
Maximum Moment (foot-kips)	142.5	-393.3	266.7	-1025.0
@Depth from Pier Head (ft.)	9.0	0	9.8	0
Minimum Length (ft.)	30	30	30	30
Lateral Capacity (kips)	32.5	73.5	65.8	152.0
Maximum Moment (foot-kips)	145.0	-407.5	413.3	-1141.7
@Depth from Pier Head (ft.)	9.0	0	11.6	0

(*) Fixed head is defined as there is no rotation in the pier head (concrete foundation surrounding the pier heads).

Uplift Capacity: Pier capacity in tension may be assumed to be 50% of the compression capacity.

Settlement: Total settlements (non-seismic) of less than ¼ inch, and differential movement of about two-thirds of total movement for single pier designed according to the preceding recommendations. If pier spacing is at least 2.5 pier diameters center-to-center, no reduction in axial load capacity is considered necessary for group effect.

Note: The entire plant area overlays a geothermal fluids reservoir that geothermal fluids extraction and reinjection is causing annual ground surface settlement of 1 to 2 inches per year. The settlement is not uniform.

Note: Soil strength parameters obtained from field data and laboratory testing were modified based on our engineering judgment and our previous experience in the general site vicinity.

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Soil Parameters: Interpretive engineering soil parameters of the subsurface soil for use in the Allpile Computer Program are presented in the table below.

Table 4 – Soil Strength Parameters

Layer Type	Depth (ft)	Unit Weight (pcf)	Friction Angle (deg)	Cohesion (ksf)	Lateral Soil Modulus, k (pci)	ϵ_{50} or Dr	Strength Reduction Factor
SM	0 to 5	115	34°	0	80	45.0	1.0
CL-CH	5 to 12	125	---	1.25	315	0.85	1.0
CL-CH	12 to 40	125	---	1.75	550	0.70	1.0
ML	40 to 50	120	24°	0.50	225	1.00	1.0

Installation: The drilled piers shall be placed in conformance to ACI 336 guidelines. Excavation for piers should be inspected by the geotechnical consultant. A tremie pipe should be used to pour concrete from the bottom up and to ensure less than five feet of free fall. All drilled piers extending below groundwater shall be cased to prevent caving or lateral deformation. Groundwater is expected to be encountered at approximately 8 feet below ground surface.

The structural steel and concrete should be placed immediately after drilling. Prior to placing any structural steel or concrete, loose soil or slough material should be removed from the bottom of the drilled pier excavation.

Slabs-On-Grade

Structural Concrete: Structural concrete slabs are those slabs (foundations) that underlie structures or covered housekeeping slabs (shades). Concrete slabs and flatwork shall be a minimum of 6 inches thick due to equipment loads. Concrete slab and flatwork reinforcement should consist of chaired rebar slab reinforcement (minimum of No. 3 bars at 18-inch centers, both horizontal directions) placed at slab mid-height to resist drying shrinkage cracking. Slab thickness and steel reinforcement are minimums only and should be verified by the structural engineer/designer knowing the actual project loadings.

All steel components of the foundation system should be protected from corrosion by maintaining a 3-inch minimum concrete cover of densely consolidated concrete at footings (by use of a vibrator).

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Control joints should be provided in all concrete slabs-on-grade at a maximum spacing (in feet) of 2 to 3 times the slab thickness (in inches) as recommended by American Concrete Institute (ACI) guidelines. All joints should form approximately square patterns to reduce randomly oriented contraction cracks. Contraction joints in the slabs should be tooled at the time of the pour or sawcut (¼ of slab depth) within 6 to 8 hours of concrete placement. Construction (cold) joints in foundations and area flatwork should either be thickened butt-joints with dowels or a thickened keyed-joint designed to resist vertical deflection at the joint.

All joints in flatwork should be sealed to prevent moisture, vermin, or foreign material intrusion. Precautions should be taken to prevent curling of slabs in this arid desert region (refer to ACI guidelines).

Concrete Mixes and Corrosivity

Selected chemical analyses for corrosivity were conducted on bulk samples of the near surface soil from the project site. The native soils were found to have S1 to S2 (moderate to severe) levels of sulfate ion concentration (1,052 to 3,006 ppm). Sulfate ions in high concentrations can attack the cementitious material in concrete, causing weakening of the cement matrix and eventual deterioration by raveling. The following table provides American Concrete Institute (ACI) recommended cement types, water-cement ratio and minimum compressive strengths for concrete in contact with soils:

Table 5. Concrete Mix Design Criteria due to Soluble Sulfate Exposure

Sulfate Exposure Class	Water-soluble Sulfate (SO_4) in soil, ppm	Cement Type	Maximum Water-Cement Ratio by weight	Minimum Strength f'c (psi)
S0	0-1,000	–	–	–
S1	1,000-2,000	II	0.50	4,000
S2	2,000-20,000	V	0.45	4,500
S3	Over 20,000	V (plus Pozzolon)	0.45	4,500

Note: From ACI 318-14 Table 19.3.1.1 and Table 19.3.2.1

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A minimum of 6.0 sacks per cubic yard of concrete (4,500 psi) of Type V Portland Cement with a maximum water/cement ratio of 0.45 (by weight) should be used for concrete placed in contact with native soil on this project (sitework including foundations and housekeeping slabs). Admixtures may be required to allow placement of this low water/cement ratio concrete.

The native soil has moderate to very severe level of chloride ion concentration (210 to 3,040 ppm). Chloride ions can cause corrosion of reinforcing steel, anchor bolts and other buried metallic conduits. Resistivity determinations on the soil indicate very severe potential for metal loss because of electrochemical corrosion processes. Mitigation of the corrosion of steel can be achieved by using steel pipes coated with epoxy corrosion inhibitors, asphaltic and epoxy coatings, cathodic protection or by encapsulating the portion of the pipe lying above groundwater with a minimum of 3 inches of densely consolidated concrete. ***No metallic water pipes or conduits should be placed below foundations.***

Foundation designs shall provide a minimum concrete cover of three (3) inches around steel reinforcing or embedded components (anchor bolts, etc.) exposed to native soil. If the 3-inch concrete edge distance cannot be achieved, all embedded steel components (anchor bolts, etc.) shall be epoxy coated for corrosion protection (in accordance with ASTM D3963/A934) or a corrosion inhibitor and a permanent waterproofing membrane shall be placed along the exterior face of the exterior footings.

Additionally, the concrete should be thoroughly vibrated at footings during placement to decrease the permeability of the concrete.

Excavations

All site excavations should conform to CalOSHA requirements for Type C soil. The contractor is solely responsible for the safety of workers entering trenches. Temporary excavations with depths of 4 feet or less may cut nearly vertical for short duration. Sandy soil slopes should be kept moist, but not saturated, to reduce the potential of raveling or sloughing. Excavations below 4 feet will require shoring or slope inclinations in conformance to CAL/OSHA regulations for Type C soil.

Surcharge loads of stockpiled soil or construction materials should be set back from the top of the slope a minimum distance equal to the height of the slope. All permanent slopes should not be steeper than 3:1 to reduce wind and rain erosion. Protected slopes with ground cover may be as steep as 2:1. However, maintenance with motorized equipment may not be possible at this inclination.

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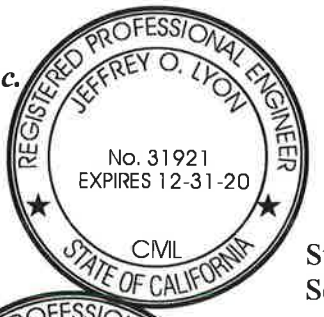
Seismic Design

This site is located in the seismically active southern California area and the site structures are subject to strong ground shaking due to potential fault movements along the Imperial and Cerro Prieto faults. Engineered design and earthquake-resistant construction are the common solutions to increase safety and development of seismic areas. Designs should comply with the latest edition of the CBC for Site Class D using the seismic coefficients given in Table 2 of this report.

Closure

We did not encounter soil conditions that would preclude implementation of the proposed project provided the recommendations contained in this report are implemented in the design and construction of this project. We appreciate the opportunity to provide our findings and professional opinions regarding geotechnical conditions at the site. If you have any questions or comments regarding our findings, please call our office at (760) 370-3000.

Respectfully Submitted,
Landmark Consultants, Inc.



Jeffrey O. Lyon, PE
President



Steven K. Williams, PG, EG
Senior Engineering Geologist



Julian R. Avalos, PE
Senior Engineer

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TABLES

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Table 1
Summary of Characteristics of Closest Known Active Faults

Fault Name	Approximate Distance (miles)	Approximate Distance (km)	Maximum Moment Magnitude (Mw)	Fault Length (km)	Slip Rate (mm/yr)
Imperial	7.0	11.2	7	62 ± 6	20 ± 5
Superstition Hills	8.4	13.5	6.6	23 ± 2	4 ± 2
Unnamed 2*	8.5	13.6			
Brawley *	8.8	14.1			
Rico *	9.9	15.9			
Unnamed 1*	12.0	19.2			
Borrego (Mexico)*	13.0	20.7			
Yuha*	13.3	21.2			
Superstition Mountain	14.7	23.5	6.6	24 ± 2	5 ± 3
Laguna Salada	14.8	23.6	7	67 ± 7	3.5 ± 1.5
Cerro Prieto *	15.2	24.3			
Pescadores (Mexico)*	17.2	27.5			
Shell Beds	17.3	27.6			
Yuha Well *	17.8	28.5			
Cucapah (Mexico)*	18.4	29.4			
Vista de Anza*	20.4	32.7			
Painted Gorge Wash*	24.0	38.4			
Ocotillo*	25.4	40.6			
Elmore Ranch	28.3	45.3	6.6	29 ± 3	1 ± 0.5
Elsinore - Coyote Mountain	29.1	46.6	6.8	39 ± 4	4 ± 2
San Jacinto - Borrego	33.6	53.8	6.6	29 ± 3	4 ± 2
Algodones *	35.6	57.0			

* Note: Faults not included in CGS database.

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Table 2
2016 California Building Code (CBC) and ASCE 7-10 Seismic Parameters

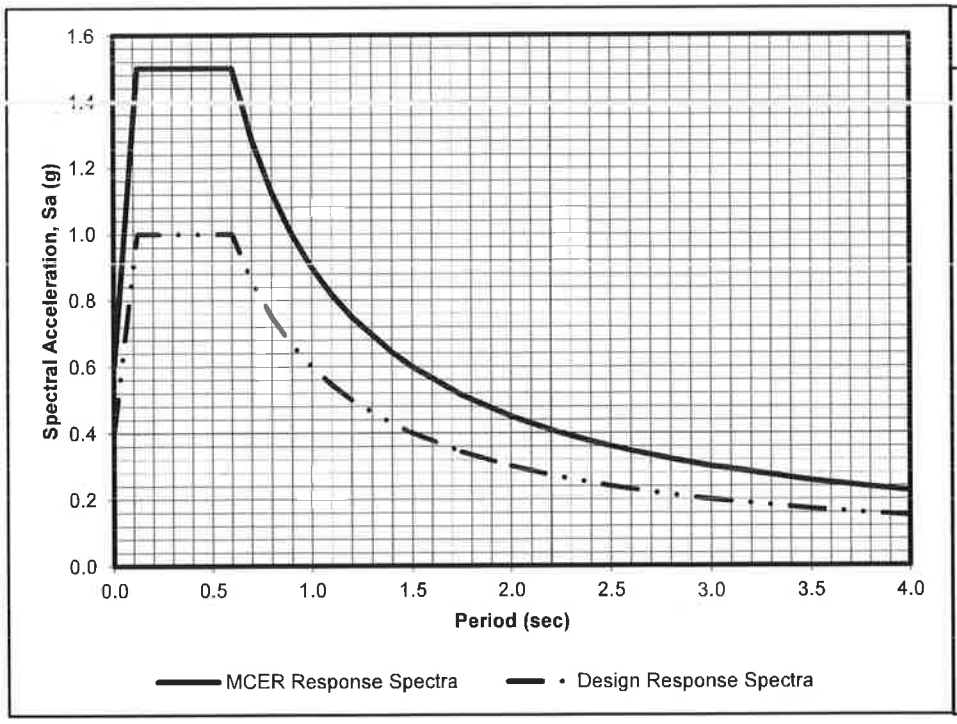
		ASCE 7-10 Reference
Soil Site Class:	**D**	Table 20.3-1
Latitude:	32.7139 N	
Longitude:	-115.5375 W	
Risk Category:	III	
Seismic Design Category:	D	

Maximum Considered Earthquake (MCE) Ground Motion

Mapped MCE_R Short Period Spectral Response	S_s	1.500 g	CBC Figure 1613.3.1(1)	
Mapped MCE_R 1 second Spectral Response	S_1	0.600 g	CBC Figure 1613.3.1(2)	
Short Period (0.2 s) Site Coefficient	F_a	1.00	CBC Table 1613.3.3(1)	
Long Period (1.0 s) Site Coefficient	F_v	1.50	CBC Table 1613.3.3(2)	
MCE_R Spectral Response Acceleration Parameter (0.2 s)	S_{MS}	1.500 g	$= F_a * S_s$	CBC Equation 16-37
MCE_R Spectral Response Acceleration Parameter (1.0 s)	S_{M1}	0.900 g	$= F_v * S_1$	CBC Equation 16-38

Design Earthquake Ground Motion

Design Spectral Response Acceleration Parameter (0.2 s)	S_{DS}	1.000 g	$= 2/3*S_{MS}$	CBC Equation 16-39
Design Spectral Response Acceleration Parameter (1.0 s)	S_{D1}	0.600 g	$= 2/3*S_{M1}$	CBC Equation 16-40
Risk Coefficient at Short Periods (less than 0.2 s)	C_{RS}	1.106		ASCE Figure 22-17
Risk Coefficient at Long Periods (greater than 1.0 s)	C_{R1}	1.073		ASCE Figure 22-18
	T_L	8.00 sec		ASCE Figure 22-12
	T_O	0.12 sec	$=0.2*S_{D1}/S_{DS}$	
	T_S	0.60 sec	$=S_{D1}/S_{DS}$	
Peak Ground Acceleration	PGA_M	0.50 g		ASCE Equation 11.8-1



Period T (sec)	Sa (g)	MCE_R Sa (g)
0.00	0.40	0.60
0.12	1.00	1.50
0.60	1.00	1.50
0.70	0.86	1.29
0.80	0.75	1.13
0.90	0.67	1.00
1.00	0.60	0.90
1.10	0.55	0.82
1.20	0.50	0.75
1.20	0.50	0.75
1.40	0.43	0.64
1.50	0.40	0.60
1.75	0.34	0.51
2.00	0.30	0.45
2.20	0.27	0.41
2.40	0.25	0.38
2.60	0.23	0.35
2.80	0.21	0.32
3.00	0.20	0.30
3.50	0.17	0.26
4.00	0.15	0.23

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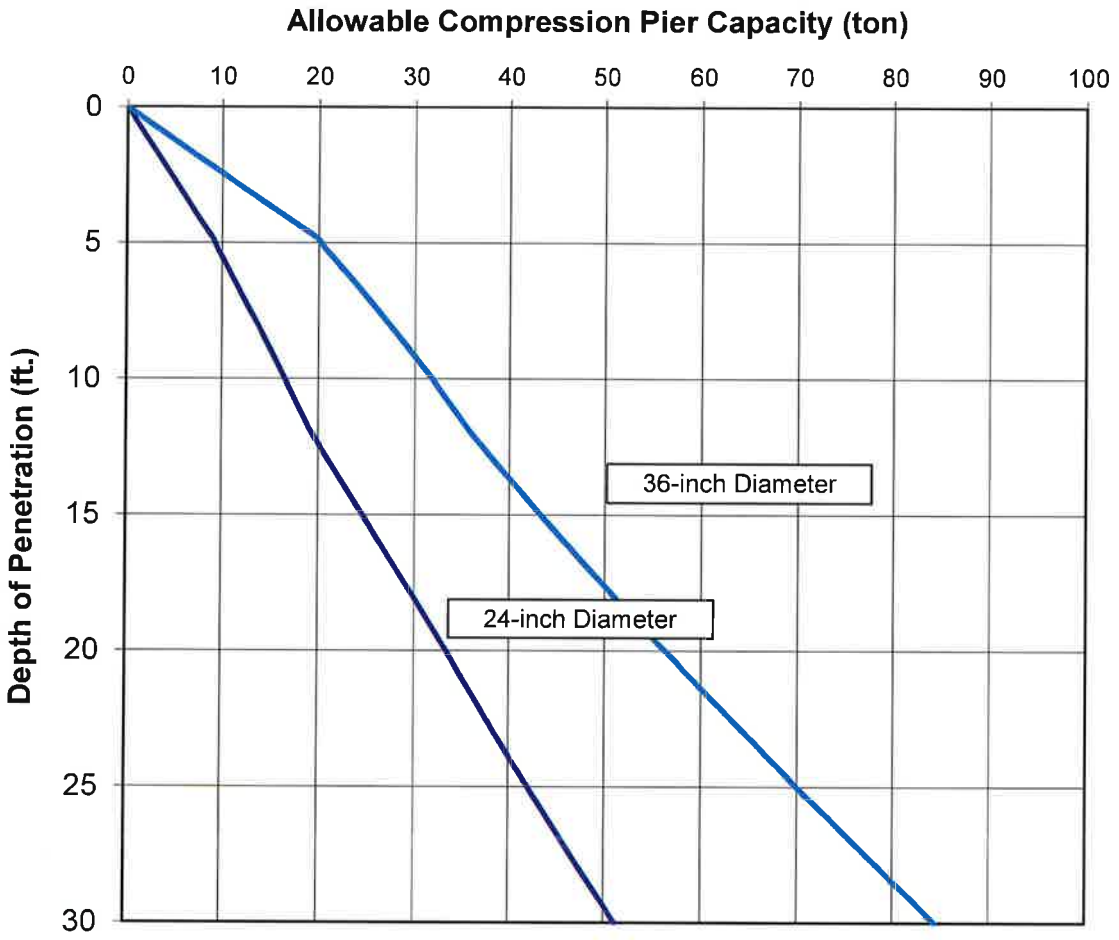

Notes:

1. Compression load capacity are based on skin friction and end-bearing capacity. The structural capacity of the piers should be checked.
2. The indicated capacities are for sustained (dead plus live) vertical compression load, and include a factor of safety of at least 2.5
3. For temporary wind or seismic load, the above values may be increased by one-third.
4. Capacities of other pier sizes are in direct proportion to the pile diameter.

LANDMARK Geo-Engineers and Geologists a DBE/MBE/SBE Company Project No.: LE19075	**Drilled Pier Compression Capacity Chart** **Ormat's Heber #2 Plant Expansion** **Heber, California**	**Figure 3**

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FIGURES

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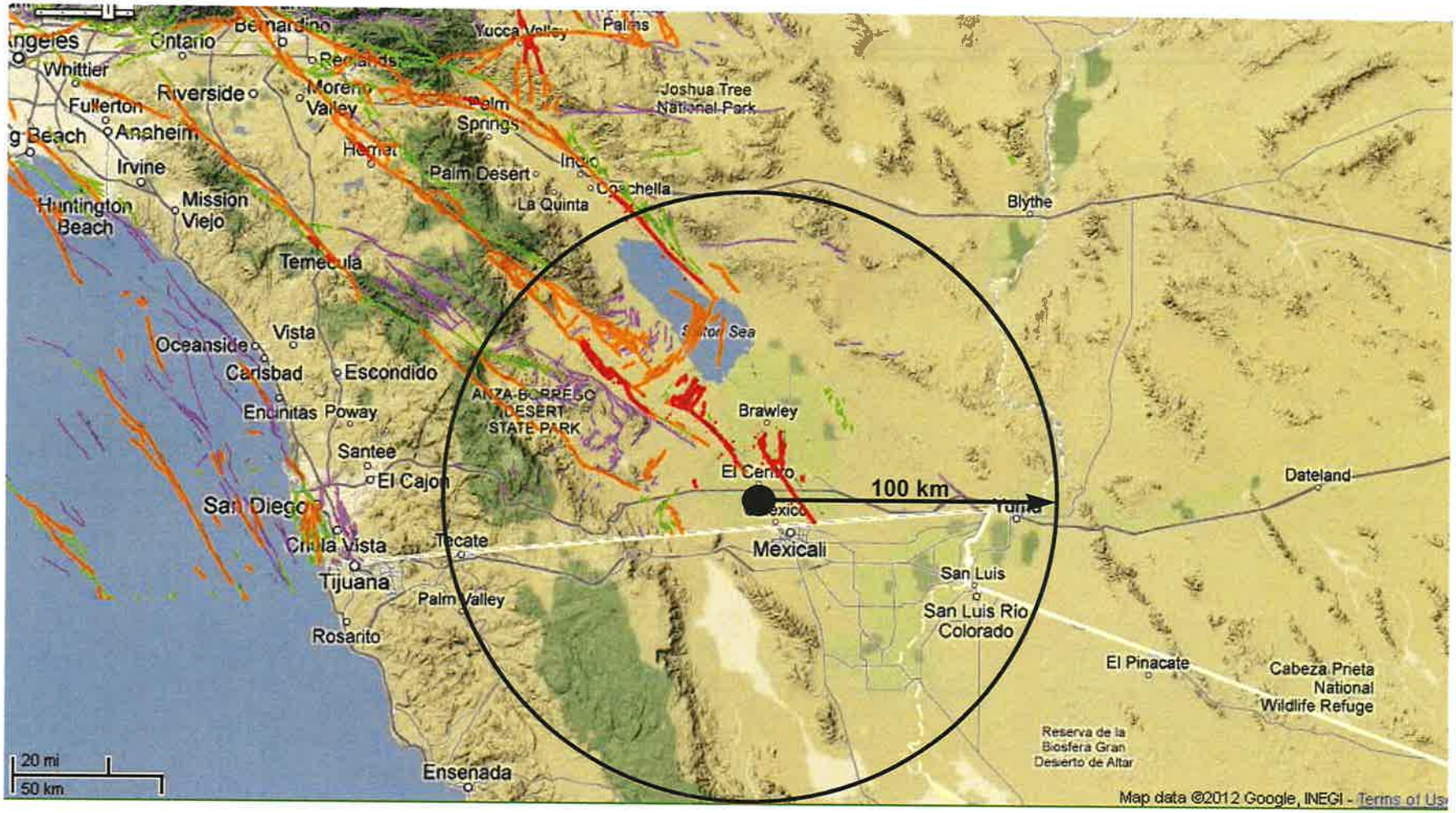

Source: California Geological Survey 2010 Fault Activity Map of California
http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html#

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Regional Fault Map

Figure 1

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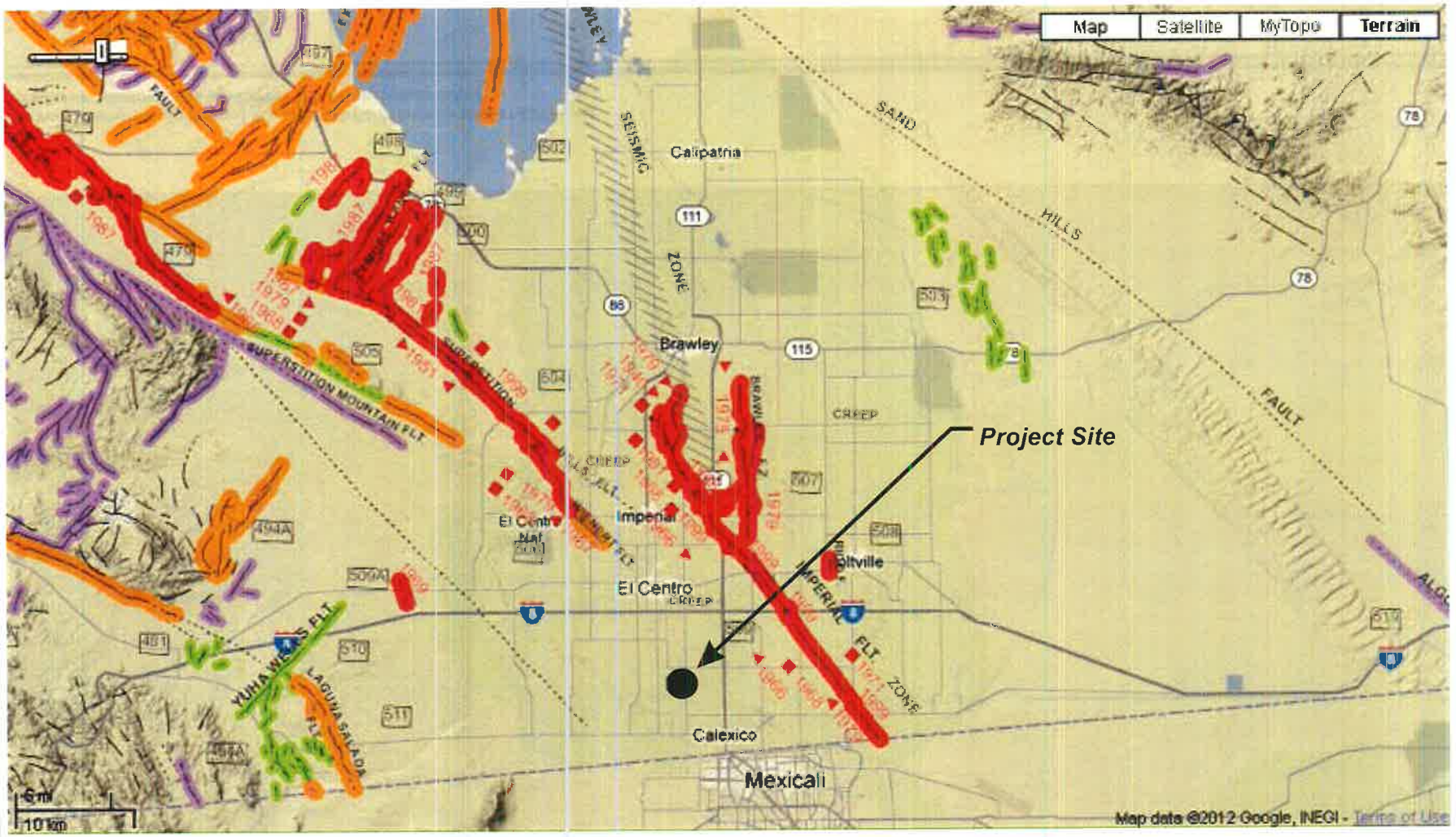

Source: California Geological Survey 2010 Fault Activity Map of California
http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html#

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Map of Local Faults

Figure 2

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APPENDIX A

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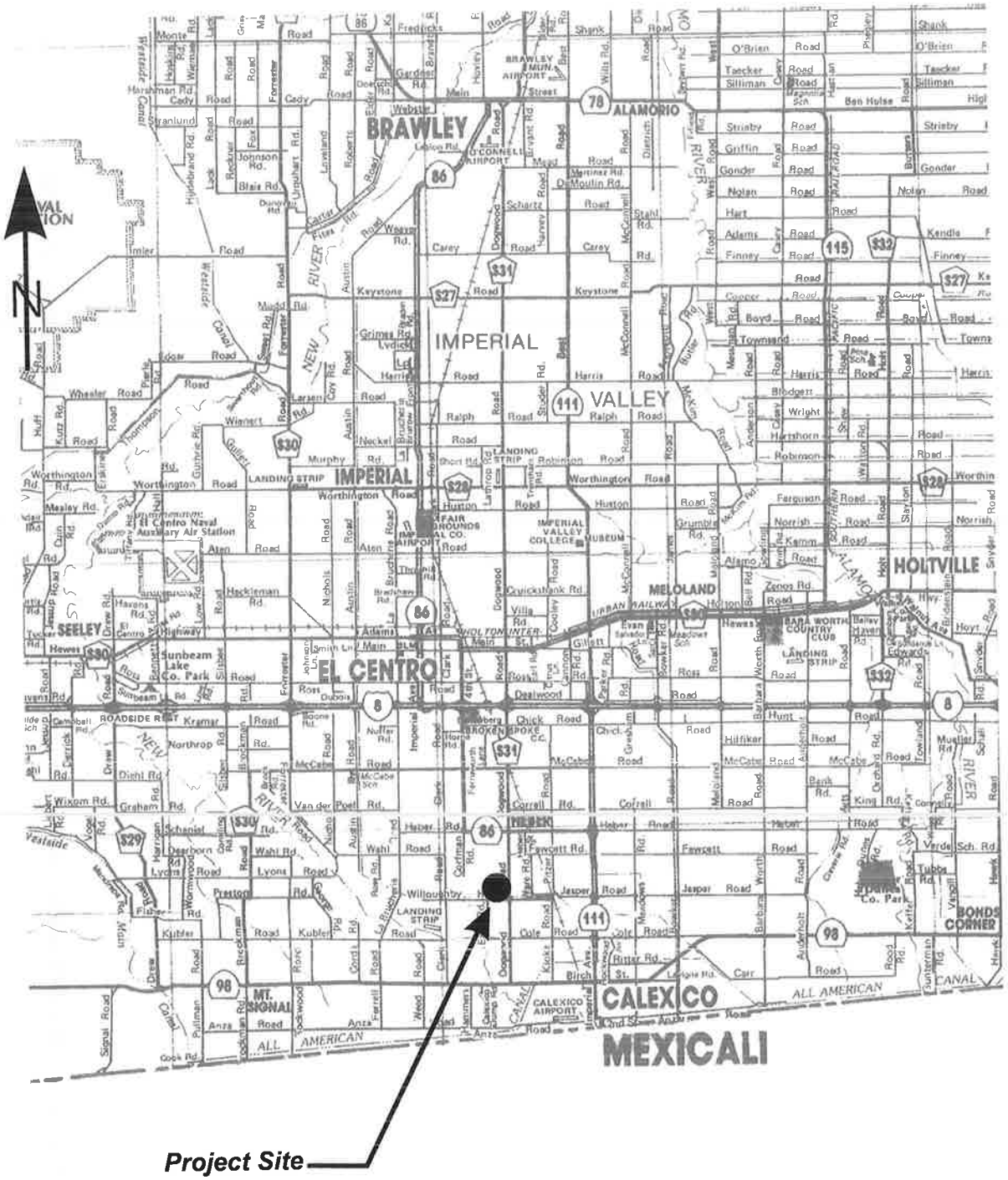

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Vicinity Map

Plate
A-1

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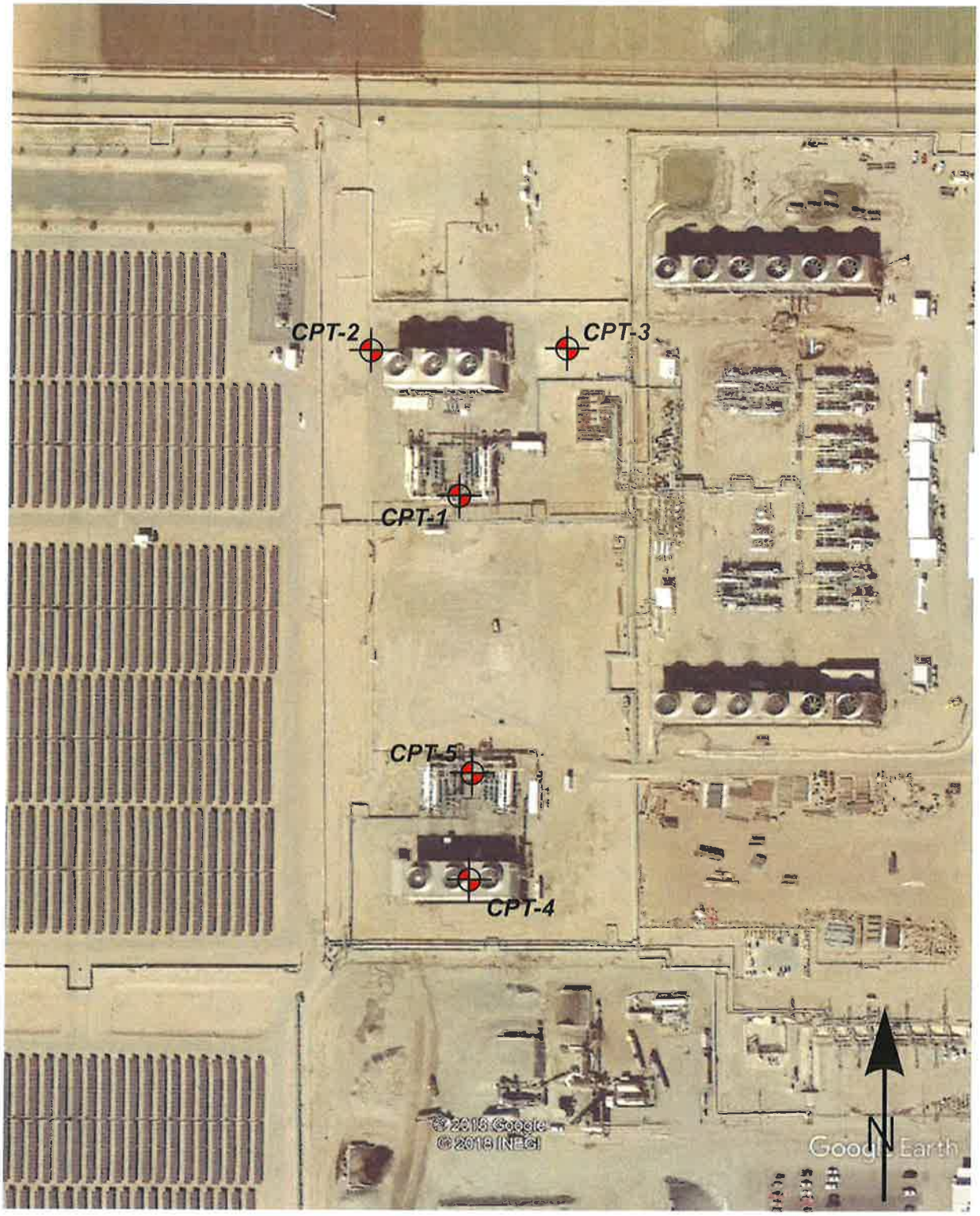

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Site and Exploration Map

Plate
A-2

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APPENDIX B

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CLIENT: Ormat Nevada Inc
PROJECT: Heber 2 Repower Project - Heber, CA

CONE PENETROMETER: Middle Earth Geotesting Truck Mounted Electric Cone with 23 ton reaction weight

LOCATION: See Site and Boring Location Plan

DATE: 12/20/2004

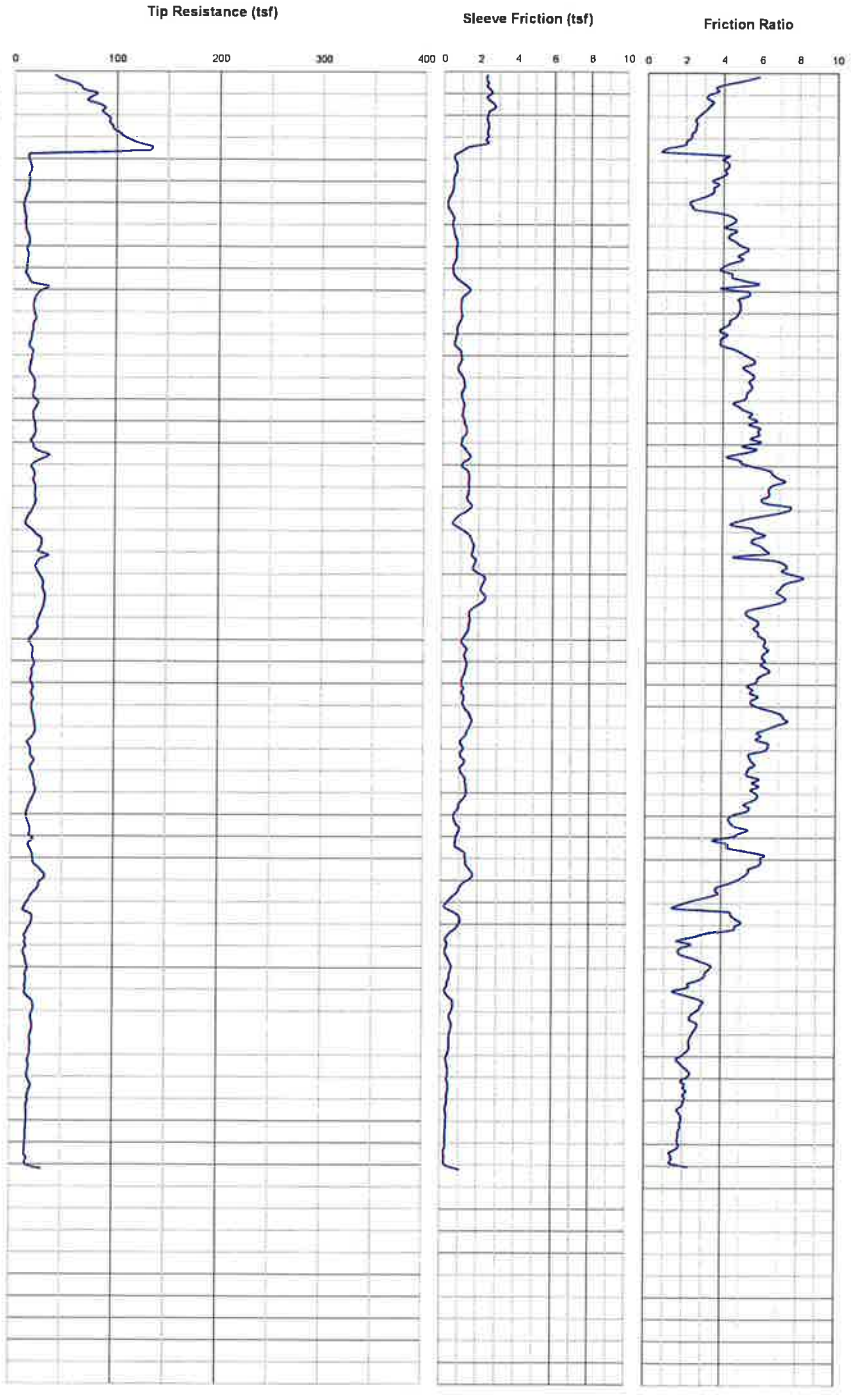
CONE SOUNDING DATA CPT-1

INTERPRETED SOIL PROFILE
From Robertson and Campanella (1989

GROUND ELEVATION +/-

DEPTH			
	Clayey Silt to Silty Clay	ML/CL	hard
	Sandy Silt to Clayey Silt	ML	very dense
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
5	Silty Clay to Clay	CL	stiff
	Silty Clay to Clay	" "	stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	stiff
10	Clay	" "	very stiff
	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
15	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
25	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
35	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Silty Clay to Clay	CL	stiff
40	Clayey Silt to Silty Clay	ML/CL	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
45	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Sandy Silt to Clayey Silt	ML	very loose
	Sandy Silt to Clayey Silt	" "	very loose
	Clayey Silt to Silty Clay	ML/CL	stiff
50	Sandy Silt to Clayey Silt	ML	very loose
55			

END OF SOUNDING AT 50 ft.



Project No.		PLATE
LE19075	LANDMARK Geo-Engineers and Geologists	B-1

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-1
Est. GWT (ft): 8
Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
0.15	0.5	47.46	5.04	Silty Clay to Clay	CL	hard	125	27		60			2.79	>10
0.30	1.0	71.19	3.50	Sandy Silt to Clayey Silt	ML	very dense	115	20	134.6	45	107	43		
0.45	1.5	76.38	3.27	Sandy Silt to Clayey Silt	ML	very dense	115	22	144.4	40	102	42		
0.60	2.0	88.21	2.88	Sandy Silt to Clayey Silt	ML	very dense	115	25	166.8	35	101	42		
0.75	2.5	94.19	2.53	Silty Sand to Sandy Silt	SM/ML	very dense	115	21	178.0	30	100	42		
0.93	3.0	101.94	2.35	Silty Sand to Sandy Silt	SM/ML	very dense	115	23	192.7	30	99	42		
1.08	3.5	123.24	1.66	Sand to Silty Sand	SP/SM	very dense	115	22	233.0	20	102	42		
1.23	4.0	53.93	2.99	Sandy Silt to Clayey Silt	ML	dense	115	15	101.9	45	76	39		
1.38	4.5	16.43	4.19	Clay	CL/CH	stiff	125	13		85			0.95	>10
1.53	5.0	15.53	3.80	Silty Clay to Clay	CL	stiff	125	9		85			0.90	>10
1.68	5.5	13.99	3.48	Silty Clay to Clay	CL	stiff	125	8		85			0.80	>10
1.83	6.0	10.16	2.42	Clayey Silt to Silty Clay	ML/CL	stiff	120	4		85			0.58	>10
1.98	6.5	10.41	3.55	Silty Clay to Clay	CL	stiff	125	6		95			0.59	>10
2.13	7.0	11.62	4.38	Clay	CL/CH	stiff	125	9		100			0.66	>10
2.28	7.5	13.29	4.44	Clay	CL/CH	stiff	125	11		95			0.76	>10
2.45	8.0	14.55	4.93	Clay	CL/CH	stiff	125	12		95			0.83	>10
2.60	8.5	13.90	4.96	Clay	CL/CH	stiff	125	11		95			0.79	>10
2.75	9.0	13.23	4.08	Clay	CL/CH	stiff	125	11		95			0.75	>10
2.90	9.5	13.66	4.68	Clay	CL/CH	stiff	125	11		100			0.77	>10
3.05	10.0	26.88	5.00	Clay	CL/CH	very stiff	125	22		80			1.55	>10
3.20	10.5	21.69	5.01	Clay	CL/CH	very stiff	125	17		85			1.24	>10
3.35	11.0	19.84	4.85	Clay	CL/CH	very stiff	125	16		90			1.13	>10
3.50	11.5	21.31	4.45	Silty Clay to Clay	CL	very stiff	125	12		85			1.22	>10
3.65	12.0	18.97	4.00	Silty Clay to Clay	CL	very stiff	125	11		85			1.08	>10
3.80	12.5	16.82	3.88	Silty Clay to Clay	CL	stiff	125	10		90			0.95	>10
3.95	13.0	18.18	4.91	Clay	CL/CH	very stiff	125	15		95			1.03	>10
4.13	13.5	17.33	5.43	Clay	CL/CH	stiff	125	14		100			0.98	>10
4.28	14.0	17.04	5.46	Clay	CL/CH	stiff	125	14		100			0.96	>10
4.43	14.5	21.21	5.45	Clay	CL/CH	very stiff	125	17		100			1.21	>10
4.58	15.0	19.96	5.21	Clay	CL/CH	very stiff	125	16		100			1.13	>10
4.73	15.5	23.41	4.80	Clay	CL/CH	very stiff	125	19		90			1.34	>10
4.88	16.0	20.50	5.51	Clay	CL/CH	very stiff	125	16		100			1.16	>10
5.03	16.5	21.94	5.88	Clay	CL/CH	very stiff	125	18		100			1.25	>10
5.18	17.0	19.22	5.48	Clay	CL/CH	very stiff	125	15		100			1.09	>10
5.33	17.5	27.57	5.03	Clay	CL/CH	very stiff	125	22		90			1.58	>10
5.48	18.0	23.29	5.22	Clay	CL/CH	very stiff	125	19		100			1.32	>10
5.65	18.5	20.85	6.67	Clay	CL/CH	very stiff	125	17		100			1.18	>10
5.80	19.0	21.33	6.77	Clay	CL/CH	very stiff	125	17		100			1.21	>10
5.95	19.5	21.97	6.29	Clay	CL/CH	very stiff	125	18		100			1.24	>10
6.10	20.0	21.34	7.09	Clay	CL/CH	very stiff	125	17		100			1.21	>10
6.25	20.5	15.48	5.72	Clay	CL/CH	stiff	125	12		100			0.86	6.21
6.40	21.0	15.87	5.20	Clay	CL/CH	stiff	125	13		100			0.88	6.32
6.55	21.5	26.53	5.79	Clay	CL/CH	very stiff	125	21		100			1.51	>10
6.70	22.0	27.19	6.21	Clay	CL/CH	very stiff	125	22		100			1.55	>10
6.85	22.5	29.12	6.18	Clay	CL/CH	very stiff	125	23		100			1.66	>10
7.00	23.0	24.40	7.41	Clay	CL/CH	very stiff	125	20		100			1.38	>10
7.18	23.5	29.74	7.65	Clay	CL/CH	very stiff	125	24		100			1.69	>10
7.33	24.0	31.24	7.01	Clay	CL/CH	very stiff	125	25		100			1.78	>10
7.48	24.5	31.71	6.74	Clay	CL/CH	very stiff	125	25		100			1.81	>10
7.63	25.0	28.38	5.36	Clay	CL/CH	very stiff	125	23		100			1.61	>10
7.78	25.5	25.50	5.79	Clay	CL/CH	very stiff	125	20		100			1.44	>10
7.93	26.0	21.23	6.01	Clay	CL/CH	very stiff	125	17		100			1.19	7.85
8.08	26.5	19.41	6.26	Clay	CL/CH	very stiff	125	16		100			1.08	6.54
8.23	27.0	21.10	6.12	Clay	CL/CH	very stiff	125	17		100			1.18	7.27
8.38	27.5	20.13	6.30	Clay	CL/CH	very stiff	125	16		100			1.12	6.54
8.53	28.0	19.23	5.66	Clay	CL/CH	very stiff	125	15		100			1.07	6.00
8.68	28.5	20.08	5.65	Clay	CL/CH	very stiff	125	16		100			1.12	6.32
8.85	29.0	20.55	5.67	Clay	CL/CH	very stiff	125	16		100			1.14	6.32
9.00	29.5	20.76	7.00	Clay	CL/CH	very stiff	125	17		100			1.15	6.32
9.15	30.0	22.80	6.88	Clay	CL/CH	very stiff	125	18		100			1.27	7.27
9.30	30.5	21.60	5.89	Clay	CL/CH	very stiff	125	17		100			1.20	6.43
9.45	31.0	17.19	6.36	Clay	CL/CH	stiff	125	14		100			0.94	4.37
9.60	31.5	20.05	5.47	Clay	CL/CH	very stiff	125	16		100			1.11	5.53
9.75	32.0	19.47	5.50	Clay	CL/CH	very stiff	125	16		100			1.07	5.10
9.90	32.5	21.74	5.63	Clay	CL/CH	very stiff	125	17		100			1.21	6.00
10.05	33.0	23.37	5.76	Clay	CL/CH	very stiff	125	19		100			1.30	6.65
10.20	33.5	20.39	5.56	Clay	CL/CH	very stiff	125	16		100			1.13	5.21
10.38	34.0	15.97	5.12	Clay	CL/CH	stiff	125	13		100			0.86	3.50
10.53	34.5	16.45	4.48	Clay	CL/CH	stiff	125	13		100			0.89	3.58
10.68	35.0	18.50	4.96	Clay	CL/CH	very stiff	125	15		100			1.01	4.18
10.83	35.5	19.11	4.05	Silty Clay to Clay	CL	very stiff	125	11		100			1.05	5.53
10.98	36.0	20.64	5.86	Clay	CL/CH	very stiff	125	17		100			1.13	4.78
11.13	36.5	25.44	5.72	Clay	CL/CH	very stiff	125	20		100			1.42	6.65
11.28	37.0	31.72	4.84	Silty Clay to Clay	CL	very stiff	125	18		100			1.79	>10
11.43	37.5	25.49	3.77	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.42	>10
11.58	38.0	17.68	2.48	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.96	6.10
11.73	38.5	15.25	3.47	Silty Clay to Clay	CL	stiff	125	9		100			0.81	3.50

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-1

Est. GWT (ft): 8

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
11.88	39.0	20.64	4.84	Clay	CL/CH	very stiff	125	17		100			1.13	4.28
12.05	39.5	15.50	3.51	Silty Clay to Clay	CL	stiff	125	9		100			0.83	3.50
12.20	40.0	14.77	2.00	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.78	4.18
12.35	40.5	13.50	2.07	Clayey Silt to Silty Clay	ML/CL	stiff	120	5		100			0.71	3.58
12.50	41.0	15.96	3.29	Silty Clay to Clay	CL	stiff	125	9		100			0.85	3.50
12.65	41.5	15.32	3.05	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.81	4.28
12.80	42.0	14.74	2.01	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.78	3.91
12.95	42.5	17.48	2.54	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.94	5.10
13.10	43.0	22.47	2.80	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.23	7.70
13.25	43.5	20.78	2.49	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.13	6.65
13.40	44.0	21.29	2.62	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.16	6.76
13.58	44.5	19.71	2.35	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.07	5.88
13.73	45.0	19.60	2.17	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.06	5.76
13.88	45.5	18.05	1.84	Sandy Silt to Clayey Silt	ML	very loose	115	5	13.8	100	14	30		
14.03	46.0	17.42	2.29	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.93	4.57
14.18	46.5	19.49	2.03	Sandy Silt to Clayey Silt	ML	very loose	115	6	14.7	100	16	30		
14.33	47.0	17.99	2.10	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.96	4.68
14.48	47.5	16.62	1.85	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.88	4.09
14.63	48.0	16.66	1.91	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.88	4.00
14.78	48.5	15.96	1.83	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.84	3.74
14.93	49.0	15.56	1.78	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.81	3.58
15.10	49.5	14.89	1.48	Sandy Silt to Clayey Silt	ML	very loose	115	4	11.0	100	7	29		
15.25	50.0	16.44	1.69	Sandy Silt to Clayey Silt	ML	very loose	115	5	12.1	100	10	29		

EEC ORIGINAL PKG

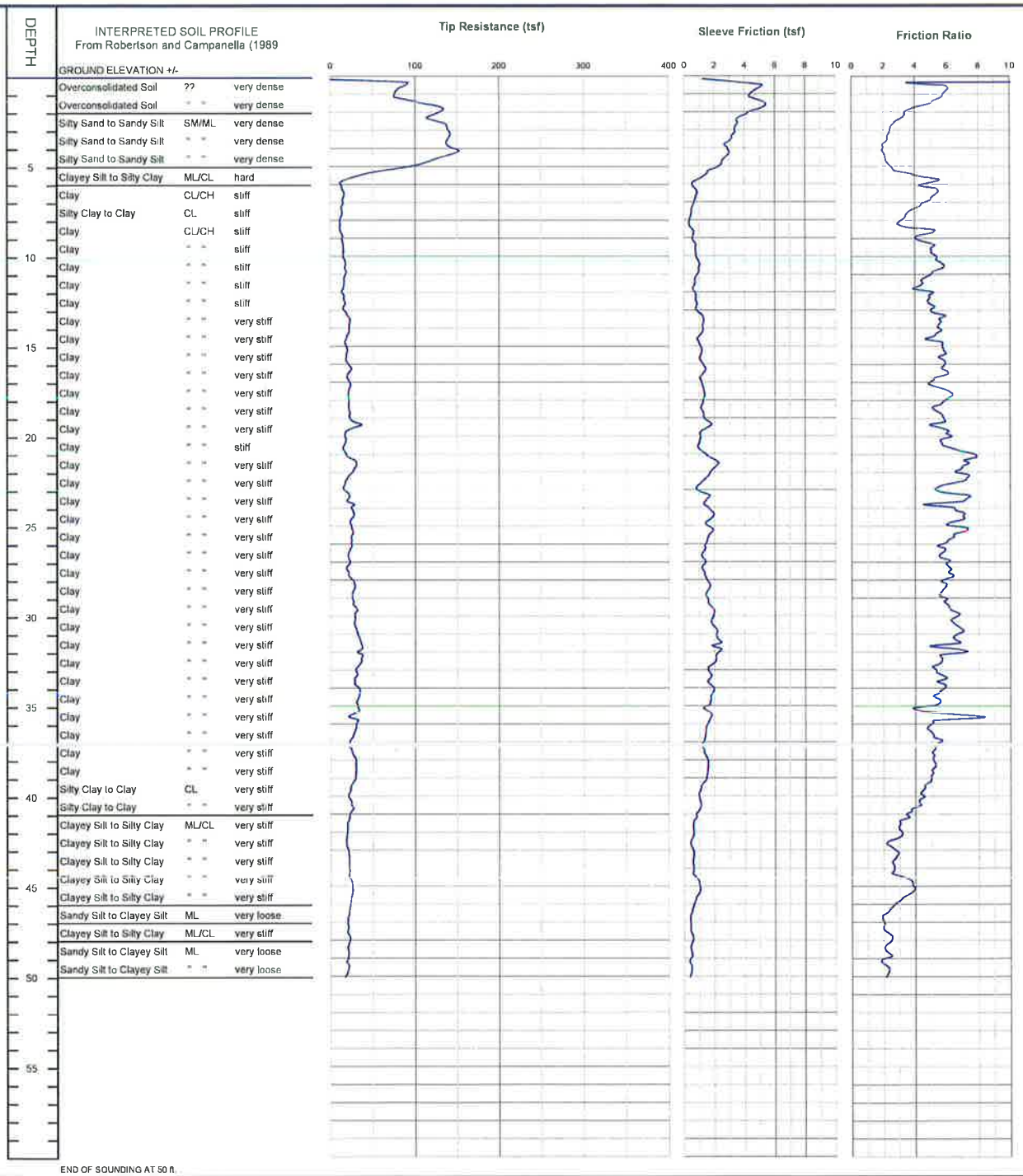
CLIENT: Ormat Nevada Inc
PROJECT: Heber 2 Repower Project - Heber, CA

CONE PENETROMETER: Middle Earth Geotesting Truck Mounted Electric Cone with 23 ton reaction weight

LOCATION: See Site and Boring Location Plan

DATE: 12/20/2004

CONE SOUNDING DATA CPT-2



Project No.		PLATE
LE19075	LANDMARK Geo-Engineers and Geologists	B-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-2
Est. GWT (ft): 8

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
0.15	0.5	60.03	169.32	Overconsolidated Soil	??	very dense	120	60	113.5	100	119	45		
0.30	1.0	77.82	5.97	Overconsolidated Soil	??	very dense	120	78	147.1	55	110	43		
0.45	1.5	91.98	5.31	Overconsolidated Soil	??	very dense	120	92	173.9	50	107	43		
0.60	2.0	129.94	3.78	Sandy Silt to Clayey Silt	ML	very dense	115	37	245.6	35	113	44		
0.75	2.5	119.62	3.11	Sandy Silt to Clayey Silt	ML	very dense	115	34	226.1	30	107	43		
0.93	3.0	137.68	2.51	Silty Sand to Sandy Silt	SM/ML	very dense	115	31	260.3	25	108	43		
1.08	3.5	140.87	2.30	Silty Sand to Sandy Silt	SM/ML	very dense	115	31	266.3	25	106	43		
1.23	4.0	139.35	2.04	Silty Sand to Sandy Silt	SM/ML	very dense	115	31	263.4	20	104	43		
1.38	4.5	144.85	2.01	Silty Sand to Sandy Silt	SM/ML	very dense	115	32	273.8	20	103	42		
1.53	5.0	113.08	2.24	Silty Sand to Sandy Silt	SM/ML	very dense	115	25	208.9	25	94	41		
1.68	5.5	52.70	3.38	Clayey Silt to Silty Clay	ML/CL	hard	120	21		50			3.08	>10
1.83	6.0	13.87	4.91	Clay	CL/CH	stiff	125	11		95			0.80	>10
1.98	6.5	15.08	5.36	Clay	CL/CH	stiff	125	12		95			0.87	>10
2.13	7.0	14.77	4.81	Clay	CL/CH	stiff	125	12		95			0.85	>10
2.28	7.5	13.38	3.90	Clay	CL/CH	stiff	125	11		90			0.76	>10
2.45	8.0	12.25	3.27	Silty Clay to Clay	CL	stiff	125	7		90			0.69	>10
2.60	8.5	11.34	3.86	Clay	CL/CH	stiff	125	9		95			0.64	>10
2.75	9.0	13.62	4.43	Clay	CL/CH	stiff	125	11		95			0.77	>10
2.90	9.5	14.76	4.97	Clay	CL/CH	stiff	125	12		95			0.84	>10
3.05	10.0	15.04	5.19	Clay	CL/CH	stiff	125	12		100			0.85	>10
3.20	10.5	17.24	5.61	Clay	CL/CH	stiff	125	14		100			0.98	>10
3.35	11.0	17.82	5.31	Clay	CL/CH	very stiff	125	14		95			1.02	>10
3.50	11.5	16.22	4.53	Clay	CL/CH	stiff	125	13		95			0.92	>10
3.65	12.0	14.59	4.45	Clay	CL/CH	stiff	125	12		100			0.82	>10
3.80	12.5	15.95	4.89	Clay	CL/CH	stiff	125	13		100			0.90	>10
3.95	13.0	16.10	5.07	Clay	CL/CH	stiff	125	13		100			0.91	>10
4.13	13.5	20.52	5.55	Clay	CL/CH	very stiff	125	16		95			1.17	>10
4.28	14.0	22.48	5.55	Clay	CL/CH	very stiff	125	18		95			1.28	>10
4.43	14.5	20.89	5.42	Clay	CL/CH	very stiff	125	17		100			1.19	>10
4.58	15.0	17.79	5.37	Clay	CL/CH	very stiff	125	14		100			1.01	>10
4.73	15.5	19.47	5.86	Clay	CL/CH	very stiff	125	16		100			1.10	>10
4.88	16.0	19.76	5.77	Clay	CL/CH	very stiff	125	16		100			1.12	>10
5.03	16.5	22.53	5.91	Clay	CL/CH	very stiff	125	18		100			1.28	>10
5.18	17.0	21.67	5.09	Clay	CL/CH	very stiff	125	17		100			1.23	>10
5.33	17.5	22.15	5.77	Clay	CL/CH	very stiff	125	18		100			1.26	>10
5.48	18.0	21.43	6.10	Clay	CL/CH	very stiff	125	17		100			1.21	>10
5.65	18.5	21.56	5.34	Clay	CL/CH	very stiff	125	17		100			1.22	>10
5.80	19.0	22.73	5.72	Clay	CL/CH	very stiff	125	18		100			1.29	>10
5.95	19.5	30.63	5.48	Clay	CL/CH	very stiff	125	25		90			1.75	>10
6.10	20.0	17.95	6.14	Clay	CL/CH	very stiff	125	14		100			1.01	8.41
6.25	20.5	17.30	5.70	Clay	CL/CH	stiff	125	14		100			0.97	7.56
6.40	21.0	16.60	6.99	Clay	CL/CH	stiff	125	13		100			0.93	6.76
6.55	21.5	26.75	7.44	Clay	CL/CH	very stiff	125	21		100			1.52	>10
6.70	22.0	28.17	6.81	Clay	CL/CH	very stiff	125	23		100			1.60	>10
6.85	22.5	20.17	7.24	Clay	CL/CH	very stiff	125	16		100			1.13	8.85
7.00	23.0	16.15	5.62	Clay	CL/CH	stiff	125	13		100			0.90	5.88
7.18	23.5	21.37	6.84	Clay	CL/CH	very stiff	125	17		100			1.20	9.19
7.33	24.0	24.23	5.98	Clay	CL/CH	very stiff	125	19		100			1.37	>10
7.48	24.5	27.09	6.88	Clay	CL/CH	very stiff	125	22		100			1.54	>10
7.63	25.0	23.97	6.46	Clay	CL/CH	very stiff	125	19		100			1.35	>10
7.78	25.5	25.90	6.98	Clay	CL/CH	very stiff	125	21		100			1.46	>10
7.93	26.0	24.80	6.17	Clay	CL/CH	very stiff	125	20		100			1.40	>10
8.08	26.5	22.94	5.66	Clay	CL/CH	very stiff	125	18		100			1.29	8.85
8.23	27.0	22.28	5.92	Clay	CL/CH	very stiff	125	18		100			1.25	8.14
8.38	27.5	20.15	6.14	Clay	CL/CH	very stiff	125	16		100			1.12	6.65
8.53	28.0	24.13	6.05	Clay	CL/CH	very stiff	125	19		100			1.36	9.00
8.68	28.5	28.28	5.86	Clay	CL/CH	very stiff	125	23		100			1.60	>10
8.85	29.0	26.02	5.73	Clay	CL/CH	very stiff	125	21		100			1.46	>10
9.00	29.5	28.06	6.01	Clay	CL/CH	very stiff	125	22		100			1.58	>10
9.15	30.0	29.72	6.57	Clay	CL/CH	very stiff	125	24		100			1.68	>10
9.30	30.5	28.55	6.41	Clay	CL/CH	very stiff	125	23		100			1.61	>10
9.45	31.0	31.07	6.84	Clay	CL/CH	very stiff	125	25		100			1.76	>10
9.60	31.5	34.71	6.59	Clay	CL/CH	very stiff	125	28		100			1.97	>10
9.75	32.0	35.27	6.25	Clay	CL/CH	hard	125	28		100			2.00	>10
9.90	32.5	37.01	5.65	Clay	CL/CH	hard	125	30		100			2.10	>10
10.05	33.0	32.37	5.31	Clay	CL/CH	very stiff	125	26		100			1.83	>10
10.20	33.5	30.28	5.70	Clay	CL/CH	very stiff	125	24		100			1.71	>10
10.38	34.0	29.97	5.71	Clay	CL/CH	very stiff	125	24		100			1.69	>10
10.53	34.5	34.16	5.42	Clay	CL/CH	very stiff	125	27		100			1.93	>10
10.68	35.0	31.53	5.44	Clay	CL/CH	very stiff	125	25		100			1.78	>10
10.83	35.5	31.18	4.96	Clay	CL/CH	very stiff	125	25		100			1.76	>10
10.98	36.0	28.08	6.21	Clay	CL/CH	very stiff	125	22		100			1.57	8.14
11.13	36.5	28.95	4.94	Clay	CL/CH	very stiff	125	23		100			1.62	8.41
11.28	37.0	23.74	5.43	Clay	CL/CH	very stiff	125	19		100			1.32	5.88
11.43	37.5	24.03	5.19	Clay	CL/CH	very stiff	125	19		100			1.33	5.88
11.58	38.0	28.73	5.16	Clay	CL/CH	very stiff	125	23		100			1.61	7.70
11.73	38.5	29.89	5.19	Clay	CL/CH	very stiff	125	24		100			1.68	8.14

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-2

Est. GWT (ft): 8

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
11.88	39.0	29.55	5.05	Clay	CL/CH	very stiff	125	24		100			1.65	7.85
12.05	39.5	25.32	4.72	Clay	CL/CH	very stiff	125	20		100			1.40	5.88
12.20	40.0	22.19	4.46	Clay	CL/CH	very stiff	125	18		100			1.22	4.68
12.35	40.5	24.43	4.30	Silty Clay to Clay	CL	very stiff	125	14		100			1.35	7.00
12.50	41.0	24.85	3.66	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.37	>10
12.65	41.5	21.29	3.25	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.16	7.41
12.80	42.0	19.81	3.04	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.08	6.43
12.95	42.5	18.87	2.79	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.02	5.88
13.10	43.0	19.60	2.48	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.06	6.10
13.25	43.5	21.70	2.84	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.18	7.13
13.40	44.0	22.24	2.62	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.22	7.27
13.58	44.5	22.52	2.78	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.23	7.41
13.73	45.0	25.15	3.77	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.38	8.85
13.88	45.5	26.20	3.80	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.45	9.59
14.03	46.0	24.44	3.02	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.34	8.14
14.18	46.5	22.65	2.43	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.24	7.00
14.33	47.0	20.81	1.98	Sandy Silt to Clayey Silt	ML	very loose	115	6	15.7	100	18	30		
14.48	47.5	20.51	2.12	Sandy Silt to Clayey Silt	ML	very loose	115	6	15.4	100	17	30		
14.63	48.0	22.61	2.50	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.23	6.65
14.78	48.5	20.83	2.13	Sandy Silt to Clayey Silt	ML	very loose	115	6	15.5	100	17	30		
14.93	49.0	20.93	2.27	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.13	5.76
15.10	49.5	20.67	2.11	Sandy Silt to Clayey Silt	ML	very loose	115	6	15.3	100	17	30		
15.25	50.0	19.06	2.25	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.02	4.78

EEC ORIGINAL PKG

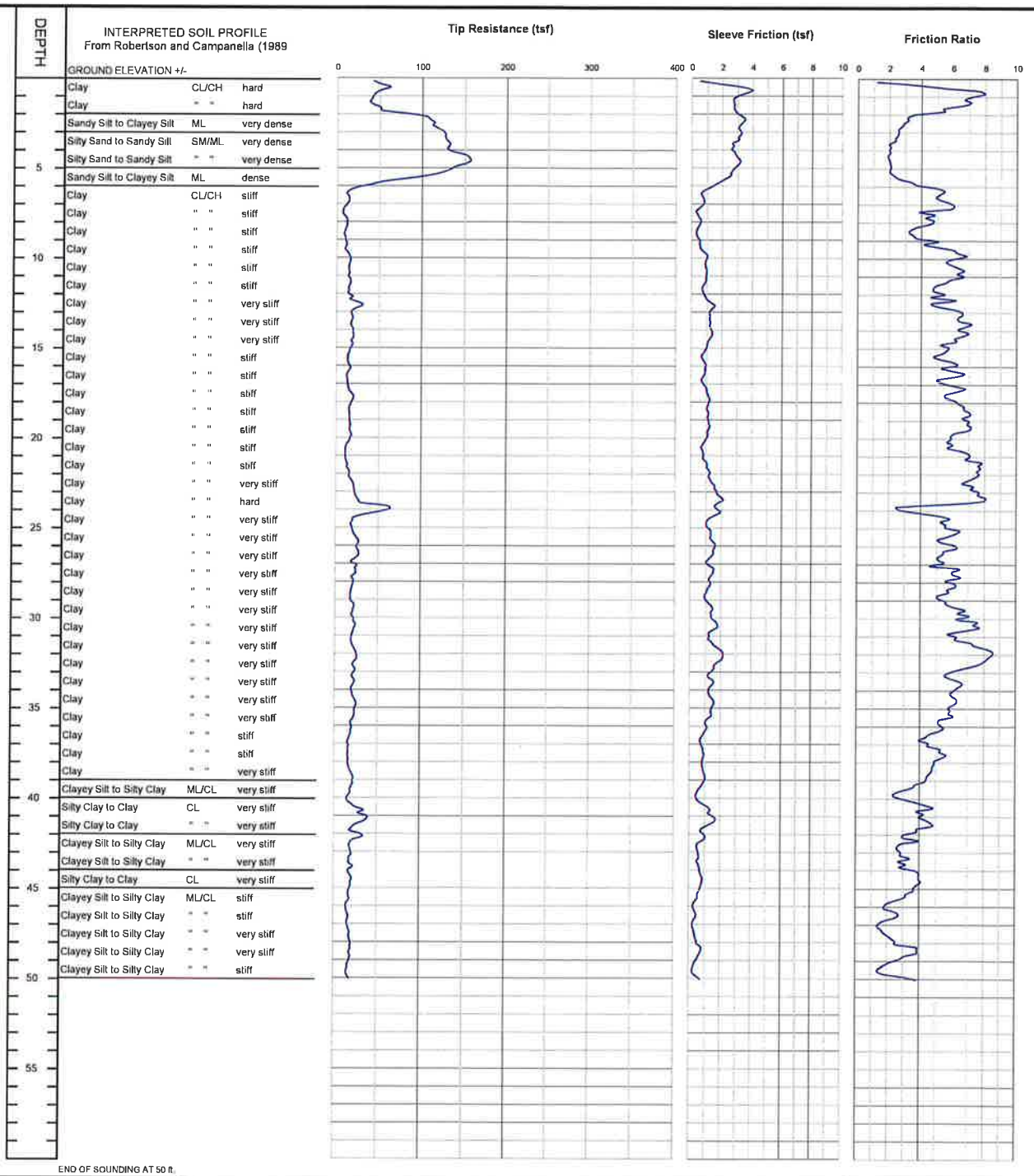
CLIENT: Ormat Nevada Inc
PROJECT: Heber 2 Repower Project - Heber, CA

CONE PENETROMETER: Middle Earth Geotesting Truck Mounted Electric Cone with 23 ton reaction weight

LOCATION: See Site and Boring Location Plan

DATE: 12/20/2004

CONE SOUNDING DATA CPT-3



Project No.		PLATE
LE19075	LANDMARK Geo-Engineers and Geologists	B-3

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-3 Est. GWT (ft): 8 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
0.15	0.5	51.76	3.36	Clayey Silt to Silty Clay	ML/CL	hard	120	21		50			3.04	>10
0.30	1.0	46.42	7.56	Clay	CL/CH	hard	125	37		75			2.73	>10
0.45	1.5	40.35	6.79	Clay	CL/CH	hard	125	32		75			2.37	>10
0.60	2.0	61.72	4.80	Silty Clay to Clay	CL	hard	125	35		55			3.62	>10
0.75	2.5	109.67	3.07	Sandy Silt to Clayey Silt	ML	very dense	115	31	207.3	35	104	43		
0.93	3.0	118.60	2.64	Silty Sand to Sandy Silt	SM/ML	very dense	115	26	224.2	30	103	42		
1.08	3.5	127.70	2.43	Silty Sand to Sandy Silt	SM/ML	very dense	115	28	241.4	25	103	42		
1.23	4.0	131.15	2.02	Silty Sand to Sandy Silt	SM/ML	very dense	115	29	247.9	25	102	42		
1.38	4.5	147.55	1.96	Silty Sand to Sandy Silt	SM/ML	very dense	115	33	278.9	20	103	42		
1.53	5.0	148.38	2.05	Silty Sand to Sandy Silt	SM/ML	very dense	115	33	271.7	20	102	42		
1.68	5.5	111.44	2.28	Silty Sand to Sandy Silt	SM/ML	very dense	115	25	194.4	25	92	41		
1.83	6.0	40.17	4.02	Clayey Silt to Silty Clay	ML/CL	hard	120	16		60			2.34	>10
1.98	6.5	13.36	5.18	Clay	CL/CH	stiff	125	11		100			0.76	>10
2.13	7.0	13.22	5.65	Clay	CL/CH	stiff	125	11		100			0.75	>10
2.28	7.5	7.68	4.85	Clay	CL/CH	firm	125	6		100			0.43	6.10
2.45	8.0	11.50	4.55	Clay	CL/CH	stiff	125	9		100			0.65	>10
2.60	8.5	10.61	3.49	Silty Clay to Clay	CL	stiff	125	6		95			0.60	>10
2.75	9.0	9.81	4.10	Clay	CL/CH	stiff	125	8		100			0.55	7.27
2.90	9.5	10.85	5.09	Clay	CL/CH	stiff	125	9		100			0.61	8.27
3.05	10.0	14.61	6.36	Clay	CL/CH	stiff	125	12		100			0.83	>10
3.20	10.5	14.97	5.91	Clay	CL/CH	stiff	125	12		100			0.85	>10
3.35	11.0	14.49	6.53	Clay	CL/CH	stiff	125	12		100			0.82	>10
3.50	11.5	15.94	5.42	Clay	CL/CH	stiff	125	13		100			0.90	>10
3.65	12.0	14.15	5.01	Clay	CL/CH	stiff	125	11		100			0.80	>10
3.80	12.5	20.31	5.15	Clay	CL/CH	very stiff	125	16		95			1.16	>10
3.95	13.0	23.81	5.79	Clay	CL/CH	very stiff	125	19		95			1.36	>10
4.13	13.5	18.35	6.42	Clay	CL/CH	very stiff	125	15		100			1.04	>10
4.28	14.0	18.13	6.73	Clay	CL/CH	very stiff	125	15		100			1.03	>10
4.43	14.5	19.70	6.56	Clay	CL/CH	very stiff	125	16		100			1.12	>10
4.58	15.0	18.07	5.71	Clay	CL/CH	very stiff	125	14		100			1.02	>10
4.73	15.5	14.86	5.24	Clay	CL/CH	stiff	125	12		100			0.83	8.27
4.88	16.0	14.60	5.69	Clay	CL/CH	stiff	125	12		100			0.82	7.70
5.03	16.5	13.49	6.25	Clay	CL/CH	stiff	125	11		100			0.75	6.43
5.18	17.0	13.31	5.44	Clay	CL/CH	stiff	125	11		100			0.74	6.10
5.33	17.5	16.20	6.21	Clay	CL/CH	stiff	125	13		100			0.91	8.27
5.48	18.0	19.16	5.98	Clay	CL/CH	very stiff	125	15		100			1.08	>10
5.65	18.5	15.49	6.80	Clay	CL/CH	stiff	125	12		100			0.86	7.13
5.80	19.0	15.81	6.89	Clay	CL/CH	stiff	125	13		100			0.88	7.13
5.95	19.5	16.32	7.00	Clay	CL/CH	stiff	125	13		100			0.91	7.27
6.10	20.0	17.26	5.95	Clay	CL/CH	stiff	125	14		100			0.97	7.85
6.25	20.5	13.28	5.76	Clay	CL/CH	stiff	125	11		100			0.73	4.89
6.40	21.0	11.14	6.84	Clay	CL/CH	stiff	125	9		100			0.60	3.58
6.55	21.5	12.48	7.40	Clay	CL/CH	stiff	125	10		100			0.68	4.18
6.70	22.0	14.92	7.62	Clay	CL/CH	stiff	125	12		100			0.82	5.42
6.85	22.5	17.77	6.98	Clay	CL/CH	stiff	125	14		100			0.99	7.00
7.00	23.0	21.45	7.34	Clay	CL/CH	very stiff	125	17		100			1.21	9.59
7.18	23.5	24.58	7.84	Clay	CL/CH	very stiff	125	20		100			1.39	>10
7.33	24.0	51.65	3.68	Clayey Silt to Silty Clay	ML/CL	hard	120	21		70			2.98	>10
7.48	24.5	34.37	4.91	Clay	CL/CH	very stiff	125	27		90			1.96	>10
7.63	25.0	18.84	5.44	Clay	CL/CH	very stiff	125	15		100			1.05	6.76
7.78	25.5	21.09	6.11	Clay	CL/CH	very stiff	125	17		100			1.18	8.00
7.93	26.0	26.12	5.49	Clay	CL/CH	very stiff	125	21		100			1.48	>10
8.08	26.5	26.28	5.55	Clay	CL/CH	very stiff	125	21		100			1.48	>10
8.23	27.0	21.92	5.06	Clay	CL/CH	very stiff	125	18		100			1.23	7.85
8.38	27.5	23.63	6.15	Clay	CL/CH	very stiff	125	19		100			1.33	8.85
8.53	28.0	20.49	6.07	Clay	CL/CH	very stiff	125	16		100			1.14	6.65
8.68	28.5	19.11	5.87	Clay	CL/CH	very stiff	125	15		100			1.06	5.88
8.85	29.0	18.15	5.24	Clay	CL/CH	very stiff	125	15		100			1.00	5.21
9.00	29.5	21.72	6.18	Clay	CL/CH	very stiff	125	17		100			1.21	6.88
9.15	30.0	20.63	6.55	Clay	CL/CH	very stiff	125	17		100			1.15	6.21
9.30	30.5	22.90	7.51	Clay	CL/CH	very stiff	125	18		100			1.28	7.13
9.45	31.0	20.57	6.23	Clay	CL/CH	very stiff	125	16		100			1.14	5.88
9.60	31.5	19.55	6.90	Clay	CL/CH	very stiff	125	16		100			1.08	5.31
9.75	32.0	23.76	8.37	Clay	CL/CH	very stiff	125	19		100			1.33	7.13
9.90	32.5	24.30	8.05	Clay	CL/CH	very stiff	125	19		100			1.36	7.27
10.05	33.0	22.78	6.54	Clay	CL/CH	very stiff	125	18		100			1.27	6.32
10.20	33.5	21.56	5.91	Clay	CL/CH	very stiff	125	17		100			1.19	5.76
10.38	34.0	20.82	6.40	Clay	CL/CH	very stiff	125	17		100			1.15	5.31
10.53	34.5	21.17	6.04	Clay	CL/CH	very stiff	125	17		100			1.17	5.31
10.68	35.0	24.71	6.05	Clay	CL/CH	very stiff	125	20		100			1.38	6.65
10.83	35.5	23.14	5.91	Clay	CL/CH	very stiff	125	19		100			1.28	5.88
10.98	36.0	19.96	5.21	Clay	CL/CH	very stiff	125	16		100			1.10	4.57
11.13	36.5	19.03	4.88	Clay	CL/CH	very stiff	125	15		100			1.04	4.18
11.28	37.0	16.19	4.33	Clay	CL/CH	stiff	125	13		100			0.87	3.28
11.43	37.5	16.02	5.36	Clay	CL/CH	stiff	125	13		100			0.86	3.14
11.58	38.0	16.15	5.06	Clay	CL/CH	stiff	125	13		100			0.87	3.14
11.73	38.5	17.81	4.75	Clay	CL/CH	stiff	125	14		100			0.96	3.50

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.
CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 12/20/2004

CONE SOUNDING: CPT-3
Est. GWT (ft): 8
Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
11.88	39.0	21.66	4.41	Silty Clay to Clay	CL	very stiff	125	12		100			1.19	6.00
12.05	39.5	20.18	3.42	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.10	7.13
12.20	40.0	17.00	2.62	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.91	5.31
12.35	40.5	20.64	4.32	Silty Clay to Clay	CL	very stiff	125	12		100			1.13	5.31
12.50	41.0	33.91	4.01	Clayey Silt to Silty Clay	ML/CL	very stiff	120	14		100			1.91	>10
12.65	41.5	31.64	4.64	Silty Clay to Clay	CL	very stiff	125	18		100			1.77	>10
12.80	42.0	23.58	3.56	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.30	8.70
12.95	42.5	24.97	3.28	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.38	9.79
13.10	43.0	19.07	2.71	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.03	5.88
13.25	43.5	18.86	2.98	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.02	5.65
13.40	44.0	19.54	3.20	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.06	5.88
13.58	44.5	19.29	3.97	Silty Clay to Clay	CL	very stiff	125	11		100			1.04	4.18
13.73	45.0	19.79	3.86	Silty Clay to Clay	CL	very stiff	125	11		100			1.07	4.28
13.88	45.5	17.66	3.31	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.94	4.76
14.03	46.0	16.42	2.18	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.87	4.18
14.18	46.5	15.61	2.35	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.82	3.74
14.33	47.0	16.68	1.80	Sandy Silt to Clayey Silt	ML	very loose	115	5	12.5	100	11	30		
14.48	47.5	18.25	1.80	Sandy Silt to Clayey Silt	ML	very loose	115	5	13.7	100	14	30		
14.63	48.0	19.39	2.43	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.04	5.21
14.78	48.5	19.39	3.87	Silty Clay to Clay	CL	very stiff	125	11		100			1.04	3.83
14.93	49.0	19.13	2.69	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.02	4.89
15.10	49.5	16.46	1.59	Sandy Silt to Clayey Silt	ML	very loose	115	5	12.1	100	10	29		
15.25	50.0	16.91	2.83	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.89	3.91

EEC ORIGINAL PKG

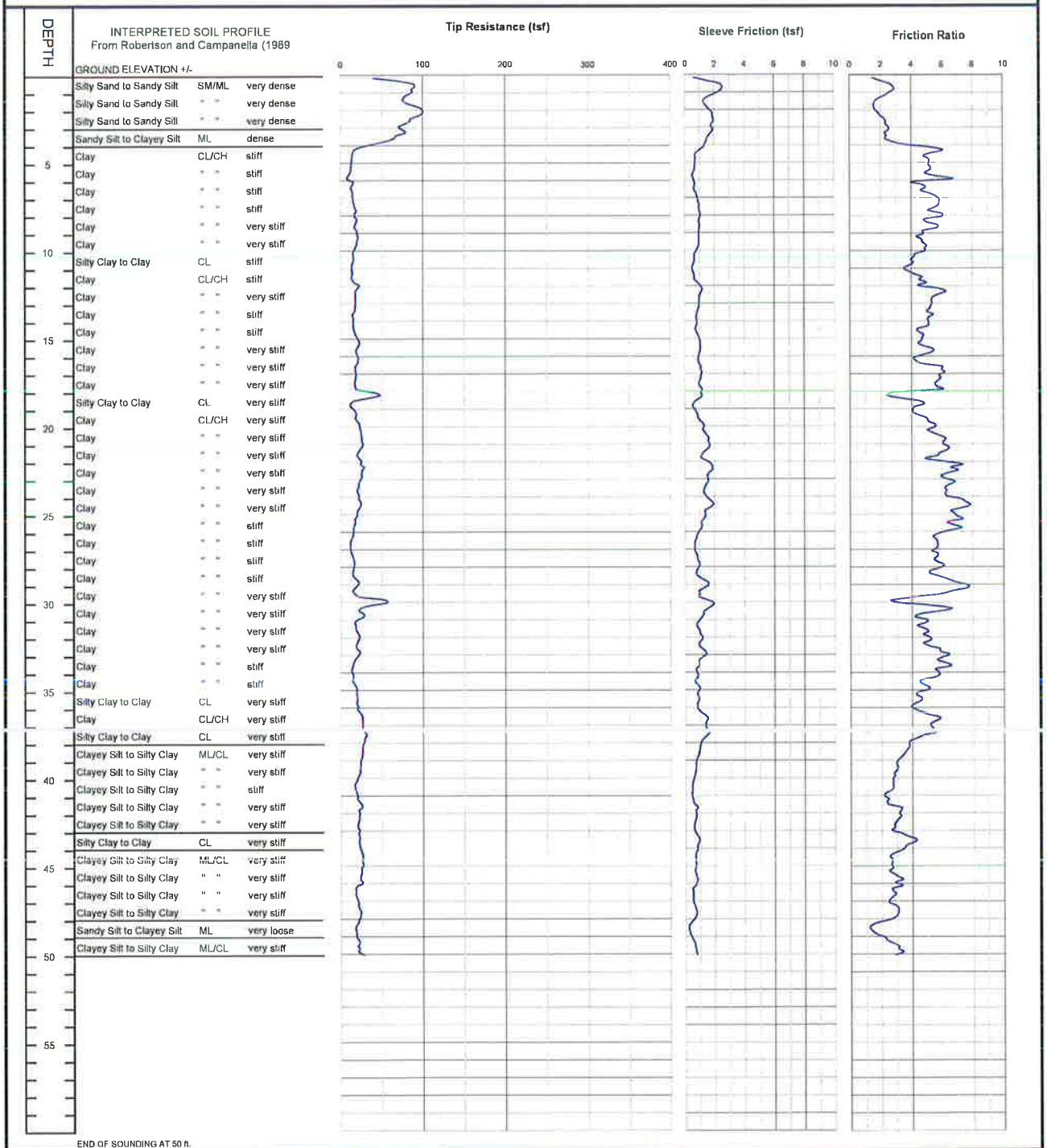
CLIENT: Ormat Nevada Inc
PROJECT: Heber 2 Repower Project - Heber, CA

CONE PENETROMETER: Middle Earth Geotesting Truck Mounted Electric Cone with 23 ton reaction weight

LOCATION: See Site and Boring Location Plan

DATE: 5/2/2007

CONE SOUNDING DATA CPT-4



Project No.		PLATE
LE19075	LANDMARK Geo-Engineers and Geologists	B-4

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 5/2/2007

CONE SOUNDING: CPT-4 Est. GWT (ft): 8 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
0.15	0.5	66.25	2.04	Silty Sand to Sandy Silt	SM/ML	very dense	115	15	125.2	35	122	45		
0.30	1.0	88.18	2.75	Sandy Silt to Clayey Silt	ML	very dense	115	25	166.7	35	114	44		
0.45	1.5	77.73	1.95	Silty Sand to Sandy Silt	SM/ML	very dense	115	17	146.9	30	103	42		
0.60	2.0	92.53	1.60	Silty Sand to Sandy Silt	SM/ML	very dense	115	21	174.9	25	103	42		
0.75	2.5	93.95	2.02	Silty Sand to Sandy Silt	SM/ML	very dense	115	21	177.6	25	100	42		
0.93	3.0	77.68	2.40	Silty Sand to Sandy Silt	SM/ML	very dense	115	17	146.8	35	91	41		
1.08	3.5	74.47	2.39	Sandy Silt to Clayey Silt	ML	dense	115	21	140.8	35	88	40		
1.23	4.0	52.73	2.83	Sandy Silt to Clayey Silt	ML	dense	115	15	99.7	45	75	39		
1.38	4.5	18.49	5.55	Clay	CL/CH	very stiff	125	15		90			1.07	>10
1.53	5.0	13.75	5.02	Clay	CL/CH	stiff	125	11		100			0.79	>10
1.68	5.5	12.39	5.11	Clay	CL/CH	stiff	125	10		100			0.71	>10
1.83	6.0	10.98	5.45	Clay	CL/CH	stiff	125	9		100			0.63	>10
1.98	6.5	13.51	4.77	Clay	CL/CH	stiff	125	11		95			0.77	>10
2.13	7.0	14.72	5.56	Clay	CL/CH	stiff	125	12		100			0.84	>10
2.28	7.5	16.58	5.71	Clay	CL/CH	stiff	125	13		95			0.95	>10
2.45	8.0	17.99	5.72	Clay	CL/CH	very stiff	125	14		95			1.03	>10
2.60	8.5	18.67	5.21	Clay	CL/CH	very stiff	125	15		90			1.07	>10
2.75	9.0	19.02	5.07	Clay	CL/CH	very stiff	125	15		90			1.09	>10
2.90	9.5	20.56	4.59	Clay	CL/CH	very stiff	125	16		85			1.18	>10
3.05	10.0	17.46	4.91	Clay	CL/CH	stiff	125	14		90			1.00	>10
3.20	10.5	15.45	4.14	Clay	CL/CH	stiff	125	12		90			0.88	>10
3.35	11.0	13.93	3.83	Silty Clay to Clay	CL	stiff	125	8		95			0.79	>10
3.50	11.5	13.83	4.23	Clay	CL/CH	stiff	125	11		100			0.78	>10
3.65	12.0	18.01	4.65	Clay	CL/CH	very stiff	125	14		95			1.02	>10
3.80	12.5	18.70	5.93	Clay	CL/CH	very stiff	125	15		100			1.06	>10
3.95	13.0	18.01	5.35	Clay	CL/CH	very stiff	125	14		100			1.02	>10
4.13	13.5	17.39	5.15	Clay	CL/CH	stiff	125	14		100			0.99	>10
4.28	14.0	14.93	5.20	Clay	CL/CH	stiff	125	12		100			0.84	9.59
4.43	14.5	15.49	4.86	Clay	CL/CH	stiff	125	12		100			0.87	>10
4.58	15.0	18.22	4.65	Clay	CL/CH	very stiff	125	15		100			1.03	>10
4.73	15.5	22.11	4.64	Clay	CL/CH	very stiff	125	18		90			1.26	>10
4.88	16.0	19.85	4.92	Clay	CL/CH	very stiff	125	16		100			1.13	>10
5.03	16.5	19.77	4.96	Clay	CL/CH	very stiff	125	16		100			1.12	>10
5.18	17.0	18.38	5.96	Clay	CL/CH	very stiff	125	15		100			1.04	>10
5.33	17.5	17.64	5.69	Clay	CL/CH	stiff	125	14		100			0.99	9.79
5.48	18.0	25.50	4.80	Clay	CL/CH	very stiff	125	20		90			1.45	>10
5.65	18.5	32.47	3.36	Clayey Silt to Silty Clay	ML/CL	very stiff	120	13		75			1.86	>10
5.80	19.0	13.48	4.36	Clay	CL/CH	stiff	125	11		100			0.75	5.53
5.95	19.5	18.41	4.55	Clay	CL/CH	very stiff	125	15		100			1.03	9.00
6.10	20.0	22.07	5.36	Clay	CL/CH	very stiff	125	18		100			1.25	>10
6.25	20.5	24.57	5.40	Clay	CL/CH	very stiff	125	20		100			1.40	>10
6.40	21.0	26.18	6.13	Clay	CL/CH	very stiff	125	21		100			1.49	>10
6.55	21.5	23.24	6.19	Clay	CL/CH	very stiff	125	19		100			1.31	>10
6.70	22.0	22.66	5.55	Clay	CL/CH	very stiff	125	18		100			1.28	>10
6.85	22.5	26.25	6.97	Clay	CL/CH	very stiff	125	21		100			1.49	>10
7.00	23.0	25.11	6.17	Clay	CL/CH	very stiff	125	20		100			1.42	>10
7.18	23.5	22.18	6.48	Clay	CL/CH	very stiff	125	18		100			1.25	>10
7.33	24.0	21.09	6.24	Clay	CL/CH	very stiff	125	17		100			1.18	8.70
7.48	24.5	23.54	7.51	Clay	CL/CH	very stiff	125	19		100			1.33	>10
7.63	25.0	21.31	6.90	Clay	CL/CH	very stiff	125	17		100			1.19	8.41
7.78	25.5	18.21	6.87	Clay	CL/CH	very stiff	125	15		100			1.01	6.21
7.93	26.0	15.91	6.78	Clay	CL/CH	stiff	125	13		100			0.88	4.89
8.08	26.5	13.54	5.59	Clay	CL/CH	stiff	125	11		100			0.74	3.66
8.23	27.0	11.78	5.53	Clay	CL/CH	stiff	125	9		100			0.63	3.00
8.38	27.5	14.49	5.56	Clay	CL/CH	stiff	125	12		100			0.79	3.91
8.53	28.0	16.02	5.84	Clay	CL/CH	stiff	125	13		100			0.88	4.47
8.68	28.5	15.04	5.37	Clay	CL/CH	stiff	125	12		100			0.82	3.91
8.85	29.0	20.59	6.98	Clay	CL/CH	very stiff	125	16		100			1.15	6.43
9.00	29.5	16.05	6.66	Clay	CL/CH	stiff	125	13		100			0.88	4.18
9.15	30.0	44.48	3.37	Clayey Silt to Silty Clay	ML/CL	hard	120	18		75			2.55	>10
9.30	30.5	27.03	5.86	Clay	CL/CH	very stiff	125	22		100			1.52	9.79
9.45	31.0	24.88	4.56	Clay	CL/CH	very stiff	125	20		100			1.39	8.14
9.60	31.5	17.85	4.68	Clay	CL/CH	stiff	125	14		100			0.98	4.57
9.75	32.0	21.43	4.98	Clay	CL/CH	very stiff	125	17		100			1.19	6.00
9.90	32.5	19.94	5.01	Clay	CL/CH	very stiff	125	16		100			1.10	5.21
10.05	33.0	21.67	6.03	Clay	CL/CH	very stiff	125	17		100			1.20	5.88
10.20	33.5	17.09	5.96	Clay	CL/CH	stiff	125	14		100			0.93	3.91
10.38	34.0	13.75	5.92	Clay	CL/CH	stiff	125	11		100			0.73	2.91
10.53	34.5	14.75	5.27	Clay	CL/CH	stiff	125	12		100			0.79	3.14
10.68	35.0	17.80	4.91	Clay	CL/CH	stiff	125	14		100			0.97	3.91
10.83	35.5	19.50	4.45	Clay	CL/CH	very stiff	125	16		100			1.07	4.47
10.98	36.0	20.06	4.23	Silty Clay to Clay	CL	very stiff	125	11		100			1.10	6.00
11.13	36.5	23.73	5.01	Clay	CL/CH	very stiff	125	19		100			1.32	6.00
11.28	37.0	26.37	5.33	Clay	CL/CH	very stiff	125	21		100			1.47	6.88
11.43	37.5	29.22	5.23	Clay	CL/CH	very stiff	125	23		100			1.64	8.14
11.58	38.0	28.26	4.00	Silty Clay to Clay	CL	very stiff	125	16		100			1.58	>10
11.73	38.5	26.29	3.66	Clayey Silt to Silty Clay	ML/CL	very stiff	120	11		100			1.46	>10

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.
CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 5/2/2007

CONE SOUNDING: CPT-4
Est. GWT (ft): 8
Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
11.88	39.0	24.98	3.19	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.39	>10
12.05	39.5	23.62	3.00	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.30	>10
12.20	40.0	21.78	2.80	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.20	8.27
12.35	40.5	17.57	2.75	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.95	5.53
12.50	41.0	19.10	2.36	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.04	6.32
12.65	41.5	22.54	2.42	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.24	8.27
12.80	42.0	23.41	3.23	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.29	8.70
12.95	42.5	22.05	3.08	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.21	7.70
13.10	43.0	21.46	2.78	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.17	7.13
13.25	43.5	22.21	3.76	Silty Clay to Clay	CL	very stiff	125	13		100			1.21	5.42
13.40	44.0	22.69	3.76	Silty Clay to Clay	CL	very stiff	125	13		100			1.24	5.53
13.58	44.5	25.69	2.81	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.42	9.59
13.73	45.0	26.50	2.66	Clayey Silt to Silty Clay	ML/CL	very stiff	120	11		100			1.46	>10
13.88	45.5	25.22	2.66	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.39	8.85
14.03	46.0	24.83	3.10	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.36	8.41
14.18	46.5	18.88	2.93	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.01	5.21
14.33	47.0	19.43	2.64	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.05	5.31
14.48	47.5	22.40	3.03	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.22	6.65
14.63	48.0	23.12	2.75	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.26	7.00
14.78	48.5	18.94	1.38	Sandy Silt to Clayey Silt	ML	very loose	115	5	14.1	100	15	30		
14.93	49.0	18.77	1.78	Sandy Silt to Clayey Silt	ML	very loose	115	5	13.9	100	14	30		
15.10	49.5	21.59	2.73	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.17	6.00
15.25	50.0	23.82	3.12	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.30	6.88

EEC ORIGINAL PKG

CLIENT: Ormat Nevada Inc
PROJECT: Heber 2 Repower Project - Heber, CA

CONE PENETROMETER: Middle Earth Geotesting Truck Mounted Electric Cone with 23 ton reaction weight

LOCATION: See Site and Boring Location Plan

DATE: 5/2/2007

CONE SOUNDING DATA CPT-5

DEPTH	INTERPRETED SOIL PROFILE From Robertson and Campanella (1989		
	GROUND ELEVATION +/-		
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Sand to Silty Sand	SP/SM	very dense
	Silty Sand to Sandy Silt	SM/ML	dense
5	Clay	CL/CH	very stiff
	Clay	" "	firm
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
10	Clay	" "	very stiff
	Silty Clay to Clay	CL	stiff
	Silty Clay to Clay	" "	stiff
	Silty Clay to Clay	" "	very stiff
	Clay	CL/CH	very stiff
15	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Silty Clay to Clay	CL	hard
25	Clay	CL/CH	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
35	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Silty Clay to Clay	" "	very stiff
	Silty Clay to Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
40	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	hard
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
45	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Sandy Silt to Clayey Silt	ML	very loose
50	Clayey Silt to Silty Clay	ML/CL	stiff
55			

END OF SOUNDING AT 50 ft.



Project No.		PLATE
LE19075	LANDMARK Geo-Engineers and Geologists	B-5

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 5/2/2007

CONE SOUNDING: CPT-5
Est. GWT (ft): 8

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
0.15	0.5	85.14	1.61	Silty Sand to Sandy Silt	SM/ML	very dense	115	19	161.0	25	130	46		
0.30	1.0	120.36	2.66	Silty Sand to Sandy Silt	SM/ML	very dense	115	27	227.5	30	124	45		
0.45	1.5	72.28	2.13	Silty Sand to Sandy Silt	SM/ML	very dense	115	16	136.6	30	101	42		
0.60	2.0	116.67	1.12	Sand to Silty Sand	SP/SM	very dense	115	21	220.6	15	110	43		
0.75	2.5	138.05	1.48	Sand to Silty Sand	SP/SM	very dense	115	25	261.0	15	111	44		
0.93	3.0	117.13	1.76	Silty Sand to Sandy Silt	SM/ML	very dense	115	26	221.4	20	104	42		
1.08	3.5	81.23	2.12	Silty Sand to Sandy Silt	SM/ML	very dense	115	18	153.5	30	90	41		
1.23	4.0	74.63	2.12	Silty Sand to Sandy Silt	SM/ML	dense	115	17	141.1	30	86	40		
1.38	4.5	34.90	3.90	Clayey Silt to Silty Clay	ML/CL	hard	120	14		60			2.04	>10
1.53	5.0	13.76	5.45	Clay	CL/CH	stiff	125	11		100			0.79	>10
1.68	5.5	7.57	7.44	Clay	CL/CH	firm	125	6		100			0.43	>10
1.83	6.0	5.99	6.88	Clay	CL/CH	firm	125	5		100			0.33	6.10
1.98	6.5	9.47	4.51	Clay	CL/CH	stiff	125	8		100			0.54	>10
2.13	7.0	11.69	4.84	Clay	CL/CH	stiff	125	9		100			0.66	>10
2.28	7.5	14.81	5.37	Clay	CL/CH	stiff	125	12		95			0.85	>10
2.45	8.0	13.05	5.28	Clay	CL/CH	stiff	125	10		100			0.74	>10
2.60	8.5	13.41	5.40	Clay	CL/CH	stiff	125	11		100			0.76	>10
2.75	9.0	15.40	5.21	Clay	CL/CH	stiff	125	12		95			0.88	>10
2.90	9.5	18.24	4.66	Clay	CL/CH	very stiff	125	15		85			1.04	>10
3.05	10.0	17.49	4.50	Clay	CL/CH	stiff	125	14		90			1.00	>10
3.20	10.5	16.07	4.15	Clay	CL/CH	stiff	125	13		90			0.91	>10
3.35	11.0	13.34	3.48	Silty Clay to Clay	CL	stiff	125	8		95			0.75	>10
3.50	11.5	12.52	3.24	Silty Clay to Clay	CL	stiff	125	7		95			0.70	>10
3.65	12.0	18.93	3.91	Silty Clay to Clay	CL	very stiff	125	11		85			1.08	>10
3.80	12.5	31.15	4.38	Silty Clay to Clay	CL	very stiff	125	18		75			1.80	>10
3.95	13.0	19.46	4.78	Clay	CL/CH	very stiff	125	16		95			1.11	>10
4.13	13.5	17.74	4.74	Clay	CL/CH	very stiff	125	14		100			1.01	>10
4.28	14.0	17.58	4.34	Clay	CL/CH	stiff	125	14		95			1.00	>10
4.43	14.5	21.21	5.18	Clay	CL/CH	very stiff	125	17		95			1.21	>10
4.58	15.0	20.43	4.83	Clay	CL/CH	very stiff	125	16		95			1.16	>10
4.73	15.5	20.79	4.75	Clay	CL/CH	very stiff	125	17		95			1.18	>10
4.88	16.0	18.89	5.75	Clay	CL/CH	very stiff	125	15		100			1.07	>10
5.03	16.5	23.41	4.88	Clay	CL/CH	very stiff	125	19		95			1.33	>10
5.18	17.0	23.59	5.34	Clay	CL/CH	very stiff	125	19		95			1.34	>10
5.33	17.5	23.27	4.98	Clay	CL/CH	very stiff	125	19		95			1.32	>10
5.48	18.0	22.19	5.13	Clay	CL/CH	very stiff	125	18		100			1.26	>10
5.65	18.5	20.81	5.10	Clay	CL/CH	very stiff	125	17		100			1.18	>10
5.80	19.0	15.78	4.92	Clay	CL/CH	stiff	125	13		100			0.88	7.13
5.95	19.5	16.06	5.23	Clay	CL/CH	stiff	125	13		100			0.90	7.00
6.10	20.0	22.81	6.58	Clay	CL/CH	very stiff	125	18		100			1.29	>10
6.25	20.5	28.53	6.30	Clay	CL/CH	very stiff	125	23		100			1.63	>10
6.40	21.0	28.99	6.06	Clay	CL/CH	very stiff	125	23		100			1.65	>10
6.55	21.5	24.82	6.26	Clay	CL/CH	very stiff	125	20		100			1.41	>10
6.70	22.0	18.48	5.79	Clay	CL/CH	very stiff	125	15		100			1.03	7.70
6.85	22.5	18.41	5.89	Clay	CL/CH	very stiff	125	15		100			1.03	7.41
7.00	23.0	15.96	6.46	Clay	CL/CH	stiff	125	13		100			0.88	5.76
7.18	23.5	46.63	4.62	Silty Clay to Clay	CL	hard	125	27		75			2.69	>10
7.33	24.0	47.09	4.48	Silty Clay to Clay	CL	hard	125	27		75			2.71	>10
7.48	24.5	23.27	4.67	Clay	CL/CH	very stiff	125	19		100			1.31	>10
7.63	25.0	21.09	5.34	Clay	CL/CH	very stiff	125	17		100			1.18	8.27
7.78	25.5	21.71	5.85	Clay	CL/CH	very stiff	125	17		100			1.22	8.41
7.93	26.0	19.90	5.47	Clay	CL/CH	very stiff	125	16		100			1.11	7.00
8.08	26.5	20.78	5.59	Clay	CL/CH	very stiff	125	17		100			1.16	7.41
8.23	27.0	21.98	5.44	Clay	CL/CH	very stiff	125	18		100			1.23	8.00
8.38	27.5	20.73	5.53	Clay	CL/CH	very stiff	125	17		100			1.16	6.88
8.53	28.0	20.36	5.62	Clay	CL/CH	very stiff	125	16		100			1.13	6.54
8.68	28.5	19.99	6.11	Clay	CL/CH	very stiff	125	16		100			1.11	6.21
8.85	29.0	18.33	5.49	Clay	CL/CH	very stiff	125	15		100			1.01	5.31
9.00	29.5	17.78	6.27	Clay	CL/CH	stiff	125	14		100			0.98	4.89
9.15	30.0	29.76	5.16	Clay	CL/CH	very stiff	125	24		100			1.68	>10
9.30	30.5	25.36	6.14	Clay	CL/CH	very stiff	125	20		100			1.42	8.56
9.45	31.0	25.65	6.08	Clay	CL/CH	very stiff	125	21		100			1.44	8.56
9.60	31.5	24.99	6.11	Clay	CL/CH	very stiff	125	20		100			1.40	8.00
9.75	32.0	24.42	5.93	Clay	CL/CH	very stiff	125	20		100			1.37	7.41
9.90	32.5	25.69	5.42	Clay	CL/CH	very stiff	125	21		100			1.44	8.00
10.05	33.0	26.43	5.06	Clay	CL/CH	very stiff	125	21		100			1.48	8.27
10.20	33.5	24.95	5.31	Clay	CL/CH	very stiff	125	20		100			1.39	7.27
10.38	34.0	22.88	5.62	Clay	CL/CH	very stiff	125	18		100			1.27	6.21
10.53	34.5	25.51	5.40	Clay	CL/CH	very stiff	125	20		100			1.42	7.27
10.68	35.0	27.31	4.56	Silty Clay to Clay	CL	very stiff	125	16		100			1.53	>10
10.83	35.5	30.04	4.55	Silty Clay to Clay	CL	very stiff	125	17		100			1.69	>10
10.98	36.0	29.52	4.52	Silty Clay to Clay	CL	very stiff	125	17		100			1.66	>10
11.13	36.5	30.25	4.64	Silty Clay to Clay	CL	very stiff	125	17		100			1.70	>10
11.28	37.0	29.39	4.68	Silty Clay to Clay	CL	very stiff	125	17		100			1.65	>10
11.43	37.5	27.60	4.22	Silty Clay to Clay	CL	very stiff	125	16		100			1.54	>10
11.58	38.0	27.92	4.11	Silty Clay to Clay	CL	very stiff	125	16		100			1.56	>10
11.73	38.5	28.57	3.77	Clayey Silt to Silty Clay	ML/CL	very stiff	120	11		100			1.60	>10

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LANDMARK CONSULTANTS, INC.
CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber 2 Repower Project - Heber, CA **Project No:** LE19075 **Date:** 5/2/2007

CONE SOUNDING: CPT-5
Est. GWT (ft): 8
Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth (m)	Base Depth (ft)	Avg Tip Qc, tsf	Avg Friction Ratio, %	Soil Classification	USCS	Density or Consistency	Est. Density (pcf)	SPT N(60)	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17 Su (tsf)	OCR
11.88	39.0	24.62	3.37	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.36	>10
12.05	39.5	22.28	3.04	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.23	8.70
12.20	40.0	24.64	3.45	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.36	>10
12.35	40.5	41.78	4.14	Clayey Silt to Silty Clay	ML/CL	hard	120	17		95			2.37	>10
12.50	41.0	64.96	3.22	Sandy Silt to Clayey Silt	ML	medium dense	115	19	51.8	70	53	35		
12.65	41.5	32.37	3.75	Clayey Silt to Silty Clay	ML/CL	very stiff	120	13		100			1.82	>10
12.80	42.0	22.75	3.82	Silty Clay to Clay	CL	very stiff	125	13		100			1.25	6.00
12.95	42.5	22.78	3.20	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.25	8.14
13.10	43.0	19.79	3.62	Silty Clay to Clay	CL	very stiff	125	11		100			1.07	4.57
13.25	43.5	23.86	3.91	Silty Clay to Clay	CL	very stiff	125	14		100			1.31	6.10
13.40	44.0	24.93	3.00	Clayey Silt to Silty Clay	ML/CL	very stiff	120	10		100			1.37	9.19
13.58	44.5	23.46	2.65	Clayey Silt to Silty Clay	ML/CL	very stiff	120	9		100			1.29	8.00
13.73	45.0	21.13	2.78	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.15	6.54
13.88	45.5	19.10	2.73	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.03	5.42
14.03	46.0	19.63	2.23	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.06	5.65
14.18	46.5	18.74	2.12	Clayey Silt to Silty Clay	ML/CL	very stiff	120	7		100			1.01	5.10
14.33	47.0	18.93	2.49	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.02	5.10
14.48	47.5	18.85	2.42	Clayey Silt to Silty Clay	ML/CL	very stiff	120	8		100			1.01	5.00
14.63	48.0	17.53	2.38	Clayey Silt to Silty Clay	ML/CL	stiff	120	7		100			0.93	4.37
14.78	48.5	16.01	2.08	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.84	3.74
14.93	49.0	20.91	1.36	Sandy Silt to Clayey Silt	ML	very loose	115	6	15.5	100	17	30		
15.10	49.5	17.29	1.76	Sandy Silt to Clayey Silt	ML	very loose	115	5	12.8	100	12	30		
15.25	50.0	13.85	1.98	Clayey Silt to Silty Clay	ML/CL	stiff	120	6		100			0.71	3.00

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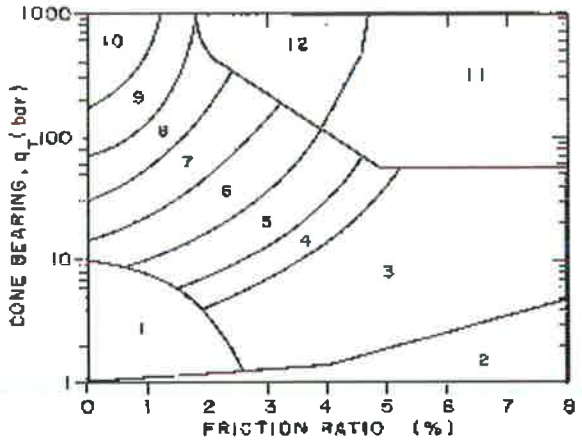
Simplified Soil Classification Chart

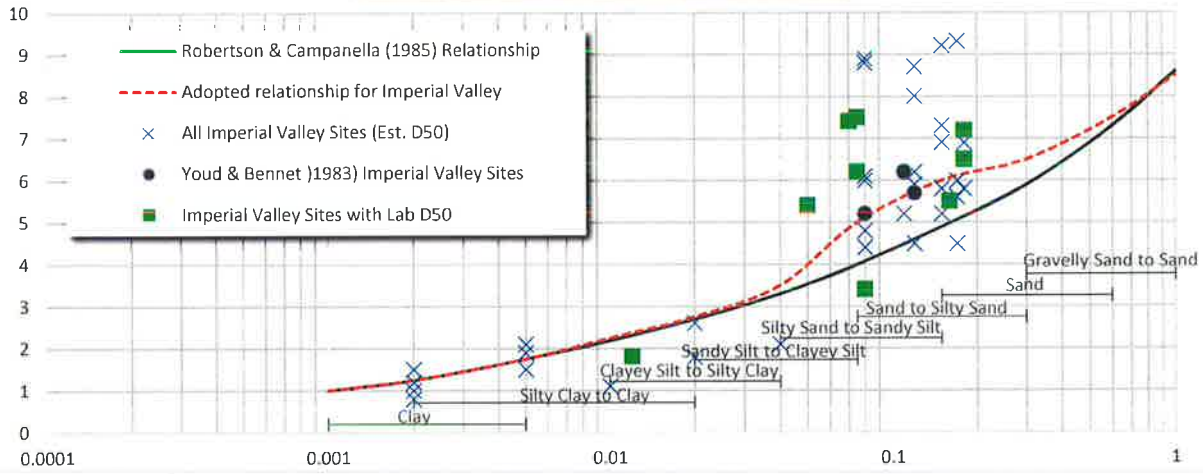
After Robertson & Campanella (1989)



Geotechnical Parameters from CPT Data:

Equivalent SPT N(60) blow count = Qc/(Qc/N Ratio)
N1(60) = Cn*N(60) Normalized SPT blow count
Cn = 1/(p'o)^0.5 < 1.6 max. from Liao & Whitman (1986)
p'o = effective overburden pressure (tsf) using unit densities given below and estimated groundwater table.
Dr = Relative density (%) from Jamiolkowski et. al. (1986) relationship
= -98 +68*log(Qc/p'o^0.5) where Qc, p'o in tonne/sqm
Note: 1 tonne/sqm = 0.1024 tsf, 1 bar =1.0443 tsf
Phi = Friction Angle estimated from either:
1. Roberton & Campanella (1983) chart:
Phi = 5.3 + 24*(log(Qc/p'o))+3(log(Qc/p'o))^2
2. Peck, Hansen & Thornburn (1974) N-Phi Correlation
3. Schmertman (1978) chart [Phi = 28+0.14*Dr for fine uniform sands]
Su = undrained shear strength (tsf)
= (Qc-p'o)/Nk where Nk varies from 10 to 22, 17 for OC clays
OCR = Overconsolidation Ratio estimated from Schmertman (1978) chart using Su/p'o ratio and estimated normal consolidated Su/p'o

Variation of Qc/N Ratio with Grain Size



Note: Assumed Properties and Adopted Qc/N Ratio based on correlations from Imperial Valley, California soils

Table of Soil Types and Assumed Properties

Zone	Soil Classification	UCS	Density (pcf)	R&C Qc/N	Adopted Qc/N	Est. PI	Fines (%)	D50 (mm)
1	Sensitive fine grained	ML	120	2	2	NP-15	65-100	0.02
2	Organic Material	OL/OH	120	1	1	--	--	--
3	Clay	CL/CH	125	1	1.25	25-40+	90-100	0.002
4	Silty Clay to Clay	CL	125	1.5	2	15-40	90-100	0.01
5	Clayey Silt to Silty Clay	ML/CL	120	2	2.75	25-May	90-100	0.02
6	Sandy Silt to Clayey Silt	ML	115	2.5	3.5	NP-10	65-100	0.04
7	Silty Sand to Sandy Silt	SM/ML	115	3	5	NP	35-75	0.075
8	Sand to Silty Sand	SP/SM	115	4	6	NP	May-35	0.15
9	Sand	SP	110	5	6.5	NP	0-5	0.3
10	Gravelly Sand to Sand	SW	115	6	7.5	NP	0-5	0.6
11	Overconsolidated Soil	--	120	1	1	NP	90-100	0.01
12	Sand to Clayey Sand	SP/SC	115	2	2	NP-5	--	---

Su (tsf)	Consistency
0-0.13	very soft
0.13-.25	soft
0.25-0.5	firm
0.5-1.0	stiff
1.0-2.0	very stiff
>2.0	hard
Dr (%)	**Relative Density**
0-15	very loose
15-35	loose
35-65	medium dense
65-85	dense
>85	very dense

LANDMARK
Geo-Engineers and Geologists

Project No: LE19075

Key to CPT Interpretation of Logs

Plate B-6

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APPENDIX C

EEC ORIGINAL PKG

Landmark Consultants, Inc.
780 N. 4th Street
El Centro, CA 92243

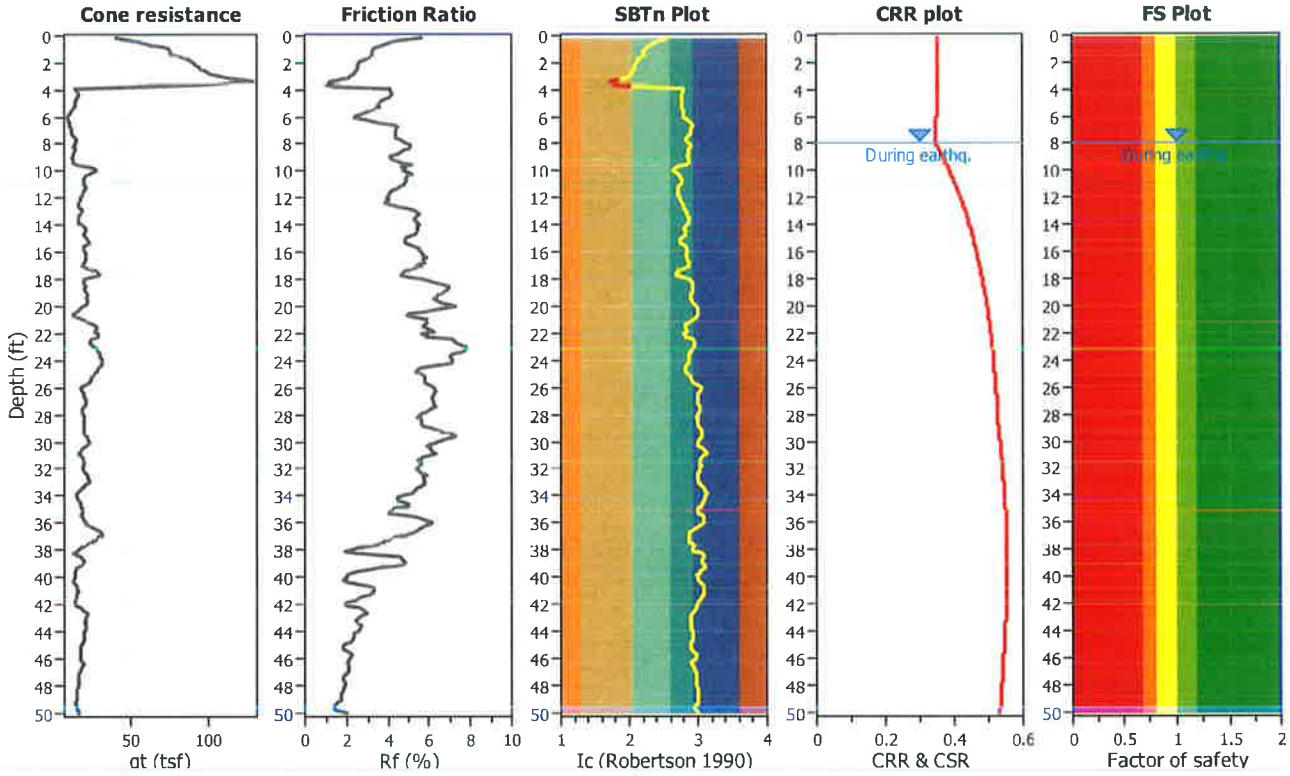
LIQUEFACTION ANALYSIS REPORT

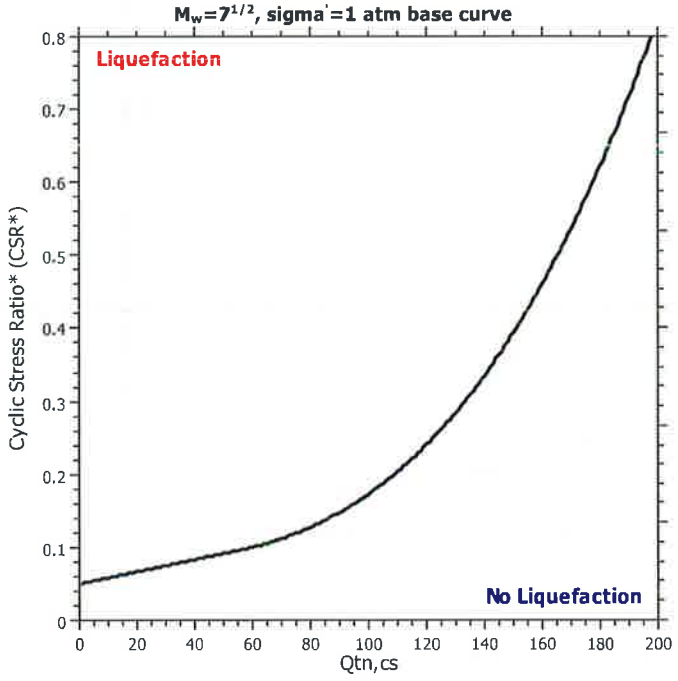
Project title : Heber 2 Repower Project **Location : Heber, CA**

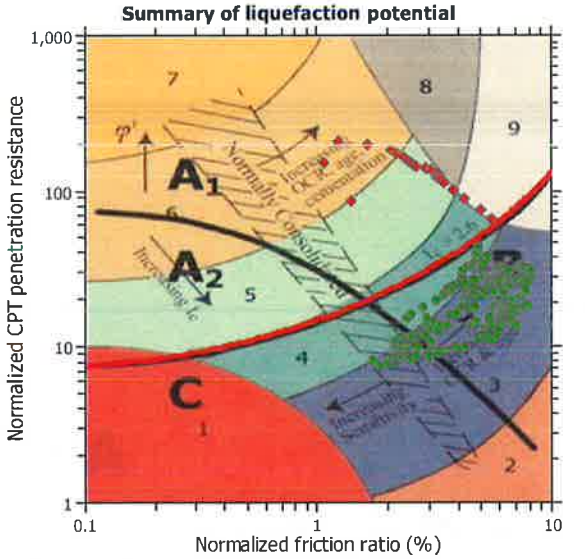
CPT file : CPT-1

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.50	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

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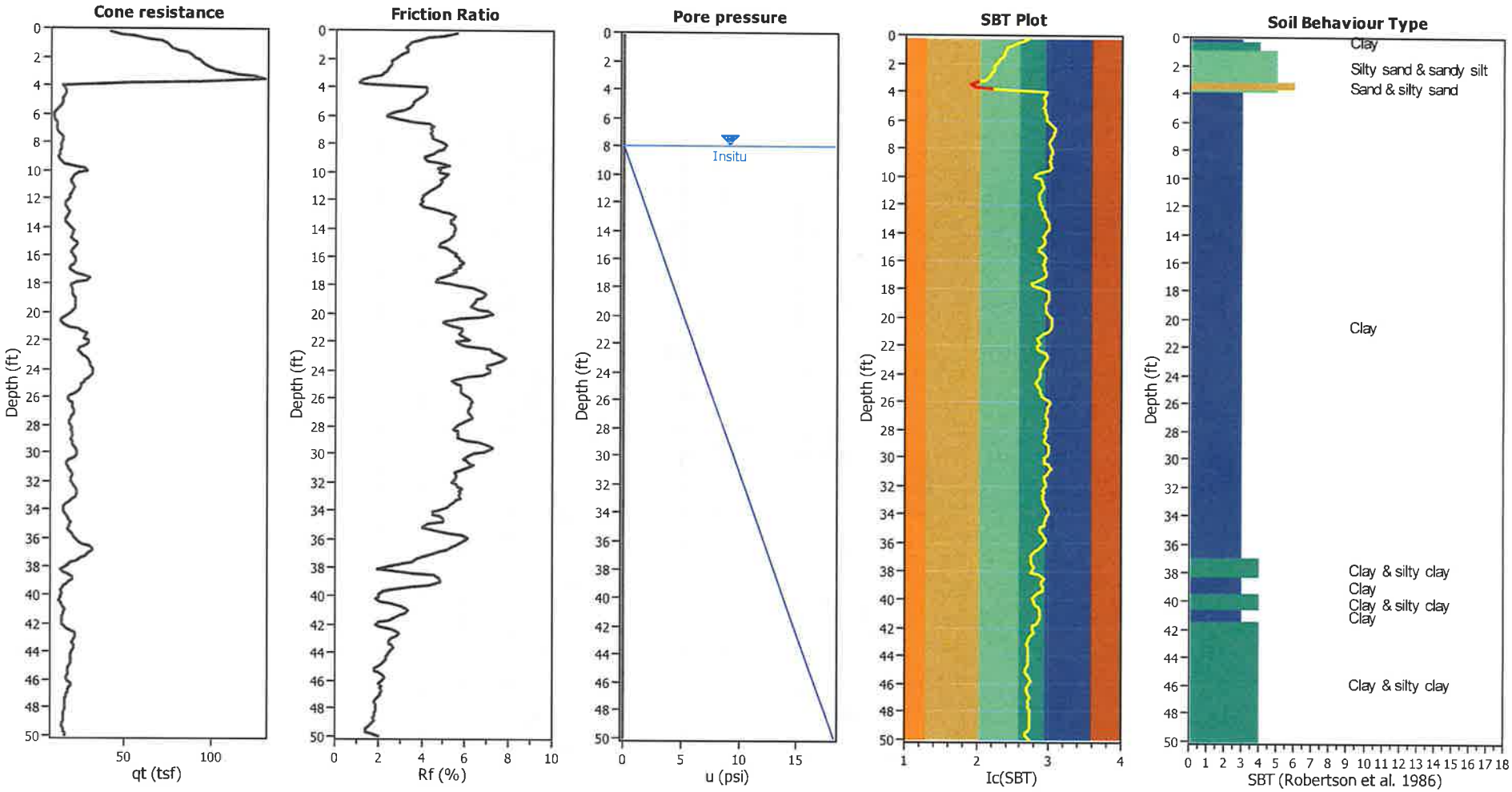
CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	8.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.50	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

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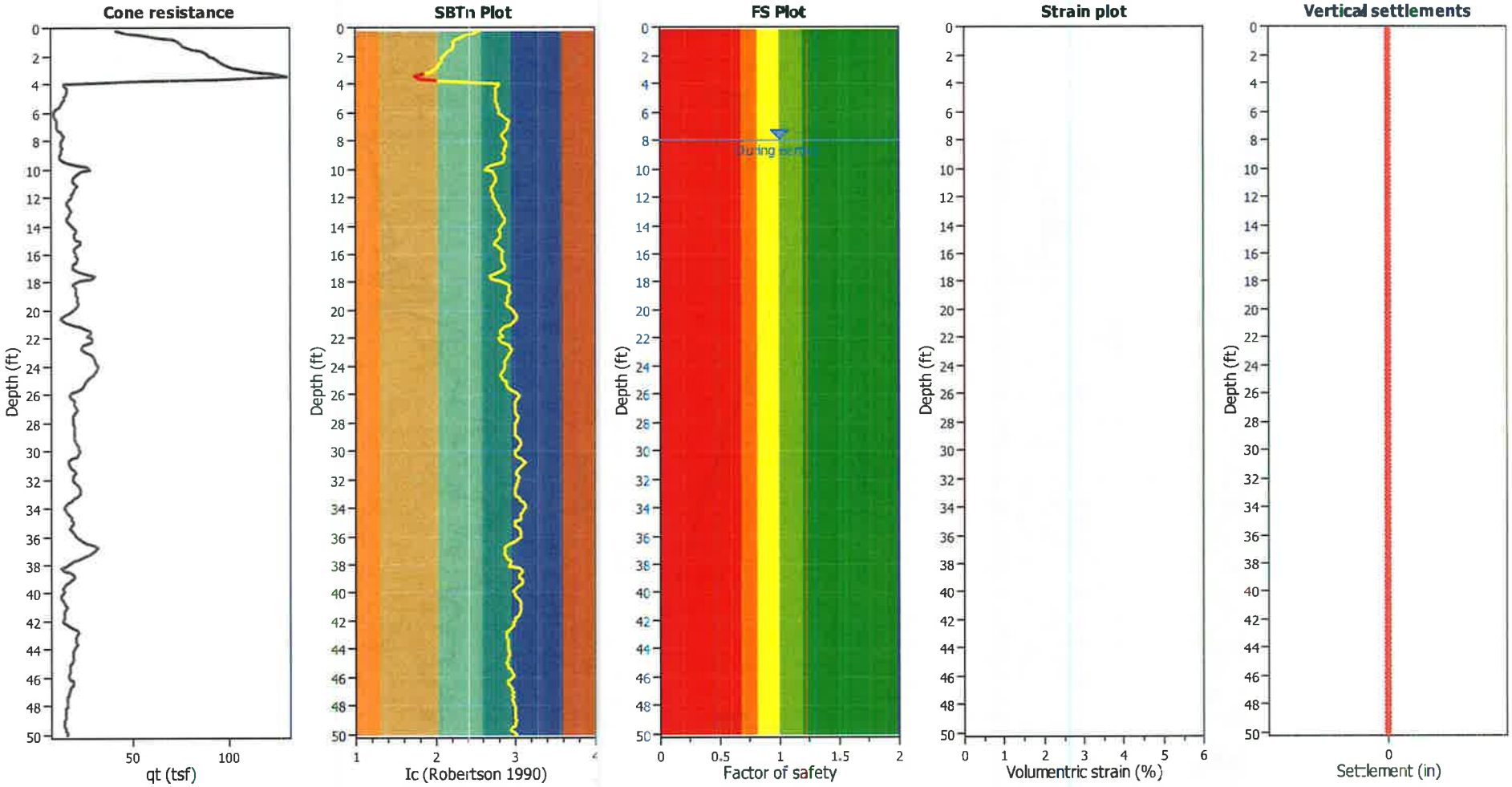
Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
8.04	119.97	2.00	0.00	0.86	0.00	8.20	118.98	2.00	0.00	0.86	0.00
8.37	118.57	2.00	0.00	0.86	0.00	8.53	116.33	2.00	0.00	0.86	0.00
8.69	111.11	2.00	0.00	0.85	0.00	8.86	105.42	2.00	0.00	0.85	0.00
9.02	103.12	2.00	0.00	0.85	0.00	9.19	106.12	2.00	0.00	0.84	0.00
9.35	114.80	2.00	0.00	0.84	0.00	9.51	129.15	2.00	0.00	0.84	0.00
9.68	142.81	2.00	0.00	0.84	0.00	9.84	155.83	2.00	0.00	0.83	0.00
10.01	158.63	2.00	0.00	0.83	0.00	10.17	154.96	2.00	0.00	0.83	0.00
10.33	145.30	2.00	0.00	0.82	0.00	10.50	138.73	2.00	0.00	0.82	0.00
10.66	137.47	2.00	0.00	0.82	0.00	10.83	136.96	2.00	0.00	0.82	0.00
10.99	137.99	2.00	0.00	0.81	0.00	11.15	137.59	2.00	0.00	0.81	0.00
11.32	134.89	2.00	0.00	0.81	0.00	11.48	129.13	2.00	0.00	0.81	0.00
11.65	123.50	2.00	0.00	0.80	0.00	11.81	121.19	2.00	0.00	0.80	0.00
11.98	119.62	2.00	0.00	0.80	0.00	12.14	117.79	2.00	0.00	0.79	0.00
12.30	113.63	2.00	0.00	0.79	0.00	12.47	115.50	2.00	0.00	0.79	0.00
12.63	123.82	2.00	0.00	0.79	0.00	12.80	132.97	2.00	0.00	0.78	0.00
12.96	139.15	2.00	0.00	0.78	0.00	13.12	139.59	2.00	0.00	0.78	0.00
13.29	136.63	2.00	0.00	0.77	0.00	13.45	131.74	2.00	0.00	0.77	0.00
13.62	130.26	2.00	0.00	0.77	0.00	13.78	134.95	2.00	0.00	0.77	0.00
13.94	140.91	2.00	0.00	0.76	0.00	14.11	145.02	2.00	0.00	0.76	0.00
14.27	146.42	2.00	0.00	0.76	0.00	14.44	144.79	2.00	0.00	0.76	0.00
14.60	141.29	2.00	0.00	0.75	0.00	14.76	138.10	2.00	0.00	0.75	0.00
14.93	137.24	2.00	0.00	0.75	0.00	15.09	138.96	2.00	0.00	0.74	0.00
15.26	139.60	2.00	0.00	0.74	0.00	15.42	140.43	2.00	0.00	0.74	0.00
15.58	139.21	2.00	0.00	0.74	0.00	15.75	140.96	2.00	0.00	0.73	0.00
15.91	141.85	2.00	0.00	0.73	0.00	16.08	145.91	2.00	0.00	0.73	0.00
16.24	147.66	2.00	0.00	0.72	0.00	16.40	149.68	2.00	0.00	0.72	0.00
16.57	145.56	2.00	0.00	0.72	0.00	16.73	140.89	2.00	0.00	0.72	0.00
16.90	134.62	2.00	0.00	0.71	0.00	17.06	136.61	2.00	0.00	0.71	0.00
17.22	140.20	2.00	0.00	0.71	0.00	17.39	146.14	2.00	0.00	0.71	0.00
17.55	148.16	2.00	0.00	0.70	0.00	17.72	144.49	2.00	0.00	0.70	0.00
17.88	139.25	2.00	0.00	0.70	0.00	18.04	138.26	2.00	0.00	0.69	0.00
18.21	144.57	2.00	0.00	0.69	0.00	18.37	151.78	2.00	0.00	0.69	0.00
18.54	154.52	2.00	0.00	0.69	0.00	18.70	153.95	2.00	0.00	0.68	0.00
18.86	153.12	2.00	0.00	0.68	0.00	19.03	151.55	2.00	0.00	0.68	0.00
19.19	150.73	2.00	0.00	0.67	0.00	19.36	148.04	2.00	0.00	0.67	0.00
19.52	147.69	2.00	0.00	0.67	0.00	19.69	151.40	2.00	0.00	0.67	0.00
19.85	154.31	2.00	0.00	0.66	0.00	20.01	150.07	2.00	0.00	0.66	0.00
20.18	135.86	2.00	0.00	0.66	0.00	20.34	119.17	2.00	0.00	0.66	0.00
20.51	104.85	2.00	0.00	0.65	0.00	20.67	104.13	2.00	0.00	0.65	0.00
20.83	114.48	2.00	0.00	0.65	0.00	21.00	131.00	2.00	0.00	0.64	0.00
21.16	142.62	2.00	0.00	0.64	0.00	21.33	149.15	2.00	0.00	0.64	0.00
21.49	153.07	2.00	0.00	0.64	0.00	21.65	154.99	2.00	0.00	0.63	0.00
21.82	156.00	2.00	0.00	0.63	0.00	21.98	152.30	2.00	0.00	0.63	0.00
22.15	154.57	2.00	0.00	0.62	0.00	22.31	156.68	2.00	0.00	0.62	0.00
22.47	159.95	2.00	0.00	0.62	0.00	22.64	157.92	2.00	0.00	0.62	0.00
22.80	160.98	2.00	0.00	0.61	0.00	22.97	169.52	2.00	0.00	0.61	0.00
23.13	176.91	2.00	0.00	0.61	0.00	23.29	178.34	2.00	0.00	0.61	0.00
23.46	174.45	2.00	0.00	0.60	0.00	23.62	171.54	2.00	0.00	0.60	0.00

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:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
23.79	172.69	2.00	0.00	0.60	0.00	23.95	175.54	2.00	0.00	0.59	0.00
24.11	175.55	2.00	0.00	0.59	0.00	24.28	168.97	2.00	0.00	0.59	0.00
24.44	157.41	2.00	0.00	0.59	0.00	24.61	146.69	2.00	0.00	0.58	0.00
24.77	140.58	2.00	0.00	0.58	0.00	24.93	139.79	2.00	0.00	0.58	0.00
25.10	139.62	2.00	0.00	0.57	0.00	25.26	138.81	2.00	0.00	0.57	0.00
25.43	136.75	2.00	0.00	0.57	0.00	25.59	133.88	2.00	0.00	0.57	0.00
25.75	129.01	2.00	0.00	0.56	0.00	25.92	123.09	2.00	0.00	0.56	0.00
26.08	121.15	2.00	0.00	0.56	0.00	26.25	124.71	2.00	0.00	0.56	0.00
26.41	127.90	2.00	0.00	0.55	0.00	26.57	128.10	2.00	0.00	0.55	0.00
26.74	126.91	2.00	0.00	0.55	0.00	26.90	128.06	2.00	0.00	0.54	0.00
27.07	129.48	2.00	0.00	0.54	0.00	27.23	128.59	2.00	0.00	0.54	0.00
27.40	126.11	2.00	0.00	0.54	0.00	27.56	122.56	2.00	0.00	0.53	0.00
27.72	119.14	2.00	0.00	0.53	0.00	27.89	116.40	2.00	0.00	0.53	0.00
28.05	117.08	2.00	0.00	0.52	0.00	28.22	116.67	2.00	0.00	0.52	0.00
28.38	118.11	2.00	0.00	0.52	0.00	28.54	118.18	2.00	0.00	0.52	0.00
28.71	118.83	2.00	0.00	0.51	0.00	28.87	118.78	2.00	0.00	0.51	0.00
29.04	120.47	2.00	0.00	0.51	0.00	29.20	126.00	2.00	0.00	0.51	0.00
29.36	131.40	2.00	0.00	0.50	0.00	29.53	135.95	2.00	0.00	0.50	0.00
29.69	136.80	2.00	0.00	0.50	0.00	29.86	135.40	2.00	0.00	0.49	0.00
30.02	131.15	2.00	0.00	0.49	0.00	30.18	127.34	2.00	0.00	0.49	0.00
30.35	121.69	2.00	0.00	0.49	0.00	30.51	115.70	2.00	0.00	0.48	0.00
30.68	111.80	2.00	0.00	0.48	0.00	30.84	112.22	2.00	0.00	0.48	0.00
31.00	112.33	2.00	0.00	0.47	0.00	31.17	111.25	2.00	0.00	0.47	0.00
31.33	112.16	2.00	0.00	0.47	0.00	31.50	114.87	2.00	0.00	0.47	0.00
31.66	114.02	2.00	0.00	0.46	0.00	31.82	110.25	2.00	0.00	0.46	0.00
31.99	108.73	2.00	0.00	0.46	0.00	32.15	112.92	2.00	0.00	0.46	0.00
32.32	116.75	2.00	0.00	0.45	0.00	32.48	119.82	2.00	0.00	0.45	0.00
32.64	120.23	2.00	0.00	0.45	0.00	32.81	121.28	2.00	0.00	0.44	0.00
32.97	120.46	2.00	0.00	0.44	0.00	33.14	117.67	2.00	0.00	0.44	0.00
33.30	111.47	2.00	0.00	0.44	0.00	33.46	105.37	2.00	0.00	0.43	0.00
33.63	100.20	2.00	0.00	0.43	0.00	33.79	95.08	2.00	0.00	0.43	0.00
33.96	90.37	2.00	0.00	0.42	0.00	34.12	87.91	2.00	0.00	0.42	0.00
34.28	90.52	2.00	0.00	0.42	0.00	34.45	96.32	2.00	0.00	0.42	0.00
34.61	99.51	2.00	0.00	0.41	0.00	34.78	99.39	2.00	0.00	0.41	0.00
34.94	95.45	2.00	0.00	0.41	0.00	35.10	92.69	2.00	0.00	0.41	0.00
35.27	91.26	2.00	0.00	0.40	0.00	35.43	95.67	2.00	0.00	0.40	0.00
35.60	104.11	2.00	0.00	0.40	0.00	35.76	111.84	2.00	0.00	0.39	0.00
35.93	115.82	2.00	0.00	0.39	0.00	36.09	116.17	2.00	0.00	0.39	0.00
36.25	118.60	2.00	0.00	0.39	0.00	36.42	122.19	2.00	0.00	0.38	0.00
36.58	126.65	2.00	0.00	0.38	0.00	36.75	127.95	2.00	0.00	0.38	0.00
36.91	123.10	2.00	0.00	0.37	0.00	37.07	114.03	2.00	0.00	0.37	0.00
37.24	104.72	2.00	0.00	0.37	0.00	37.40	98.46	2.00	0.00	0.37	0.00
37.57	91.59	2.00	0.00	0.36	0.00	37.73	82.25	2.00	0.00	0.36	0.00
37.89	70.62	2.00	0.00	0.36	0.00	38.06	60.48	2.00	0.00	0.35	0.00
38.22	63.21	2.00	0.00	0.35	0.00	38.39	76.34	2.00	0.00	0.35	0.00
38.55	91.11	2.00	0.00	0.35	0.00	38.71	98.86	2.00	0.00	0.34	0.00
38.88	99.34	2.00	0.00	0.34	0.00	39.04	95.61	2.00	0.00	0.34	0.00
39.21	86.80	2.00	0.00	0.34	0.00	39.37	76.19	2.00	0.00	0.33	0.00

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:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
39.53	64.64	2.00	0.00	0.33	0.00	39.70	60.43	2.00	0.00	0.33	0.00
39.86	58.79	2.00	0.00	0.32	0.00	40.03	58.19	2.00	0.00	0.32	0.00
40.19	55.59	2.00	0.00	0.32	0.00	40.35	57.57	2.00	0.00	0.32	0.00
40.52	62.98	2.00	0.00	0.31	0.00	40.68	69.67	2.00	0.00	0.31	0.00
40.85	73.76	2.00	0.00	0.31	0.00	41.01	74.59	2.00	0.00	0.30	0.00
41.17	72.68	2.00	0.00	0.30	0.00	41.34	69.91	2.00	0.00	0.30	0.00
41.50	66.62	2.00	0.00	0.30	0.00	41.67	63.67	2.00	0.00	0.29	0.00
41.83	58.22	2.00	0.00	0.29	0.00	41.99	56.51	2.00	0.00	0.29	0.00
42.16	59.31	2.00	0.00	0.29	0.00	42.32	68.96	2.00	0.00	0.28	0.00
42.49	76.21	2.00	0.00	0.28	0.00	42.65	79.83	2.00	0.00	0.28	0.00
42.81	78.47	2.00	0.00	0.27	0.00	42.98	75.37	2.00	0.00	0.27	0.00
43.14	72.19	2.00	0.00	0.27	0.00	43.31	72.07	2.00	0.00	0.27	0.00
43.47	73.96	2.00	0.00	0.26	0.00	43.64	75.40	2.00	0.00	0.26	0.00
43.80	74.08	2.00	0.00	0.26	0.00	43.96	71.55	2.00	0.00	0.25	0.00
44.13	69.30	2.00	0.00	0.25	0.00	44.29	68.40	2.00	0.00	0.25	0.00
44.46	68.25	2.00	0.00	0.25	0.00	44.62	67.81	2.00	0.00	0.24	0.00
44.78	65.86	2.00	0.00	0.24	0.00	44.95	62.49	2.00	0.00	0.24	0.00
45.11	59.84	2.00	0.00	0.24	0.00	45.28	59.58	2.00	0.00	0.23	0.00
45.44	61.66	2.00	0.00	0.23	0.00	45.60	63.62	2.00	0.00	0.23	0.00
45.77	63.78	2.00	0.00	0.22	0.00	45.93	62.47	2.00	0.00	0.22	0.00
46.10	62.45	2.00	0.00	0.22	0.00	46.26	63.43	2.00	0.00	0.22	0.00
46.42	64.80	2.00	0.00	0.21	0.00	46.59	63.69	2.00	0.00	0.21	0.00
46.75	62.33	2.00	0.00	0.21	0.00	46.92	61.14	2.00	0.00	0.20	0.00
47.08	60.30	2.00	0.00	0.20	0.00	47.24	58.40	2.00	0.00	0.20	0.00
47.41	57.02	2.00	0.00	0.20	0.00	47.57	56.85	2.00	0.00	0.19	0.00
47.74	57.68	2.00	0.00	0.19	0.00	47.90	57.58	2.00	0.00	0.19	0.00
48.06	57.06	2.00	0.00	0.19	0.00	48.23	56.18	2.00	0.00	0.18	0.00
48.39	55.57	2.00	0.00	0.18	0.00	48.56	54.87	2.00	0.00	0.18	0.00
48.72	54.42	2.00	0.00	0.17	0.00	48.88	54.29	2.00	0.00	0.17	0.00
49.05	53.61	2.00	0.00	0.17	0.00	49.21	51.61	2.00	0.00	0.17	0.00
49.38	49.82	2.00	0.00	0.16	0.00	49.54	49.51	2.00	0.00	0.16	0.00
49.70	49.89	2.00	0.00	0.16	0.00	49.87	54.16	2.00	0.00	0.15	0.00
50.03	57.29	2.00	0.00	0.15	0.00						

Total estimated settlement: 0.00

Abbreviations

$Q_{tn,cs}$:	Equivalent clean sand normalized cone resistance
FS:	Factor of safety against liquefaction
e_v (%):	Post-liquefaction volumentric strain
DF:	e_v depth weighting factor
Settlement:	Calculated settlement

EEC ORIGINAL PKG

LANDMARK
Geo-Engineers and Geologists

Landmark Consultants, Inc.
780 N. 4th Street
El Centro, CA 92243

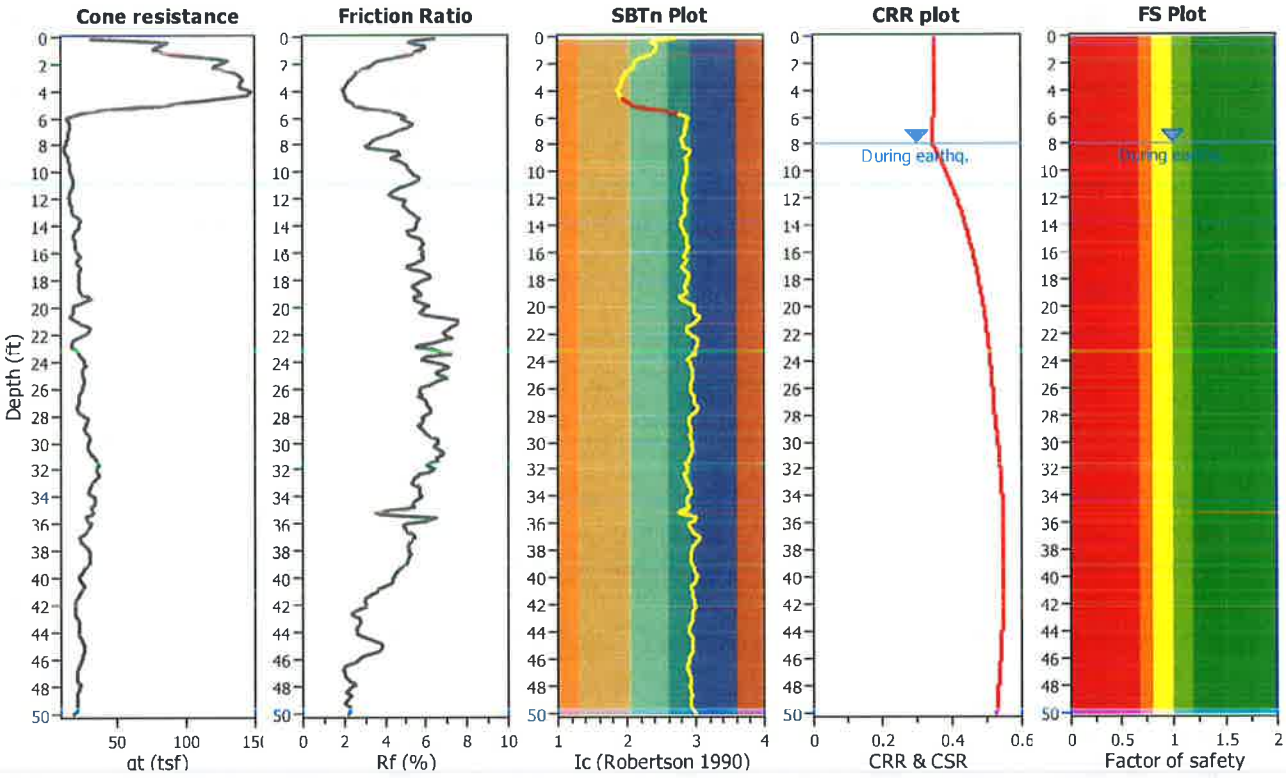
LIQUEFACTION ANALYSIS REPORT

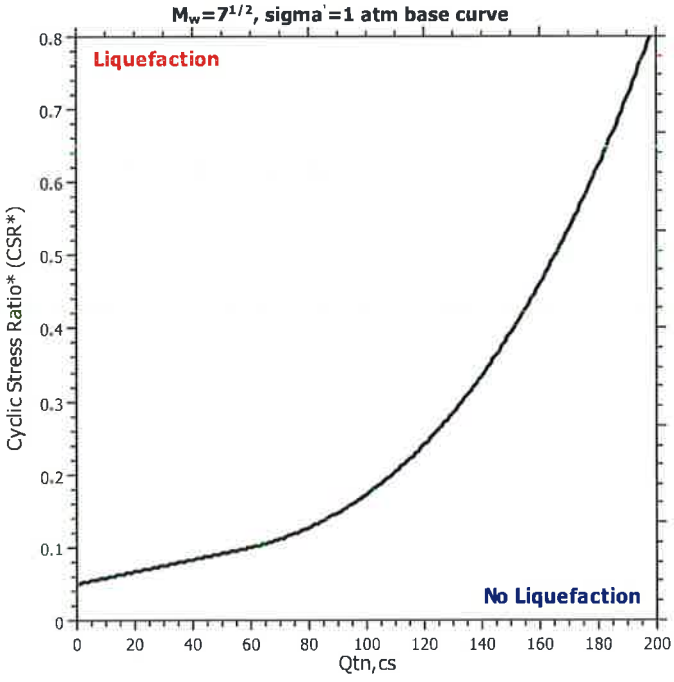
Project title : Heber 2 Repower Project **Location : Heber, CA**

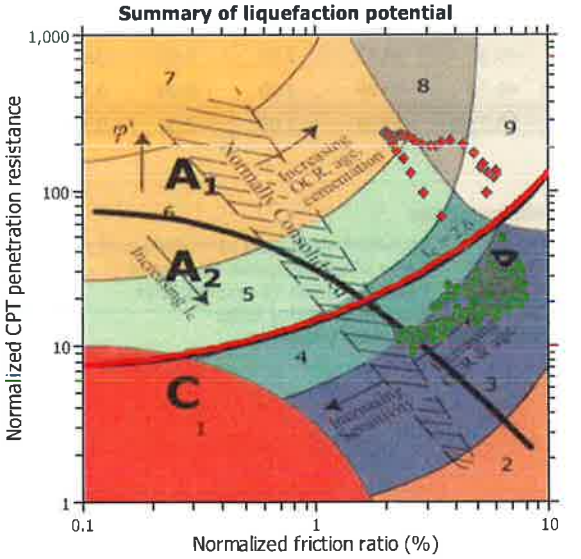
CPT file : CPT-2

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.50	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

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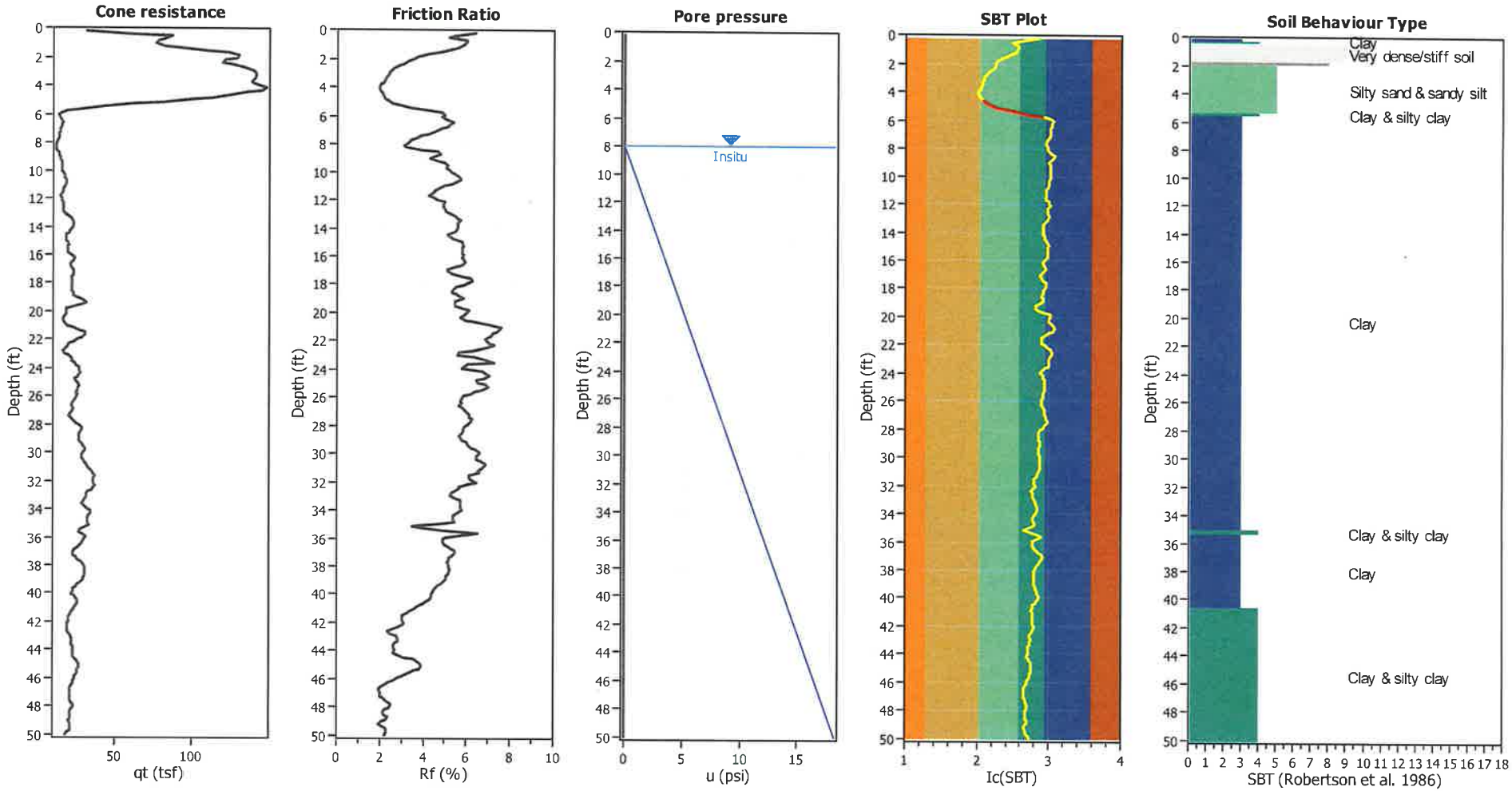
CPT basic interpretation plots



Input parameters and analysis data

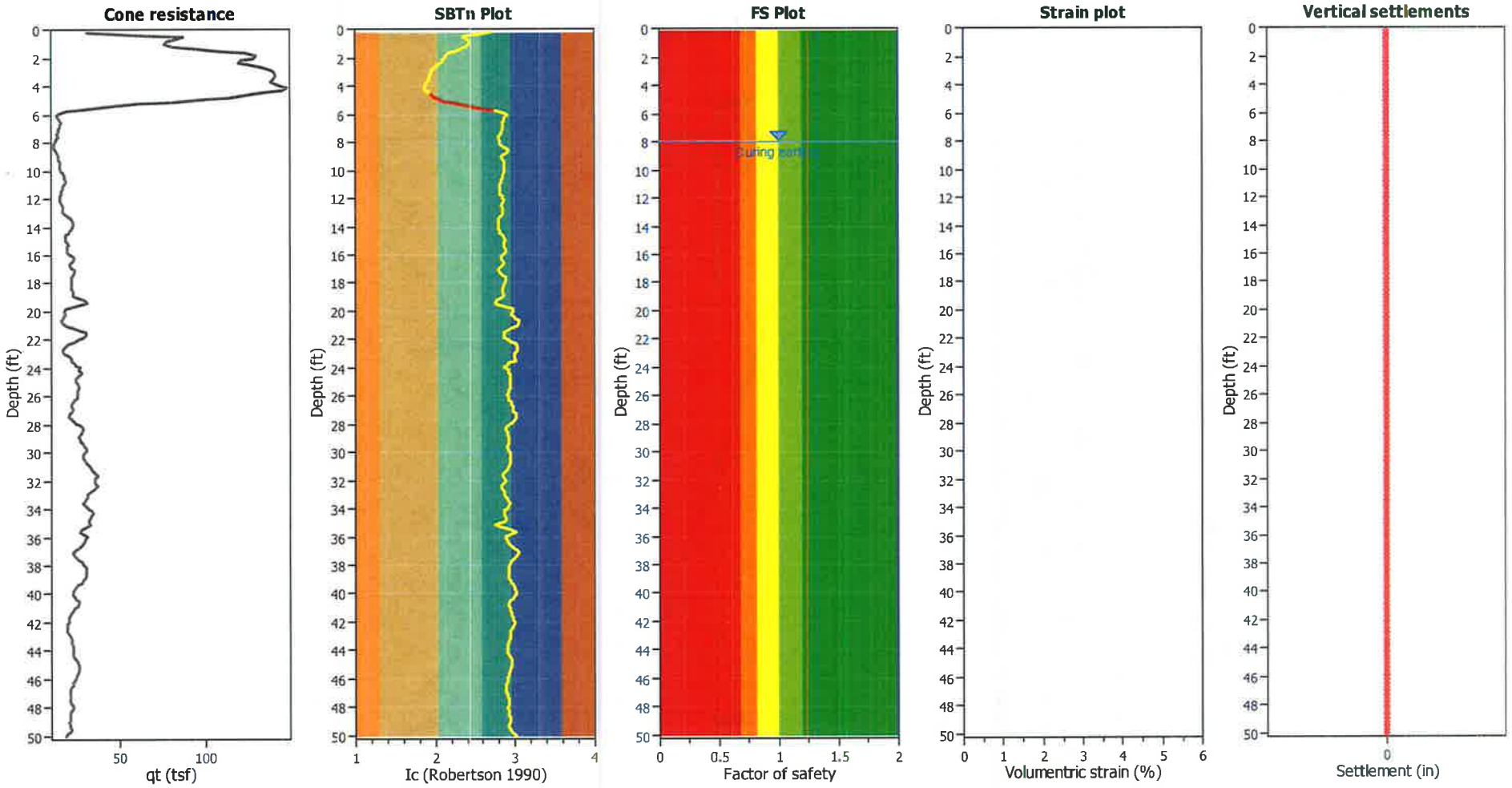
Analysis method:	NCEER (1998)	Depth to water table (erthq.):	8.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.50	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

EEC ORIGINAL PKG

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
8.04	87.36	2.00	0.00	0.86	0.00	8.20	87.19	2.00	0.00	0.86	0.00
8.37	96.18	2.00	0.00	0.86	0.00	8.53	106.38	2.00	0.00	0.86	0.00
8.69	112.48	2.00	0.00	0.85	0.00	8.86	110.89	2.00	0.00	0.85	0.00
9.02	111.02	2.00	0.00	0.85	0.00	9.19	116.47	2.00	0.00	0.84	0.00
9.35	122.07	2.00	0.00	0.84	0.00	9.51	124.70	2.00	0.00	0.84	0.00
9.68	124.57	2.00	0.00	0.84	0.00	9.84	125.67	2.00	0.00	0.83	0.00
10.01	128.65	2.00	0.00	0.83	0.00	10.17	133.81	2.00	0.00	0.83	0.00
10.33	139.27	2.00	0.00	0.82	0.00	10.50	141.24	2.00	0.00	0.82	0.00
10.66	140.53	2.00	0.00	0.82	0.00	10.83	137.12	2.00	0.00	0.82	0.00
10.99	132.08	2.00	0.00	0.81	0.00	11.15	125.69	2.00	0.00	0.81	0.00
11.32	121.22	2.00	0.00	0.81	0.00	11.48	118.55	2.00	0.00	0.81	0.00
11.65	114.78	2.00	0.00	0.80	0.00	11.81	114.47	2.00	0.00	0.80	0.00
11.98	117.86	2.00	0.00	0.80	0.00	12.14	123.32	2.00	0.00	0.79	0.00
12.30	124.95	2.00	0.00	0.79	0.00	12.47	126.35	2.00	0.00	0.79	0.00
12.63	127.12	2.00	0.00	0.79	0.00	12.80	126.75	2.00	0.00	0.78	0.00
12.96	128.67	2.00	0.00	0.78	0.00	13.12	137.01	2.00	0.00	0.78	0.00
13.29	146.43	2.00	0.00	0.77	0.00	13.45	152.65	2.00	0.00	0.77	0.00
13.62	152.23	2.00	0.00	0.77	0.00	13.78	150.77	2.00	0.00	0.77	0.00
13.94	149.69	2.00	0.00	0.76	0.00	14.11	147.77	2.00	0.00	0.76	0.00
14.27	143.23	2.00	0.00	0.76	0.00	14.44	134.40	2.00	0.00	0.76	0.00
14.60	130.85	2.00	0.00	0.75	0.00	14.76	131.78	2.00	0.00	0.75	0.00
14.93	137.68	2.00	0.00	0.75	0.00	15.09	141.06	2.00	0.00	0.74	0.00
15.26	142.59	2.00	0.00	0.74	0.00	15.42	140.26	2.00	0.00	0.74	0.00
15.58	137.71	2.00	0.00	0.74	0.00	15.75	138.11	2.00	0.00	0.73	0.00
15.91	142.76	2.00	0.00	0.73	0.00	16.08	148.65	2.00	0.00	0.73	0.00
16.24	151.42	2.00	0.00	0.72	0.00	16.40	149.65	2.00	0.00	0.72	0.00
16.57	142.62	2.00	0.00	0.72	0.00	16.73	137.02	2.00	0.00	0.72	0.00
16.90	134.47	2.00	0.00	0.71	0.00	17.06	136.99	2.00	0.00	0.71	0.00
17.22	140.40	2.00	0.00	0.71	0.00	17.39	144.16	2.00	0.00	0.71	0.00
17.55	147.16	2.00	0.00	0.70	0.00	17.72	147.34	2.00	0.00	0.70	0.00
17.88	145.63	2.00	0.00	0.70	0.00	18.04	142.20	2.00	0.00	0.69	0.00
18.21	137.49	2.00	0.00	0.69	0.00	18.37	134.79	2.00	0.00	0.69	0.00
18.54	135.52	2.00	0.00	0.69	0.00	18.70	138.83	2.00	0.00	0.68	0.00
18.86	142.10	2.00	0.00	0.68	0.00	19.03	147.42	2.00	0.00	0.68	0.00
19.19	153.72	2.00	0.00	0.67	0.00	19.36	155.93	2.00	0.00	0.67	0.00
19.52	149.47	2.00	0.00	0.67	0.00	19.69	138.34	2.00	0.00	0.67	0.00
19.85	130.61	2.00	0.00	0.66	0.00	20.01	127.39	2.00	0.00	0.66	0.00
20.18	126.45	2.00	0.00	0.66	0.00	20.34	122.79	2.00	0.00	0.66	0.00
20.51	120.62	2.00	0.00	0.65	0.00	20.67	123.16	2.00	0.00	0.65	0.00
20.83	132.56	2.00	0.00	0.65	0.00	21.00	144.81	2.00	0.00	0.64	0.00
21.16	158.42	2.00	0.00	0.64	0.00	21.33	169.86	2.00	0.00	0.64	0.00
21.49	175.02	2.00	0.00	0.64	0.00	21.65	173.22	2.00	0.00	0.63	0.00
21.82	164.99	2.00	0.00	0.63	0.00	21.98	158.59	2.00	0.00	0.63	0.00
22.15	151.83	2.00	0.00	0.62	0.00	22.31	144.28	2.00	0.00	0.62	0.00
22.47	133.91	2.00	0.00	0.62	0.00	22.64	122.50	2.00	0.00	0.62	0.00
22.80	113.97	2.00	0.00	0.61	0.00	22.97	115.77	2.00	0.00	0.61	0.00
23.13	130.82	2.00	0.00	0.61	0.00	23.29	142.43	2.00	0.00	0.61	0.00
23.46	145.56	2.00	0.00	0.60	0.00	23.62	138.07	2.00	0.00	0.60	0.00

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
23.79	137.78	2.00	0.00	0.60	0.00	23.95	142.26	2.00	0.00	0.59	0.00
24.11	152.61	2.00	0.00	0.59	0.00	24.28	157.26	2.00	0.00	0.59	0.00
24.44	157.24	2.00	0.00	0.59	0.00	24.61	149.93	2.00	0.00	0.58	0.00
24.77	142.55	2.00	0.00	0.58	0.00	24.93	143.51	2.00	0.00	0.58	0.00
25.10	149.66	2.00	0.00	0.57	0.00	25.26	152.78	2.00	0.00	0.57	0.00
25.43	148.83	2.00	0.00	0.57	0.00	25.59	143.18	2.00	0.00	0.57	0.00
25.75	139.46	2.00	0.00	0.56	0.00	25.92	135.62	2.00	0.00	0.56	0.00
26.08	133.19	2.00	0.00	0.56	0.00	26.25	130.04	2.00	0.00	0.56	0.00
26.41	126.80	2.00	0.00	0.55	0.00	26.57	123.29	2.00	0.00	0.55	0.00
26.74	124.77	2.00	0.00	0.55	0.00	26.90	128.04	2.00	0.00	0.54	0.00
27.07	127.87	2.00	0.00	0.54	0.00	27.23	124.65	2.00	0.00	0.54	0.00
27.40	123.42	2.00	0.00	0.54	0.00	27.56	125.82	2.00	0.00	0.53	0.00
27.72	129.41	2.00	0.00	0.53	0.00	27.89	132.22	2.00	0.00	0.53	0.00
28.05	136.18	2.00	0.00	0.52	0.00	28.22	139.19	2.00	0.00	0.52	0.00
28.38	139.58	2.00	0.00	0.52	0.00	28.54	136.40	2.00	0.00	0.52	0.00
28.71	132.41	2.00	0.00	0.51	0.00	28.87	131.90	2.00	0.00	0.51	0.00
29.04	133.41	2.00	0.00	0.51	0.00	29.20	135.88	2.00	0.00	0.51	0.00
29.36	139.24	2.00	0.00	0.50	0.00	29.53	144.11	2.00	0.00	0.50	0.00
29.69	147.91	2.00	0.00	0.50	0.00	29.86	148.75	2.00	0.00	0.49	0.00
30.02	146.27	2.00	0.00	0.49	0.00	30.18	143.95	2.00	0.00	0.49	0.00
30.35	143.23	2.00	0.00	0.49	0.00	30.51	146.19	2.00	0.00	0.48	0.00
30.68	150.88	2.00	0.00	0.48	0.00	30.84	153.31	2.00	0.00	0.48	0.00
31.00	153.80	2.00	0.00	0.47	0.00	31.17	154.28	2.00	0.00	0.47	0.00
31.33	157.57	2.00	0.00	0.47	0.00	31.50	153.01	2.00	0.00	0.47	0.00
31.66	154.59	2.00	0.00	0.46	0.00	31.82	152.70	2.00	0.00	0.46	0.00
31.99	155.75	2.00	0.00	0.46	0.00	32.15	151.09	2.00	0.00	0.46	0.00
32.32	147.83	2.00	0.00	0.45	0.00	32.48	145.76	2.00	0.00	0.45	0.00
32.64	140.14	2.00	0.00	0.45	0.00	32.81	133.97	2.00	0.00	0.44	0.00
32.97	130.32	2.00	0.00	0.44	0.00	33.14	132.24	2.00	0.00	0.44	0.00
33.30	133.70	2.00	0.00	0.44	0.00	33.46	131.98	2.00	0.00	0.43	0.00
33.63	130.38	2.00	0.00	0.43	0.00	33.79	132.66	2.00	0.00	0.43	0.00
33.96	137.36	2.00	0.00	0.42	0.00	34.12	139.02	2.00	0.00	0.42	0.00
34.28	136.49	2.00	0.00	0.42	0.00	34.45	134.01	2.00	0.00	0.42	0.00
34.61	131.99	2.00	0.00	0.41	0.00	34.78	130.99	2.00	0.00	0.41	0.00
34.94	124.05	2.00	0.00	0.41	0.00	35.10	106.18	2.00	0.00	0.41	0.00
35.27	108.32	2.00	0.00	0.40	0.00	35.43	116.24	2.00	0.00	0.40	0.00
35.60	131.29	2.00	0.00	0.40	0.00	35.76	128.43	2.00	0.00	0.39	0.00
35.93	124.20	2.00	0.00	0.39	0.00	36.09	120.99	2.00	0.00	0.39	0.00
36.25	118.67	2.00	0.00	0.39	0.00	36.42	117.46	2.00	0.00	0.38	0.00
36.58	116.41	2.00	0.00	0.38	0.00	36.75	114.96	2.00	0.00	0.38	0.00
36.91	112.18	2.00	0.00	0.37	0.00	37.07	109.16	2.00	0.00	0.37	0.00
37.24	108.67	2.00	0.00	0.37	0.00	37.40	109.91	2.00	0.00	0.37	0.00
37.57	113.02	2.00	0.00	0.36	0.00	37.73	115.42	2.00	0.00	0.36	0.00
37.89	118.48	2.00	0.00	0.36	0.00	38.06	120.42	2.00	0.00	0.35	0.00
38.22	120.97	2.00	0.00	0.35	0.00	38.39	120.42	2.00	0.00	0.35	0.00
38.55	119.67	2.00	0.00	0.35	0.00	38.71	118.51	2.00	0.00	0.34	0.00
38.88	117.61	2.00	0.00	0.34	0.00	39.04	115.20	2.00	0.00	0.34	0.00
39.21	110.80	2.00	0.00	0.34	0.00	39.37	105.70	2.00	0.00	0.33	0.00

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
39.53	101.48	2.00	0.00	0.33	0.00	39.70	98.49	2.00	0.00	0.33	0.00
39.86	96.59	2.00	0.00	0.32	0.00	40.03	95.67	2.00	0.00	0.32	0.00
40.19	97.13	2.00	0.00	0.32	0.00	40.35	98.64	2.00	0.00	0.32	0.00
40.52	98.88	2.00	0.00	0.31	0.00	40.68	96.83	2.00	0.00	0.31	0.00
40.85	92.14	2.00	0.00	0.31	0.00	41.01	88.77	2.00	0.00	0.30	0.00
41.17	84.35	2.00	0.00	0.30	0.00	41.34	81.40	2.00	0.00	0.30	0.00
41.50	77.39	2.00	0.00	0.30	0.00	41.67	76.16	2.00	0.00	0.29	0.00
41.83	76.40	2.00	0.00	0.29	0.00	41.99	76.66	2.00	0.00	0.29	0.00
42.16	75.61	2.00	0.00	0.29	0.00	42.32	71.98	2.00	0.00	0.28	0.00
42.49	68.05	2.00	0.00	0.28	0.00	42.65	66.80	2.00	0.00	0.28	0.00
42.81	69.47	2.00	0.00	0.27	0.00	42.98	73.47	2.00	0.00	0.27	0.00
43.14	75.84	2.00	0.00	0.27	0.00	43.31	76.24	2.00	0.00	0.27	0.00
43.47	75.02	2.00	0.00	0.26	0.00	43.64	74.38	2.00	0.00	0.26	0.00
43.80	74.31	2.00	0.00	0.26	0.00	43.96	74.98	2.00	0.00	0.25	0.00
44.13	74.60	2.00	0.00	0.25	0.00	44.29	76.20	2.00	0.00	0.25	0.00
44.46	80.54	2.00	0.00	0.25	0.00	44.62	86.78	2.00	0.00	0.24	0.00
44.78	90.93	2.00	0.00	0.24	0.00	44.95	93.24	2.00	0.00	0.24	0.00
45.11	93.73	2.00	0.00	0.24	0.00	45.28	92.65	2.00	0.00	0.23	0.00
45.44	89.03	2.00	0.00	0.23	0.00	45.60	84.92	2.00	0.00	0.23	0.00
45.77	80.93	2.00	0.00	0.22	0.00	45.93	77.69	2.00	0.00	0.22	0.00
46.10	74.24	2.00	0.00	0.22	0.00	46.26	71.34	2.00	0.00	0.22	0.00
46.42	68.07	2.00	0.00	0.21	0.00	46.59	65.10	2.00	0.00	0.21	0.00
46.75	63.06	2.00	0.00	0.21	0.00	46.92	62.80	2.00	0.00	0.20	0.00
47.08	63.25	2.00	0.00	0.20	0.00	47.24	63.50	2.00	0.00	0.20	0.00
47.41	64.30	2.00	0.00	0.20	0.00	47.57	66.85	2.00	0.00	0.19	0.00
47.74	69.90	2.00	0.00	0.19	0.00	47.90	71.36	2.00	0.00	0.19	0.00
48.06	69.62	2.00	0.00	0.19	0.00	48.23	66.49	2.00	0.00	0.18	0.00
48.39	64.48	2.00	0.00	0.18	0.00	48.56	65.33	2.00	0.00	0.18	0.00
48.72	67.11	2.00	0.00	0.17	0.00	48.88	66.06	2.00	0.00	0.17	0.00
49.05	63.01	2.00	0.00	0.17	0.00	49.21	61.74	2.00	0.00	0.17	0.00
49.38	63.70	2.00	0.00	0.16	0.00	49.54	65.97	2.00	0.00	0.16	0.00
49.70	65.40	2.00	0.00	0.16	0.00	49.87	62.98	2.00	0.00	0.15	0.00
50.03	60.76	2.00	0.00	0.15	0.00						

Total estimated settlement: 0.00

Abbreviations

$Q_{tn,cs}$:	Equivalent clean sand normalized cone resistance
FS:	Factor of safety against liquefaction
e_v (%):	Post-liquefaction volumentric strain
DF:	e_v depth weighting factor
Settlement:	Calculated settlement

EEC ORIGINAL PKG

LANDMARK
Geo-Engineers and Geologists

Landmark Consultants, Inc.
780 N. 4th Street
El Centro, CA 92243

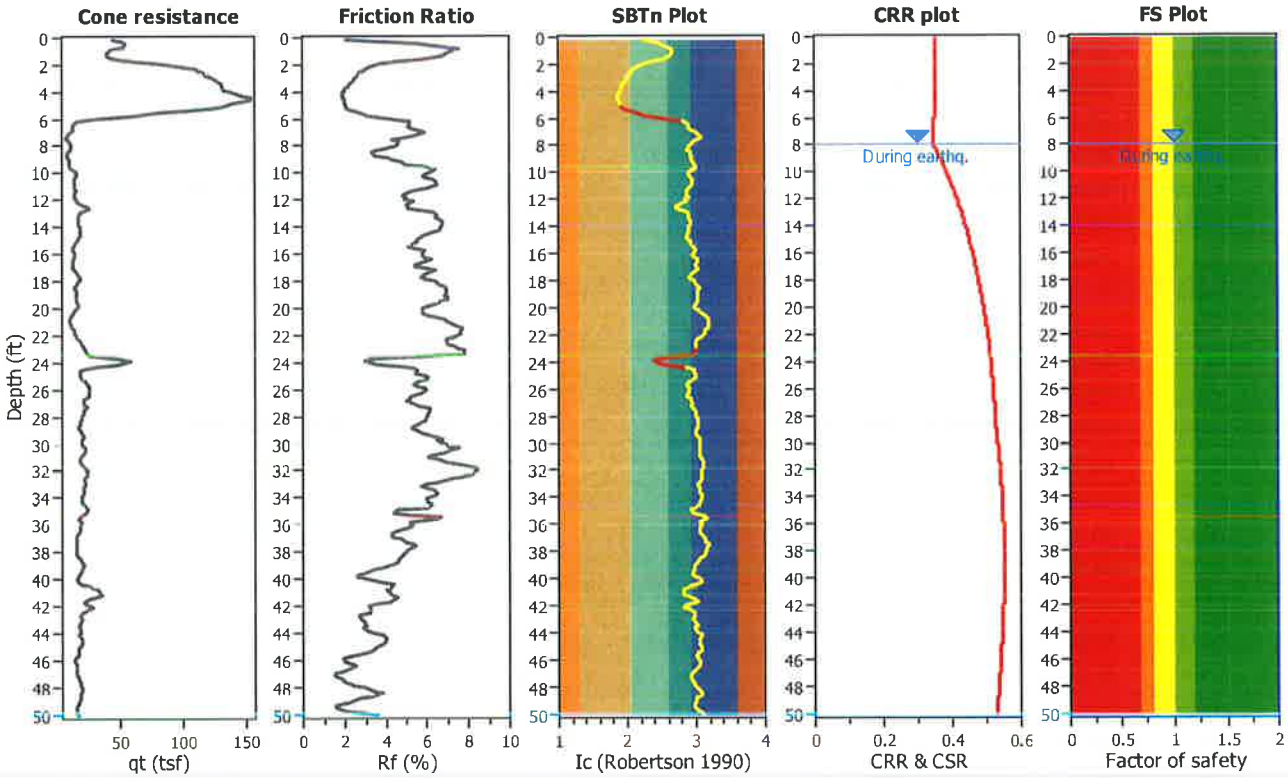
LIQUEFACTION ANALYSIS REPORT

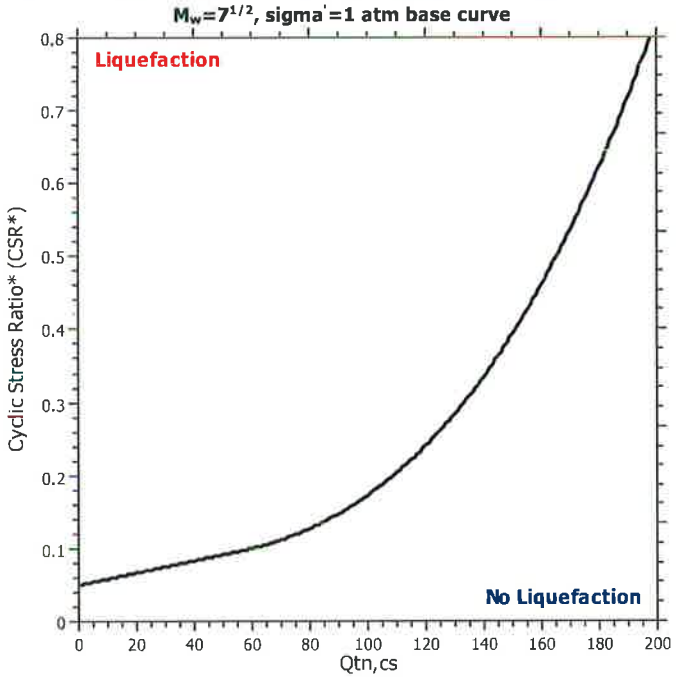
Project title : Heber 2 Repower Project **Location : Heber, CA**

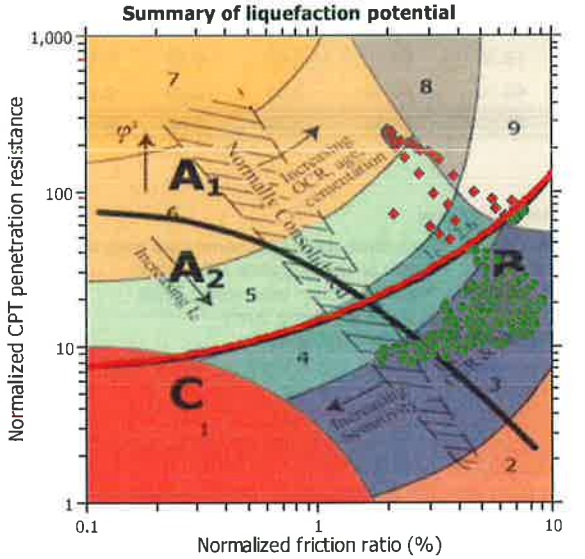
CPT file : CPT-3

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.50	Unit weight calculation:	Based on SBT	K_o applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

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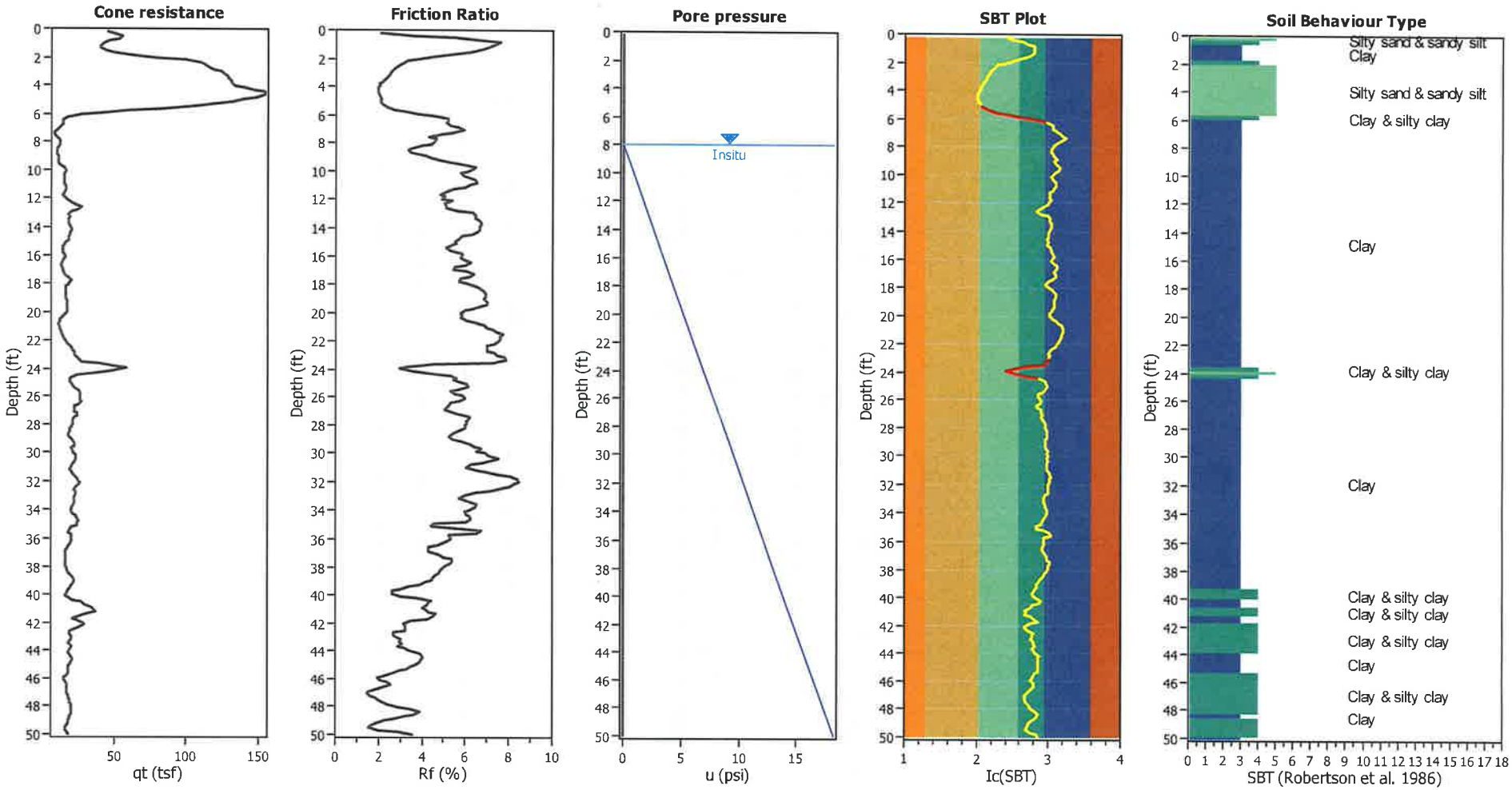
CPT basic interpretation plots



Input parameters and analysis data

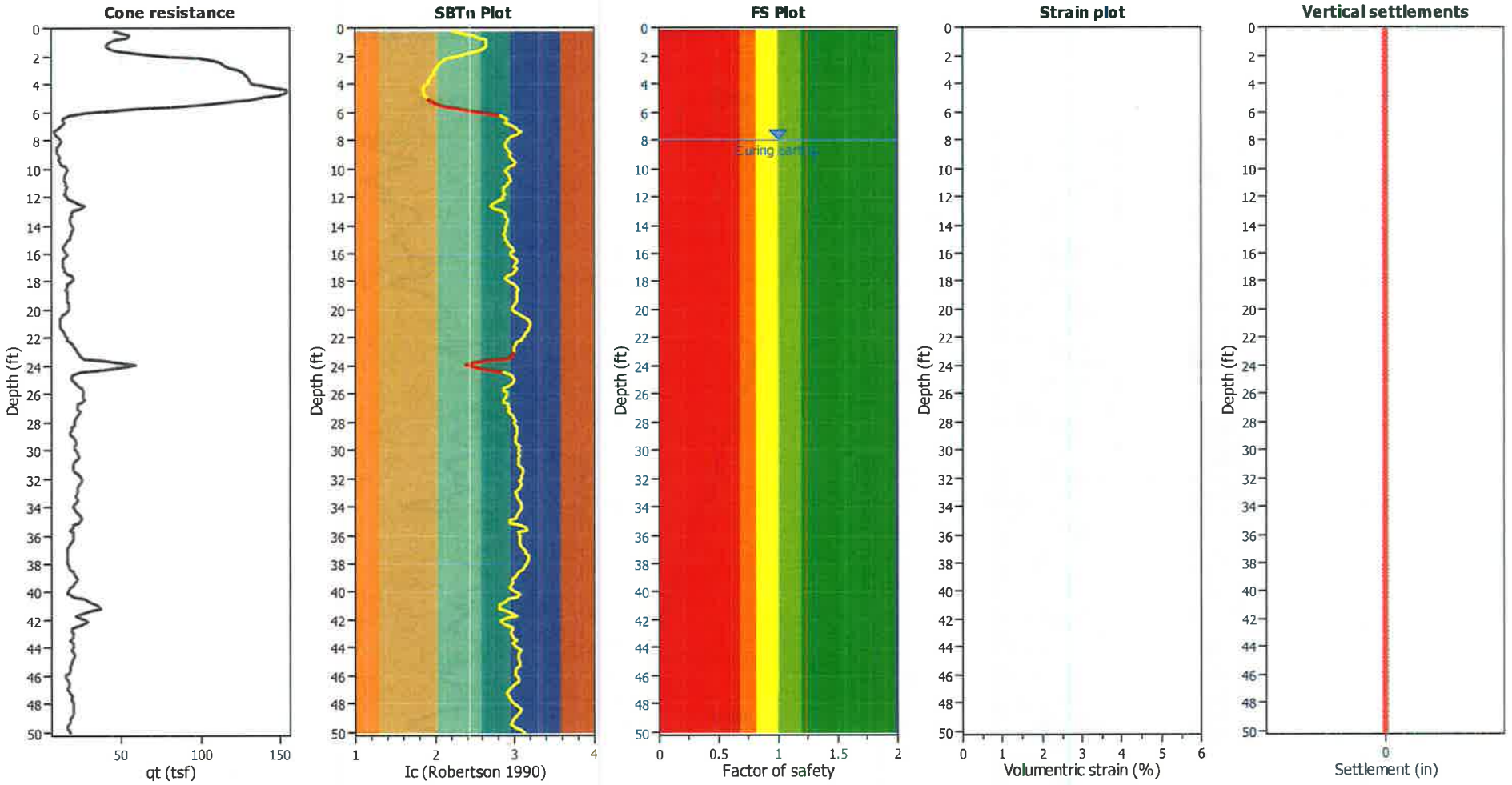
Analysis method:	NCEER (1998)	Depth to water table (erthq.):	8.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.50	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to
9. Very stiff fine grained

EEC ORIGINAL PKG

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
8.04	105.22	2.00	0.00	0.86	0.00	8.20	98.09	2.00	0.00	0.86	0.00
8.37	89.48	2.00	0.00	0.86	0.00	8.53	84.06	2.00	0.00	0.86	0.00
8.69	85.12	2.00	0.00	0.85	0.00	8.86	93.40	2.00	0.00	0.85	0.00
9.02	99.67	2.00	0.00	0.85	0.00	9.19	104.91	2.00	0.00	0.84	0.00
9.35	106.95	2.00	0.00	0.84	0.00	9.51	115.87	2.00	0.00	0.84	0.00
9.68	128.34	2.00	0.00	0.84	0.00	9.84	137.59	2.00	0.00	0.83	0.00
10.01	139.16	2.00	0.00	0.83	0.00	10.17	135.75	2.00	0.00	0.83	0.00
10.33	134.00	2.00	0.00	0.82	0.00	10.50	136.19	2.00	0.00	0.82	0.00
10.66	138.03	2.00	0.00	0.82	0.00	10.83	138.95	2.00	0.00	0.82	0.00
10.99	137.77	2.00	0.00	0.81	0.00	11.15	136.64	2.00	0.00	0.81	0.00
11.32	132.10	2.00	0.00	0.81	0.00	11.48	125.76	2.00	0.00	0.81	0.00
11.65	120.13	2.00	0.00	0.80	0.00	11.81	120.19	2.00	0.00	0.80	0.00
11.98	125.19	2.00	0.00	0.80	0.00	12.14	132.55	2.00	0.00	0.79	0.00
12.30	140.53	2.00	0.00	0.79	0.00	12.47	151.43	2.00	0.00	0.79	0.00
12.63	157.43	2.00	0.00	0.79	0.00	12.80	158.94	2.00	0.00	0.78	0.00
12.96	155.22	2.00	0.00	0.78	0.00	13.12	152.28	2.00	0.00	0.78	0.00
13.29	151.52	2.00	0.00	0.77	0.00	13.45	152.54	2.00	0.00	0.77	0.00
13.62	152.19	2.00	0.00	0.77	0.00	13.78	153.09	2.00	0.00	0.77	0.00
13.94	154.64	2.00	0.00	0.76	0.00	14.11	156.69	2.00	0.00	0.76	0.00
14.27	155.45	2.00	0.00	0.76	0.00	14.44	149.53	2.00	0.00	0.76	0.00
14.60	141.82	2.00	0.00	0.75	0.00	14.76	137.16	2.00	0.00	0.75	0.00
14.93	132.83	2.00	0.00	0.75	0.00	15.09	128.46	2.00	0.00	0.74	0.00
15.26	120.02	2.00	0.00	0.74	0.00	15.42	114.98	2.00	0.00	0.74	0.00
15.58	115.12	2.00	0.00	0.74	0.00	15.75	121.64	2.00	0.00	0.73	0.00
15.91	125.61	2.00	0.00	0.73	0.00	16.08	126.76	2.00	0.00	0.73	0.00
16.24	125.34	2.00	0.00	0.72	0.00	16.40	122.47	2.00	0.00	0.72	0.00
16.57	116.72	2.00	0.00	0.72	0.00	16.73	112.12	2.00	0.00	0.72	0.00
16.90	113.22	2.00	0.00	0.71	0.00	17.06	120.49	2.00	0.00	0.71	0.00
17.22	126.45	2.00	0.00	0.71	0.00	17.39	130.53	2.00	0.00	0.71	0.00
17.55	132.64	2.00	0.00	0.70	0.00	17.72	135.99	2.00	0.00	0.70	0.00
17.88	137.42	2.00	0.00	0.70	0.00	18.04	136.58	2.00	0.00	0.69	0.00
18.21	132.83	2.00	0.00	0.69	0.00	18.37	131.91	2.00	0.00	0.69	0.00
18.54	132.44	2.00	0.00	0.69	0.00	18.70	132.83	2.00	0.00	0.68	0.00
18.86	132.94	2.00	0.00	0.68	0.00	19.03	132.94	2.00	0.00	0.68	0.00
19.19	135.47	2.00	0.00	0.67	0.00	19.36	134.98	2.00	0.00	0.67	0.00
19.52	132.82	2.00	0.00	0.67	0.00	19.69	129.87	2.00	0.00	0.67	0.00
19.85	126.97	2.00	0.00	0.66	0.00	20.01	123.39	2.00	0.00	0.66	0.00
20.18	116.87	2.00	0.00	0.66	0.00	20.34	109.55	2.00	0.00	0.66	0.00
20.51	105.52	2.00	0.00	0.65	0.00	20.67	105.35	2.00	0.00	0.65	0.00
20.83	107.65	2.00	0.00	0.65	0.00	21.00	108.62	2.00	0.00	0.64	0.00
21.16	112.61	2.00	0.00	0.64	0.00	21.33	117.42	2.00	0.00	0.64	0.00
21.49	121.92	2.00	0.00	0.64	0.00	21.65	125.67	2.00	0.00	0.63	0.00
21.82	129.09	2.00	0.00	0.63	0.00	21.98	130.92	2.00	0.00	0.63	0.00
22.15	132.02	2.00	0.00	0.62	0.00	22.31	133.84	2.00	0.00	0.62	0.00
22.47	140.34	2.00	0.00	0.62	0.00	22.64	144.51	2.00	0.00	0.62	0.00
22.80	149.71	2.00	0.00	0.61	0.00	22.97	152.21	2.00	0.00	0.61	0.00
23.13	158.62	2.00	0.00	0.61	0.00	23.29	164.29	2.00	0.00	0.61	0.00
23.46	163.34	2.00	0.00	0.60	0.00	23.62	149.57	2.00	0.00	0.60	0.00

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
23.79	137.21	2.00	0.00	0.60	0.00	23.95	138.01	2.00	0.00	0.59	0.00
24.11	142.14	2.00	0.00	0.59	0.00	24.28	141.20	2.00	0.00	0.59	0.00
24.44	130.89	2.00	0.00	0.59	0.00	24.61	121.03	2.00	0.00	0.58	0.00
24.77	117.62	2.00	0.00	0.58	0.00	24.93	121.38	2.00	0.00	0.58	0.00
25.10	126.27	2.00	0.00	0.57	0.00	25.26	130.22	2.00	0.00	0.57	0.00
25.43	129.59	2.00	0.00	0.57	0.00	25.59	131.09	2.00	0.00	0.57	0.00
25.75	135.18	2.00	0.00	0.56	0.00	25.92	139.49	2.00	0.00	0.56	0.00
26.08	139.40	2.00	0.00	0.56	0.00	26.25	137.13	2.00	0.00	0.56	0.00
26.41	133.24	2.00	0.00	0.55	0.00	26.57	128.22	2.00	0.00	0.55	0.00
26.74	120.94	2.00	0.00	0.55	0.00	26.90	117.65	2.00	0.00	0.54	0.00
27.07	123.39	2.00	0.00	0.54	0.00	27.23	130.15	2.00	0.00	0.54	0.00
27.40	134.00	2.00	0.00	0.54	0.00	27.56	130.29	2.00	0.00	0.53	0.00
27.72	125.72	2.00	0.00	0.53	0.00	27.89	123.53	2.00	0.00	0.53	0.00
28.05	123.09	2.00	0.00	0.52	0.00	28.22	121.41	2.00	0.00	0.52	0.00
28.38	117.09	2.00	0.00	0.52	0.00	28.54	111.50	2.00	0.00	0.52	0.00
28.71	108.31	2.00	0.00	0.51	0.00	28.87	107.69	2.00	0.00	0.51	0.00
29.04	112.56	2.00	0.00	0.51	0.00	29.20	119.74	2.00	0.00	0.51	0.00
29.36	125.93	2.00	0.00	0.50	0.00	29.53	127.06	2.00	0.00	0.50	0.00
29.69	126.51	2.00	0.00	0.50	0.00	29.86	125.39	2.00	0.00	0.49	0.00
30.02	129.92	2.00	0.00	0.49	0.00	30.18	135.27	2.00	0.00	0.49	0.00
30.35	140.32	2.00	0.00	0.49	0.00	30.51	137.30	2.00	0.00	0.48	0.00
30.68	129.14	2.00	0.00	0.48	0.00	30.84	120.95	2.00	0.00	0.48	0.00
31.00	116.56	2.00	0.00	0.47	0.00	31.17	119.19	2.00	0.00	0.47	0.00
31.33	123.11	2.00	0.00	0.47	0.00	31.50	131.51	2.00	0.00	0.47	0.00
31.66	140.19	2.00	0.00	0.46	0.00	31.82	148.00	2.00	0.00	0.46	0.00
31.99	151.97	2.00	0.00	0.46	0.00	32.15	151.52	2.00	0.00	0.46	0.00
32.32	145.89	2.00	0.00	0.45	0.00	32.48	138.22	2.00	0.00	0.45	0.00
32.64	131.44	2.00	0.00	0.45	0.00	32.81	126.66	2.00	0.00	0.44	0.00
32.97	120.92	2.00	0.00	0.44	0.00	33.14	115.82	2.00	0.00	0.44	0.00
33.30	117.32	2.00	0.00	0.44	0.00	33.46	122.10	2.00	0.00	0.43	0.00
33.63	123.45	2.00	0.00	0.43	0.00	33.79	118.97	2.00	0.00	0.43	0.00
33.96	114.29	2.00	0.00	0.42	0.00	34.12	113.26	2.00	0.00	0.42	0.00
34.28	116.07	2.00	0.00	0.42	0.00	34.45	120.77	2.00	0.00	0.42	0.00
34.61	124.37	2.00	0.00	0.41	0.00	34.78	124.30	2.00	0.00	0.41	0.00
34.94	107.22	2.00	0.00	0.41	0.00	35.10	104.14	2.00	0.00	0.41	0.00
35.27	103.90	2.00	0.00	0.40	0.00	35.43	114.48	2.00	0.00	0.40	0.00
35.60	108.91	2.00	0.00	0.40	0.00	35.76	103.69	2.00	0.00	0.39	0.00
35.93	103.19	2.00	0.00	0.39	0.00	36.09	102.94	2.00	0.00	0.39	0.00
36.25	100.79	2.00	0.00	0.39	0.00	36.42	95.16	2.00	0.00	0.38	0.00
36.58	89.61	2.00	0.00	0.38	0.00	36.75	86.08	2.00	0.00	0.38	0.00
36.91	85.66	2.00	0.00	0.37	0.00	37.07	88.52	2.00	0.00	0.37	0.00
37.24	90.83	2.00	0.00	0.37	0.00	37.40	92.89	2.00	0.00	0.37	0.00
37.57	92.98	2.00	0.00	0.36	0.00	37.73	92.32	2.00	0.00	0.36	0.00
37.89	90.55	2.00	0.00	0.36	0.00	38.06	89.64	2.00	0.00	0.35	0.00
38.22	90.25	2.00	0.00	0.35	0.00	38.39	91.89	2.00	0.00	0.35	0.00
38.55	94.23	2.00	0.00	0.35	0.00	38.71	96.50	2.00	0.00	0.34	0.00
38.88	96.89	2.00	0.00	0.34	0.00	39.04	94.80	2.00	0.00	0.34	0.00
39.21	90.16	2.00	0.00	0.34	0.00	39.37	83.66	2.00	0.00	0.33	0.00

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
39.53	76.97	2.00	0.00	0.33	0.00	39.70	70.89	2.00	0.00	0.33	0.00
39.86	68.91	2.00	0.00	0.32	0.00	40.03	71.76	2.00	0.00	0.32	0.00
40.19	81.13	2.00	0.00	0.32	0.00	40.35	93.57	2.00	0.00	0.32	0.00
40.52	103.75	2.00	0.00	0.31	0.00	40.68	107.44	2.00	0.00	0.31	0.00
40.85	110.91	2.00	0.00	0.31	0.00	41.01	115.14	2.00	0.00	0.30	0.00
41.17	118.91	2.00	0.00	0.30	0.00	41.34	114.80	2.00	0.00	0.30	0.00
41.50	103.67	2.00	0.00	0.30	0.00	41.67	91.95	2.00	0.00	0.29	0.00
41.83	88.04	2.00	0.00	0.29	0.00	41.99	90.47	2.00	0.00	0.29	0.00
42.16	92.83	2.00	0.00	0.29	0.00	42.32	87.29	2.00	0.00	0.28	0.00
42.49	78.72	2.00	0.00	0.28	0.00	42.65	71.54	2.00	0.00	0.28	0.00
42.81	71.84	2.00	0.00	0.27	0.00	42.98	73.65	2.00	0.00	0.27	0.00
43.14	75.58	2.00	0.00	0.27	0.00	43.31	74.00	2.00	0.00	0.27	0.00
43.47	73.64	2.00	0.00	0.26	0.00	43.64	73.86	2.00	0.00	0.26	0.00
43.80	76.92	2.00	0.00	0.26	0.00	43.96	78.92	2.00	0.00	0.25	0.00
44.13	81.06	2.00	0.00	0.25	0.00	44.29	83.91	2.00	0.00	0.25	0.00
44.46	85.95	2.00	0.00	0.25	0.00	44.62	85.68	2.00	0.00	0.24	0.00
44.78	83.55	2.00	0.00	0.24	0.00	44.95	80.58	2.00	0.00	0.24	0.00
45.11	77.10	2.00	0.00	0.24	0.00	45.28	74.16	2.00	0.00	0.23	0.00
45.44	71.31	2.00	0.00	0.23	0.00	45.60	66.96	2.00	0.00	0.23	0.00
45.77	60.99	2.00	0.00	0.22	0.00	45.93	55.97	2.00	0.00	0.22	0.00
46.10	56.91	2.00	0.00	0.22	0.00	46.26	61.03	2.00	0.00	0.22	0.00
46.42	64.41	2.00	0.00	0.21	0.00	46.59	62.81	2.00	0.00	0.21	0.00
46.75	58.05	2.00	0.00	0.21	0.00	46.92	53.06	2.00	0.00	0.20	0.00
47.08	52.59	2.00	0.00	0.20	0.00	47.24	54.97	2.00	0.00	0.20	0.00
47.41	58.19	2.00	0.00	0.20	0.00	47.57	61.05	2.00	0.00	0.19	0.00
47.74	64.16	2.00	0.00	0.19	0.00	47.90	66.86	2.00	0.00	0.19	0.00
48.06	73.10	2.00	0.00	0.19	0.00	48.23	77.76	2.00	0.00	0.18	0.00
48.39	80.72	2.00	0.00	0.18	0.00	48.56	78.24	2.00	0.00	0.18	0.00
48.72	74.42	2.00	0.00	0.17	0.00	48.88	68.90	2.00	0.00	0.17	0.00
49.05	63.15	2.00	0.00	0.17	0.00	49.21	57.14	2.00	0.00	0.17	0.00
49.38	52.74	2.00	0.00	0.16	0.00	49.54	51.53	2.00	0.00	0.16	0.00
49.70	56.86	2.00	0.00	0.16	0.00	49.87	66.86	2.00	0.00	0.15	0.00
50.03	74.65	2.00	0.00	0.15	0.00						

Total estimated settlement: 0.00

Abbreviations

$Q_{tn,cs}$:	Equivalent clean sand normalized cone resistance
FS:	Factor of safety against liquefaction
e_v (%):	Post-liquefaction volumentric strain
DF:	e_v depth weighting factor
Settlement:	Calculated settlement

EEC ORIGINAL PKG

LANDMARK
Geo-Engineers and Geologists

Landmark Consultants, Inc.
780 N. 4th Street
El Centro, CA 92243

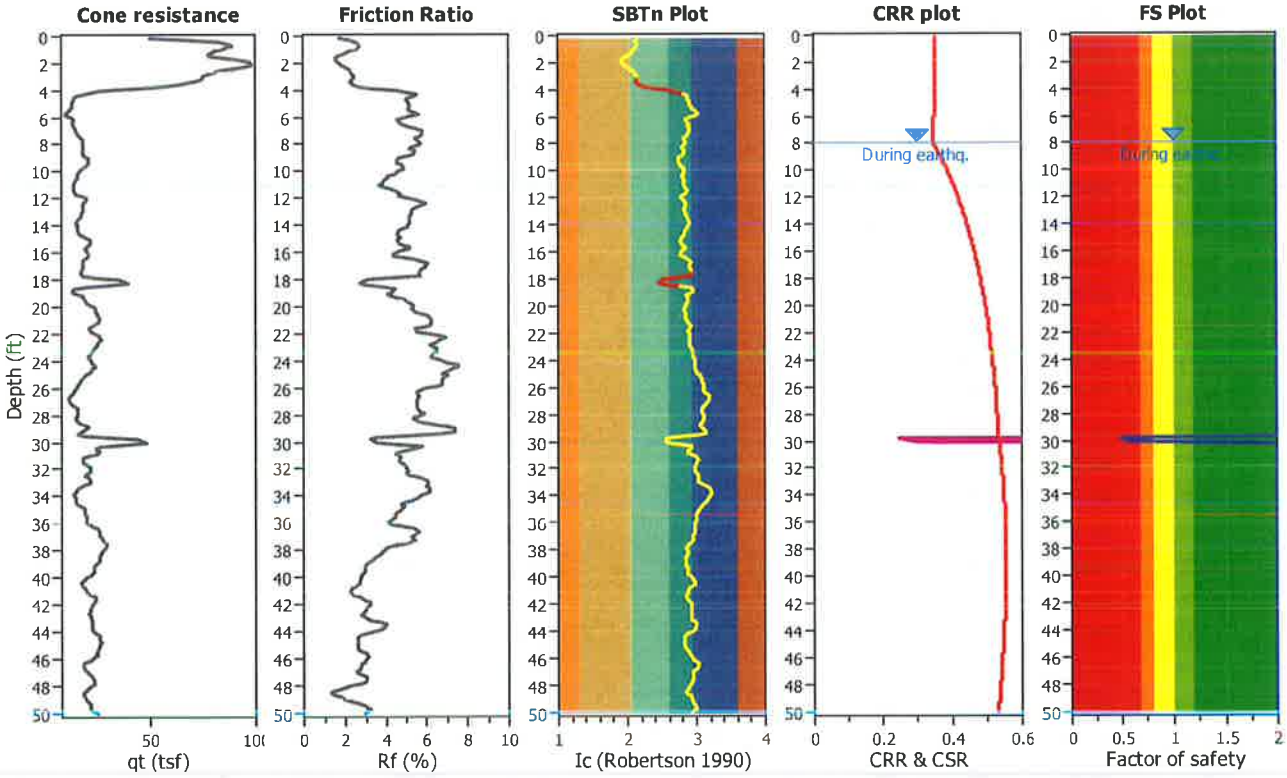
LIQUEFACTION ANALYSIS REPORT

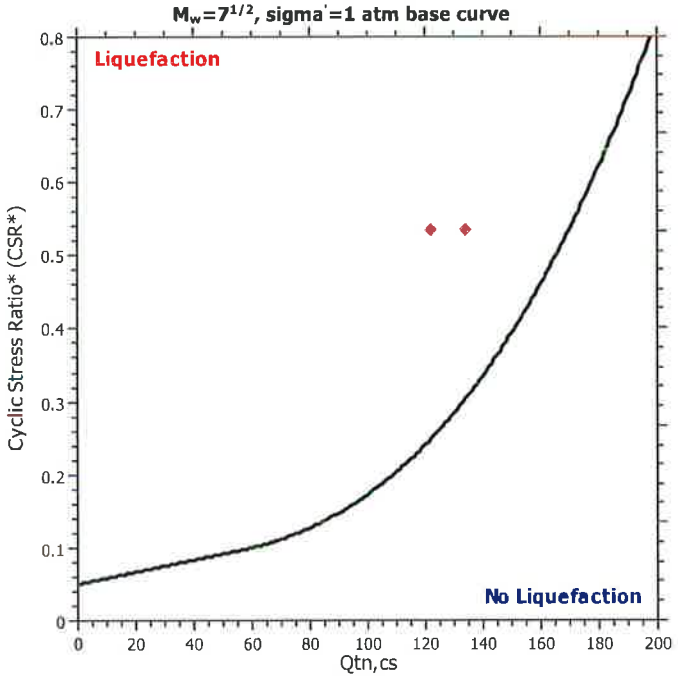
Project title : Heber 2 Repower Project **Location : Heber, CA**

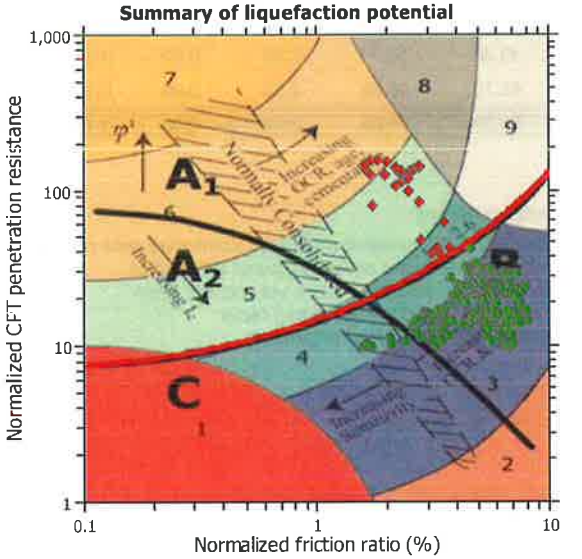
CPT file : CPT-4

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.50	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

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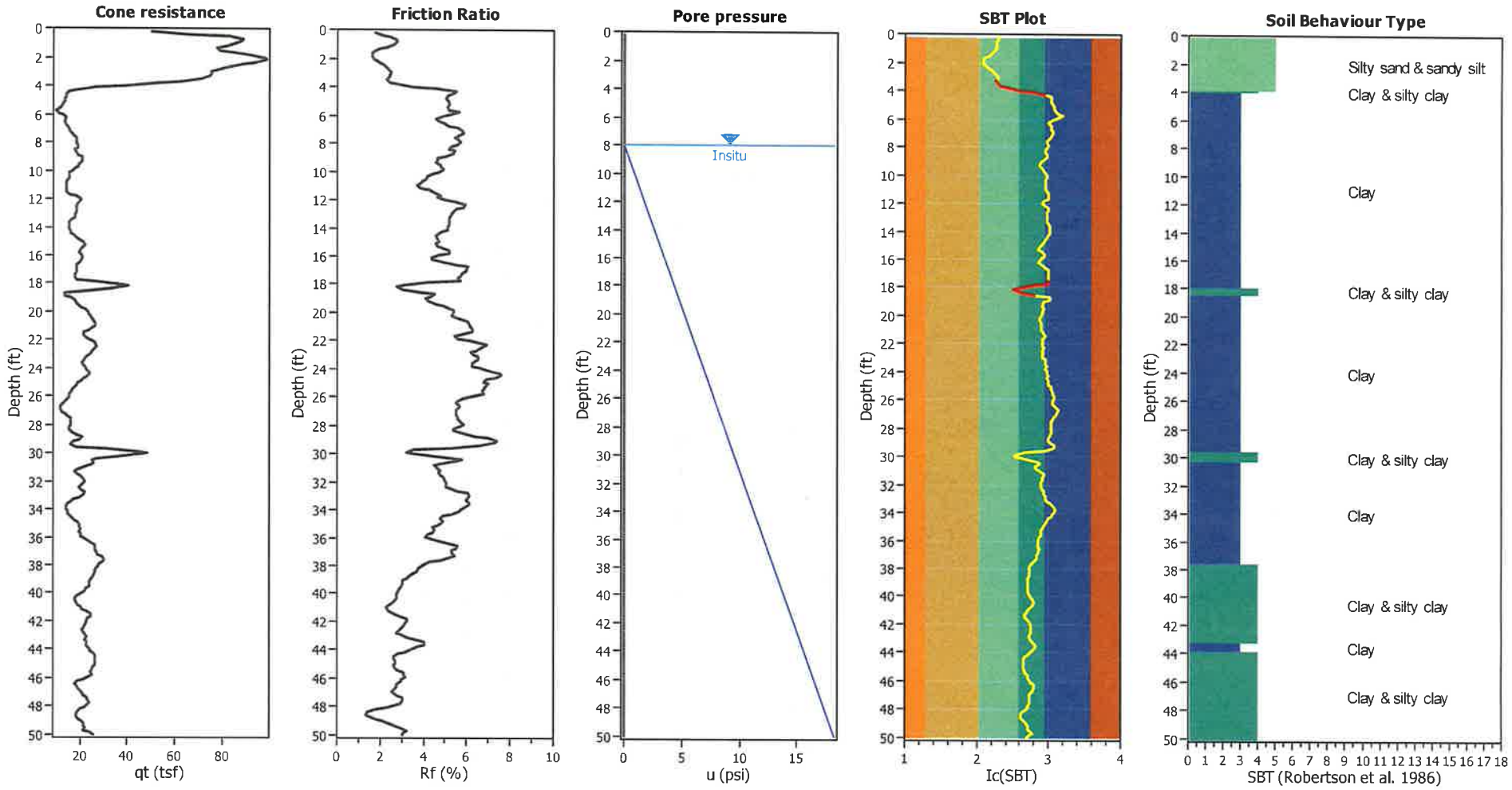
CPT basic interpretation plots



Input parameters and analysis data

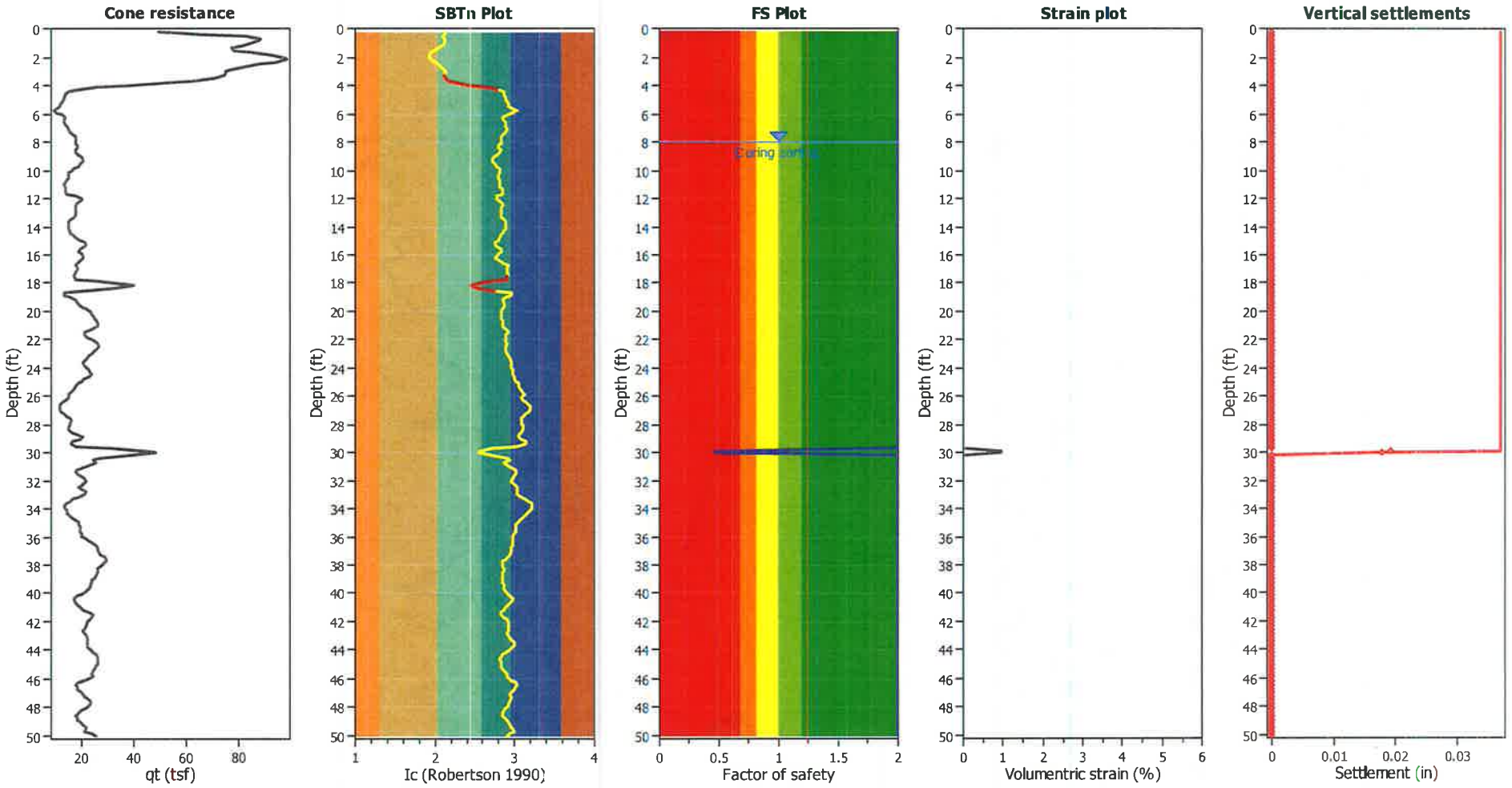
Analysis method:	NCEER (1998)	Depth to water table (erthq.):	8.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.50	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

EEC ORIGINAL PKG

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
8.04	142.33	2.00	0.00	0.86	0.00	8.20	139.48	2.00	0.00	0.86	0.00
8.37	138.37	2.00	0.00	0.86	0.00	8.53	139.38	2.00	0.00	0.86	0.00
8.69	139.25	2.00	0.00	0.85	0.00	8.86	137.40	2.00	0.00	0.85	0.00
9.02	135.29	2.00	0.00	0.85	0.00	9.19	135.08	2.00	0.00	0.84	0.00
9.35	134.94	2.00	0.00	0.84	0.00	9.51	135.74	2.00	0.00	0.84	0.00
9.68	134.20	2.00	0.00	0.84	0.00	9.84	130.53	2.00	0.00	0.83	0.00
10.01	123.17	2.00	0.00	0.83	0.00	10.17	117.24	2.00	0.00	0.83	0.00
10.33	113.17	2.00	0.00	0.82	0.00	10.50	112.17	2.00	0.00	0.82	0.00
10.66	108.77	2.00	0.00	0.82	0.00	10.83	104.41	2.00	0.00	0.82	0.00
10.99	101.82	2.00	0.00	0.81	0.00	11.15	104.52	2.00	0.00	0.81	0.00
11.32	109.26	2.00	0.00	0.81	0.00	11.48	112.95	2.00	0.00	0.81	0.00
11.65	119.67	2.00	0.00	0.80	0.00	11.81	128.35	2.00	0.00	0.80	0.00
11.98	140.47	2.00	0.00	0.80	0.00	12.14	147.20	2.00	0.00	0.79	0.00
12.30	148.82	2.00	0.00	0.79	0.00	12.47	144.70	2.00	0.00	0.79	0.00
12.63	140.44	2.00	0.00	0.79	0.00	12.80	138.49	2.00	0.00	0.78	0.00
12.96	137.16	2.00	0.00	0.78	0.00	13.12	135.57	2.00	0.00	0.78	0.00
13.29	132.50	2.00	0.00	0.77	0.00	13.45	129.05	2.00	0.00	0.77	0.00
13.62	125.64	2.00	0.00	0.77	0.00	13.78	124.00	2.00	0.00	0.77	0.00
13.94	123.55	2.00	0.00	0.76	0.00	14.11	123.41	2.00	0.00	0.76	0.00
14.27	120.42	2.00	0.00	0.76	0.00	14.44	118.59	2.00	0.00	0.76	0.00
14.60	119.72	2.00	0.00	0.75	0.00	14.76	124.75	2.00	0.00	0.75	0.00
14.93	129.68	2.00	0.00	0.75	0.00	15.09	132.02	2.00	0.00	0.74	0.00
15.26	133.55	2.00	0.00	0.74	0.00	15.42	134.74	2.00	0.00	0.74	0.00
15.58	134.99	2.00	0.00	0.74	0.00	15.75	133.14	2.00	0.00	0.73	0.00
15.91	128.53	2.00	0.00	0.73	0.00	16.08	125.13	2.00	0.00	0.73	0.00
16.24	124.40	2.00	0.00	0.72	0.00	16.40	129.52	2.00	0.00	0.72	0.00
16.57	133.92	2.00	0.00	0.72	0.00	16.73	138.54	2.00	0.00	0.72	0.00
16.90	138.35	2.00	0.00	0.71	0.00	17.06	138.11	2.00	0.00	0.71	0.00
17.22	135.17	2.00	0.00	0.71	0.00	17.39	131.59	2.00	0.00	0.71	0.00
17.55	129.88	2.00	0.00	0.70	0.00	17.72	132.65	2.00	0.00	0.70	0.00
17.88	129.80	2.00	0.00	0.70	0.00	18.04	125.42	2.00	0.00	0.69	0.00
18.21	120.72	2.00	0.00	0.69	0.00	18.37	117.18	2.00	0.00	0.69	0.00
18.54	111.78	2.00	0.00	0.69	0.00	18.70	102.14	2.00	0.00	0.68	0.00
18.86	99.81	2.00	0.00	0.68	0.00	19.03	103.57	2.00	0.00	0.68	0.00
19.19	110.46	2.00	0.00	0.67	0.00	19.36	115.60	2.00	0.00	0.67	0.00
19.52	121.21	2.00	0.00	0.67	0.00	19.69	128.63	2.00	0.00	0.67	0.00
19.85	135.46	2.00	0.00	0.66	0.00	20.01	137.97	2.00	0.00	0.66	0.00
20.18	138.68	2.00	0.00	0.66	0.00	20.34	141.42	2.00	0.00	0.66	0.00
20.51	148.20	2.00	0.00	0.65	0.00	20.67	152.28	2.00	0.00	0.65	0.00
20.83	154.70	2.00	0.00	0.65	0.00	21.00	155.14	2.00	0.00	0.64	0.00
21.16	153.33	2.00	0.00	0.64	0.00	21.33	146.51	2.00	0.00	0.64	0.00
21.49	137.48	2.00	0.00	0.64	0.00	21.65	130.46	2.00	0.00	0.63	0.00
21.82	135.64	2.00	0.00	0.63	0.00	21.98	146.28	2.00	0.00	0.63	0.00
22.15	157.92	2.00	0.00	0.62	0.00	22.31	162.22	2.00	0.00	0.62	0.00
22.47	158.98	2.00	0.00	0.62	0.00	22.64	153.08	2.00	0.00	0.62	0.00
22.80	147.97	2.00	0.00	0.61	0.00	22.97	147.24	2.00	0.00	0.61	0.00
23.13	146.00	2.00	0.00	0.61	0.00	23.29	142.46	2.00	0.00	0.61	0.00
23.46	137.35	2.00	0.00	0.60	0.00	23.62	134.72	2.00	0.00	0.60	0.00

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
23.79	135.51	2.00	0.00	0.60	0.00	23.95	140.30	2.00	0.00	0.59	0.00
24.11	148.28	2.00	0.00	0.59	0.00	24.28	155.88	2.00	0.00	0.59	0.00
24.44	157.27	2.00	0.00	0.59	0.00	24.61	150.21	2.00	0.00	0.58	0.00
24.77	141.21	2.00	0.00	0.58	0.00	24.93	135.75	2.00	0.00	0.58	0.00
25.10	133.99	2.00	0.00	0.57	0.00	25.26	129.44	2.00	0.00	0.57	0.00
25.43	124.86	2.00	0.00	0.57	0.00	25.59	121.99	2.00	0.00	0.57	0.00
25.75	119.46	2.00	0.00	0.56	0.00	25.92	114.39	2.00	0.00	0.56	0.00
26.08	108.01	2.00	0.00	0.56	0.00	26.25	102.56	2.00	0.00	0.56	0.00
26.41	98.09	2.00	0.00	0.55	0.00	26.57	94.88	2.00	0.00	0.55	0.00
26.74	93.00	2.00	0.00	0.55	0.00	26.90	92.55	2.00	0.00	0.54	0.00
27.07	94.48	2.00	0.00	0.54	0.00	27.23	98.16	2.00	0.00	0.54	0.00
27.40	102.11	2.00	0.00	0.54	0.00	27.56	105.58	2.00	0.00	0.53	0.00
27.72	108.32	2.00	0.00	0.53	0.00	27.89	108.90	2.00	0.00	0.53	0.00
28.05	105.70	2.00	0.00	0.52	0.00	28.22	101.01	2.00	0.00	0.52	0.00
28.38	101.21	2.00	0.00	0.52	0.00	28.54	109.35	2.00	0.00	0.52	0.00
28.71	122.45	2.00	0.00	0.51	0.00	28.87	132.20	2.00	0.00	0.51	0.00
29.04	132.26	2.00	0.00	0.51	0.00	29.20	122.61	2.00	0.00	0.51	0.00
29.36	113.45	2.00	0.00	0.50	0.00	29.53	108.45	2.00	0.00	0.50	0.00
29.69	112.51	2.00	0.00	0.50	0.00	29.86	122.10	0.47	0.98	0.49	0.02
30.02	134.00	0.57	0.90	0.49	0.02	30.18	139.79	2.00	0.00	0.49	0.00
30.35	134.38	2.00	0.00	0.49	0.00	30.51	125.58	2.00	0.00	0.48	0.00
30.68	118.58	2.00	0.00	0.48	0.00	30.84	113.67	2.00	0.00	0.48	0.00
31.00	107.11	2.00	0.00	0.47	0.00	31.17	101.29	2.00	0.00	0.47	0.00
31.33	99.19	2.00	0.00	0.47	0.00	31.50	101.98	2.00	0.00	0.47	0.00
31.66	105.65	2.00	0.00	0.46	0.00	31.82	110.41	2.00	0.00	0.46	0.00
31.99	112.05	2.00	0.00	0.46	0.00	32.15	110.51	2.00	0.00	0.46	0.00
32.32	106.64	2.00	0.00	0.45	0.00	32.48	106.90	2.00	0.00	0.45	0.00
32.64	113.40	2.00	0.00	0.45	0.00	32.81	120.33	2.00	0.00	0.44	0.00
32.97	120.02	2.00	0.00	0.44	0.00	33.14	113.57	2.00	0.00	0.44	0.00
33.30	105.91	2.00	0.00	0.44	0.00	33.46	102.21	2.00	0.00	0.43	0.00
33.63	98.16	2.00	0.00	0.43	0.00	33.79	94.29	2.00	0.00	0.43	0.00
33.96	92.81	2.00	0.00	0.42	0.00	34.12	94.31	2.00	0.00	0.42	0.00
34.28	92.55	2.00	0.00	0.42	0.00	34.45	90.14	2.00	0.00	0.42	0.00
34.61	91.88	2.00	0.00	0.41	0.00	34.78	97.81	2.00	0.00	0.41	0.00
34.94	99.81	2.00	0.00	0.41	0.00	35.10	98.30	2.00	0.00	0.41	0.00
35.27	96.86	2.00	0.00	0.40	0.00	35.43	97.74	2.00	0.00	0.40	0.00
35.60	97.15	2.00	0.00	0.40	0.00	35.76	95.38	2.00	0.00	0.39	0.00
35.93	94.33	2.00	0.00	0.39	0.00	36.09	98.44	2.00	0.00	0.39	0.00
36.25	106.57	2.00	0.00	0.39	0.00	36.42	116.11	2.00	0.00	0.38	0.00
36.58	121.17	2.00	0.00	0.38	0.00	36.75	121.27	2.00	0.00	0.38	0.00
36.91	118.99	2.00	0.00	0.37	0.00	37.07	118.97	2.00	0.00	0.37	0.00
37.24	121.97	2.00	0.00	0.37	0.00	37.40	122.80	2.00	0.00	0.37	0.00
37.57	119.74	2.00	0.00	0.36	0.00	37.73	112.21	2.00	0.00	0.36	0.00
37.89	105.81	2.00	0.00	0.36	0.00	38.06	101.75	2.00	0.00	0.35	0.00
38.22	99.67	2.00	0.00	0.35	0.00	38.39	97.89	2.00	0.00	0.35	0.00
38.55	95.90	2.00	0.00	0.35	0.00	38.71	93.10	2.00	0.00	0.34	0.00
38.88	89.59	2.00	0.00	0.34	0.00	39.04	86.60	2.00	0.00	0.34	0.00
39.21	85.25	2.00	0.00	0.34	0.00	39.37	84.76	2.00	0.00	0.33	0.00

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:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
39.53	83.85	2.00	0.00	0.33	0.00	39.70	81.80	2.00	0.00	0.33	0.00
39.86	79.22	2.00	0.00	0.32	0.00	40.03	76.47	2.00	0.00	0.32	0.00
40.19	73.46	2.00	0.00	0.32	0.00	40.35	71.67	2.00	0.00	0.32	0.00
40.52	70.72	2.00	0.00	0.31	0.00	40.68	69.95	2.00	0.00	0.31	0.00
40.85	69.28	2.00	0.00	0.31	0.00	41.01	69.53	2.00	0.00	0.30	0.00
41.17	71.27	2.00	0.00	0.30	0.00	41.34	74.52	2.00	0.00	0.30	0.00
41.50	80.79	2.00	0.00	0.30	0.00	41.67	83.97	2.00	0.00	0.29	0.00
41.83	85.73	2.00	0.00	0.29	0.00	41.99	83.77	2.00	0.00	0.29	0.00
42.16	83.35	2.00	0.00	0.29	0.00	42.32	81.51	2.00	0.00	0.28	0.00
42.49	78.90	2.00	0.00	0.28	0.00	42.65	77.04	2.00	0.00	0.28	0.00
42.81	76.77	2.00	0.00	0.27	0.00	42.98	78.97	2.00	0.00	0.27	0.00
43.14	83.16	2.00	0.00	0.27	0.00	43.31	88.56	2.00	0.00	0.27	0.00
43.47	91.55	2.00	0.00	0.26	0.00	43.64	91.06	2.00	0.00	0.26	0.00
43.80	88.91	2.00	0.00	0.26	0.00	43.96	86.77	2.00	0.00	0.25	0.00
44.13	84.65	2.00	0.00	0.25	0.00	44.29	82.07	2.00	0.00	0.25	0.00
44.46	80.48	2.00	0.00	0.25	0.00	44.62	80.38	2.00	0.00	0.24	0.00
44.78	80.96	2.00	0.00	0.24	0.00	44.95	80.56	2.00	0.00	0.24	0.00
45.11	79.49	2.00	0.00	0.24	0.00	45.28	79.02	2.00	0.00	0.23	0.00
45.44	79.84	2.00	0.00	0.23	0.00	45.60	82.76	2.00	0.00	0.23	0.00
45.77	83.63	2.00	0.00	0.22	0.00	45.93	82.78	2.00	0.00	0.22	0.00
46.10	77.11	2.00	0.00	0.22	0.00	46.26	72.76	2.00	0.00	0.22	0.00
46.42	69.37	2.00	0.00	0.21	0.00	46.59	69.74	2.00	0.00	0.21	0.00
46.75	69.62	2.00	0.00	0.21	0.00	46.92	69.91	2.00	0.00	0.20	0.00
47.08	72.01	2.00	0.00	0.20	0.00	47.24	75.02	2.00	0.00	0.20	0.00
47.41	78.40	2.00	0.00	0.20	0.00	47.57	79.97	2.00	0.00	0.19	0.00
47.74	79.74	2.00	0.00	0.19	0.00	47.90	76.12	2.00	0.00	0.19	0.00
48.06	69.32	2.00	0.00	0.19	0.00	48.23	60.53	2.00	0.00	0.18	0.00
48.39	53.50	2.00	0.00	0.18	0.00	48.56	51.55	2.00	0.00	0.18	0.00
48.72	53.74	2.00	0.00	0.17	0.00	48.88	58.38	2.00	0.00	0.17	0.00
49.05	63.34	2.00	0.00	0.17	0.00	49.21	68.92	2.00	0.00	0.17	0.00
49.38	72.80	2.00	0.00	0.16	0.00	49.54	76.03	2.00	0.00	0.16	0.00
49.70	77.80	2.00	0.00	0.16	0.00	49.87	79.94	2.00	0.00	0.15	0.00
50.03	81.33	2.00	0.00	0.15	0.00						

Total estimated settlement: 0.04

Abbreviations

$Q_{tn,cs}$:	Equivalent clean sand normalized cone resistance
FS:	Factor of safety against liquefaction
e_v (%):	Post-liquefaction volumentric strain
DF:	e_v depth weighting factor
Settlement:	Calculated settlement

EEC ORIGINAL PKG

LANDMARK
Geo-Engineers and Geologists

Landmark Consultants, Inc.
780 N. 4th Street
El Centro, CA 92243

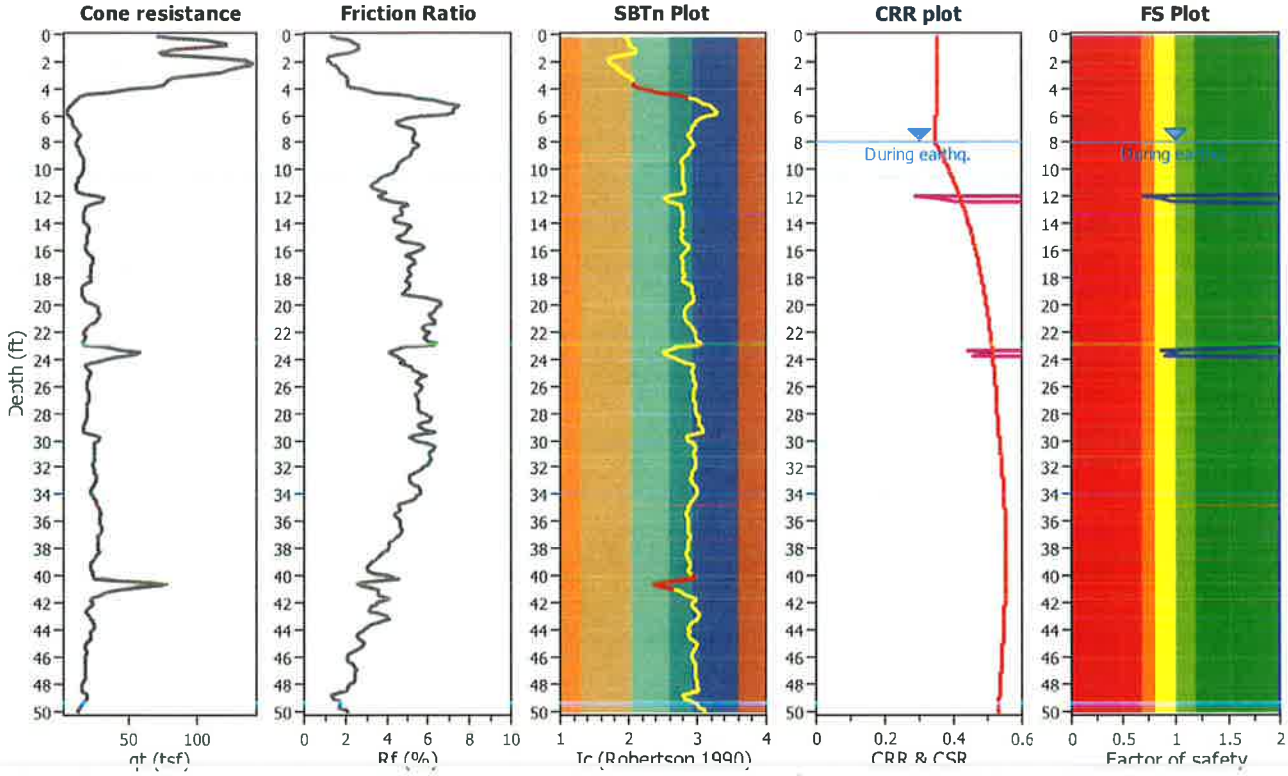
LIQUEFACTION ANALYSIS REPORT

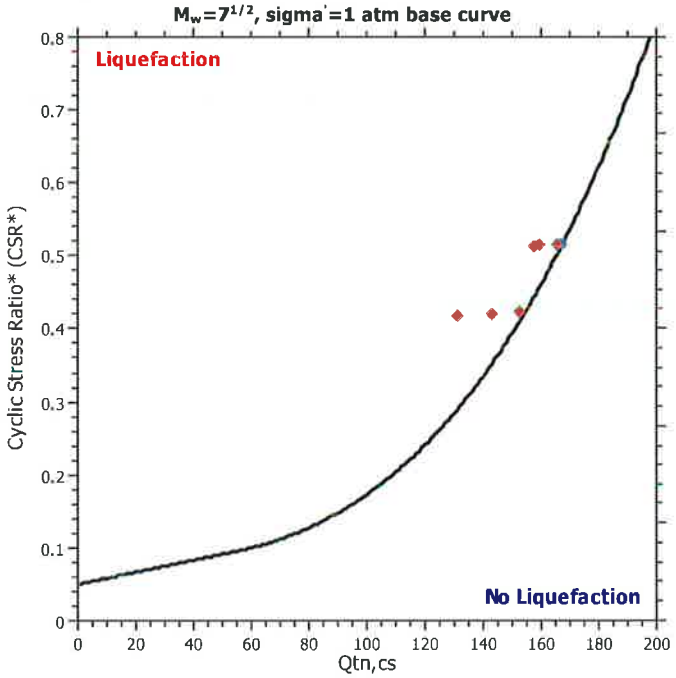
Project title : Heber 2 Repower Project **Location : Heber, CA**

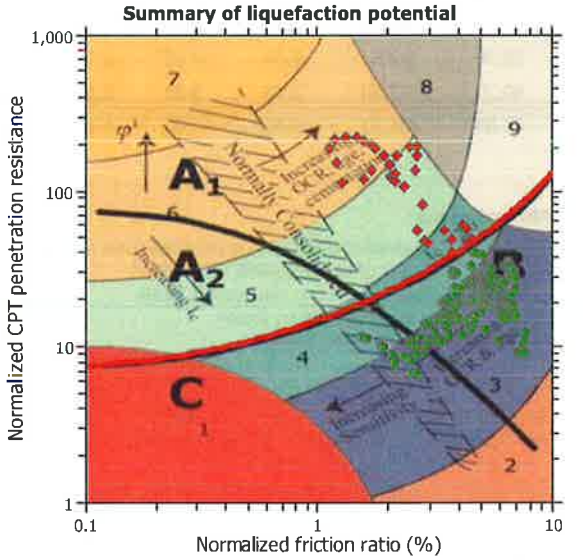
CPT file : CPT-5

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.00	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.50	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

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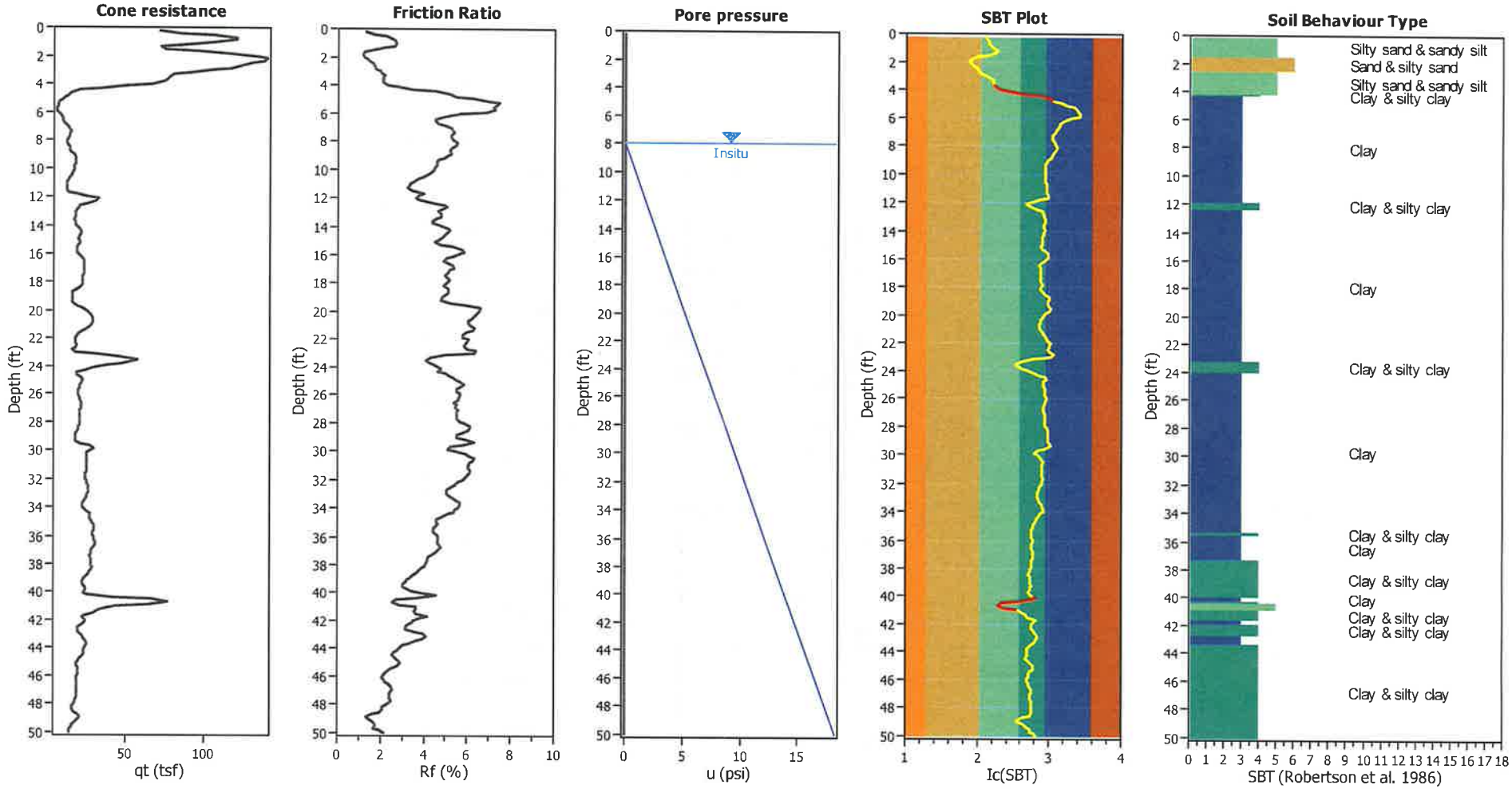
CPT basic interpretation plots



Input parameters and analysis data

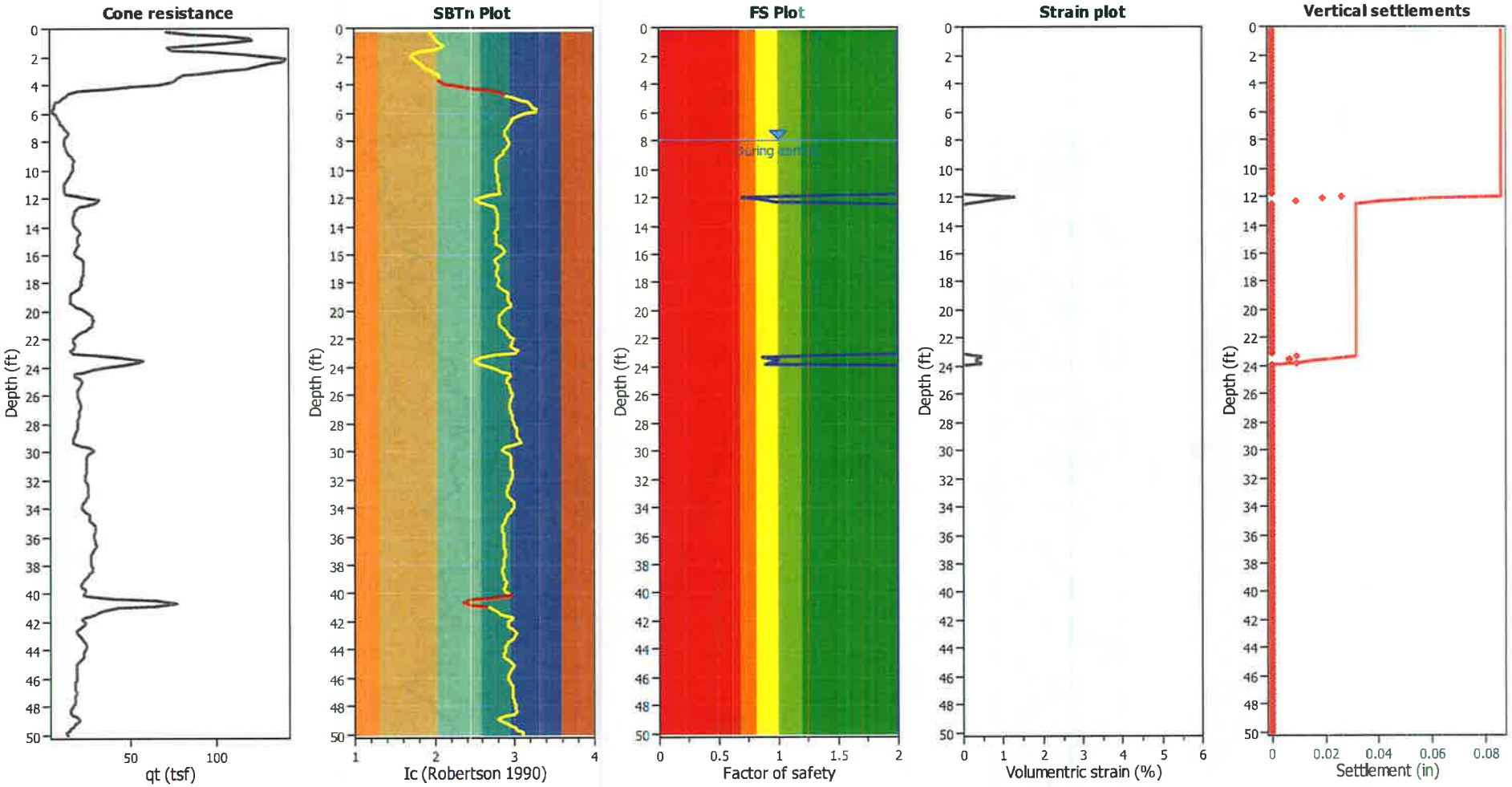
Analysis method:	NCEER (1998)	Depth to water table (erthq.):	8.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.50	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

EEC ORIGINAL PKG

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

EEC ORIGINAL PKG

:: **Post-earthquake settlement due to soil liquefaction** ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
8.04	119.22	2.00	0.00	0.86	0.00	8.20	120.85	2.00	0.00	0.86	0.00
8.37	121.77	2.00	0.00	0.86	0.00	8.53	121.74	2.00	0.00	0.86	0.00
8.69	123.66	2.00	0.00	0.85	0.00	8.86	127.30	2.00	0.00	0.85	0.00
9.02	130.40	2.00	0.00	0.85	0.00	9.19	130.61	2.00	0.00	0.84	0.00
9.35	129.25	2.00	0.00	0.84	0.00	9.51	127.22	2.00	0.00	0.84	0.00
9.68	125.93	2.00	0.00	0.84	0.00	9.84	124.71	2.00	0.00	0.83	0.00
10.01	123.50	2.00	0.00	0.83	0.00	10.17	120.59	2.00	0.00	0.83	0.00
10.33	115.49	2.00	0.00	0.82	0.00	10.50	108.81	2.00	0.00	0.82	0.00
10.66	102.72	2.00	0.00	0.82	0.00	10.83	97.88	2.00	0.00	0.82	0.00
10.99	94.40	2.00	0.00	0.81	0.00	11.15	93.33	2.00	0.00	0.81	0.00
11.32	92.09	2.00	0.00	0.81	0.00	11.48	95.09	2.00	0.00	0.81	0.00
11.65	105.48	2.00	0.00	0.80	0.00	11.81	117.60	2.00	0.00	0.80	0.00
11.98	131.26	0.69	1.33	0.80	0.03	12.14	143.05	0.84	0.96	0.79	0.02
12.30	152.70	0.97	0.47	0.79	0.01	12.47	152.80	2.00	0.00	0.79	0.00
12.63	143.18	2.00	0.00	0.79	0.00	12.80	134.31	2.00	0.00	0.78	0.00
12.96	130.65	2.00	0.00	0.78	0.00	13.12	129.65	2.00	0.00	0.78	0.00
13.29	127.91	2.00	0.00	0.77	0.00	13.45	124.35	2.00	0.00	0.77	0.00
13.62	120.29	2.00	0.00	0.77	0.00	13.78	120.60	2.00	0.00	0.77	0.00
13.94	128.55	2.00	0.00	0.76	0.00	14.11	137.42	2.00	0.00	0.76	0.00
14.27	142.24	2.00	0.00	0.76	0.00	14.44	141.06	2.00	0.00	0.76	0.00
14.60	138.35	2.00	0.00	0.75	0.00	14.76	133.75	2.00	0.00	0.75	0.00
14.93	129.06	2.00	0.00	0.75	0.00	15.09	127.77	2.00	0.00	0.74	0.00
15.26	132.22	2.00	0.00	0.74	0.00	15.42	138.42	2.00	0.00	0.74	0.00
15.58	140.75	2.00	0.00	0.74	0.00	15.75	139.78	2.00	0.00	0.73	0.00
15.91	138.74	2.00	0.00	0.73	0.00	16.08	138.05	2.00	0.00	0.73	0.00
16.24	137.36	2.00	0.00	0.72	0.00	16.40	138.60	2.00	0.00	0.72	0.00
16.57	143.48	2.00	0.00	0.72	0.00	16.73	146.06	2.00	0.00	0.72	0.00
16.90	145.22	2.00	0.00	0.71	0.00	17.06	141.94	2.00	0.00	0.71	0.00
17.22	139.81	2.00	0.00	0.71	0.00	17.39	137.72	2.00	0.00	0.71	0.00
17.55	137.02	2.00	0.00	0.70	0.00	17.72	137.39	2.00	0.00	0.70	0.00
17.88	136.19	2.00	0.00	0.70	0.00	18.04	135.45	2.00	0.00	0.69	0.00
18.21	132.44	2.00	0.00	0.69	0.00	18.37	130.93	2.00	0.00	0.69	0.00
18.54	124.17	2.00	0.00	0.69	0.00	18.70	118.78	2.00	0.00	0.68	0.00
18.86	113.72	2.00	0.00	0.68	0.00	19.03	112.47	2.00	0.00	0.68	0.00
19.19	112.04	2.00	0.00	0.67	0.00	19.36	117.35	2.00	0.00	0.67	0.00
19.52	128.21	2.00	0.00	0.67	0.00	19.69	143.57	2.00	0.00	0.67	0.00
19.85	153.43	2.00	0.00	0.66	0.00	20.01	160.71	2.00	0.00	0.66	0.00
20.18	163.07	2.00	0.00	0.66	0.00	20.34	164.44	2.00	0.00	0.66	0.00
20.51	162.92	2.00	0.00	0.65	0.00	20.67	161.17	2.00	0.00	0.65	0.00
20.83	160.88	2.00	0.00	0.65	0.00	21.00	160.69	2.00	0.00	0.64	0.00
21.16	158.54	2.00	0.00	0.64	0.00	21.33	151.78	2.00	0.00	0.64	0.00
21.49	140.81	2.00	0.00	0.64	0.00	21.65	130.93	2.00	0.00	0.63	0.00
21.82	126.27	2.00	0.00	0.63	0.00	21.98	126.66	2.00	0.00	0.63	0.00
22.15	126.16	2.00	0.00	0.62	0.00	22.31	126.33	2.00	0.00	0.62	0.00
22.47	126.09	2.00	0.00	0.62	0.00	22.64	123.91	2.00	0.00	0.62	0.00
22.80	121.99	2.00	0.00	0.61	0.00	22.97	126.99	2.00	0.00	0.61	0.00
23.13	143.39	2.00	0.00	0.61	0.00	23.29	157.57	0.86	0.48	0.61	0.01
23.46	167.32	1.00	0.33	0.60	0.01	23.62	165.76	0.98	0.33	0.60	0.01

EEC ORIGINAL PKG

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
23.79	159.66	0.89	0.47	0.60	0.01	23.95	148.21	2.00	0.00	0.59	0.00
24.11	135.94	2.00	0.00	0.59	0.00	24.28	120.89	2.00	0.00	0.59	0.00
24.44	113.50	2.00	0.00	0.59	0.00	24.61	115.23	2.00	0.00	0.58	0.00
24.77	123.04	2.00	0.00	0.58	0.00	24.93	128.87	2.00	0.00	0.58	0.00
25.10	131.54	2.00	0.00	0.57	0.00	25.26	130.14	2.00	0.00	0.57	0.00
25.43	125.79	2.00	0.00	0.57	0.00	25.59	121.98	2.00	0.00	0.57	0.00
25.75	120.15	2.00	0.00	0.56	0.00	25.92	121.20	2.00	0.00	0.56	0.00
26.08	122.21	2.00	0.00	0.56	0.00	26.25	122.93	2.00	0.00	0.56	0.00
26.41	122.83	2.00	0.00	0.55	0.00	26.57	122.65	2.00	0.00	0.55	0.00
26.74	123.77	2.00	0.00	0.55	0.00	26.90	123.52	2.00	0.00	0.54	0.00
27.07	122.85	2.00	0.00	0.54	0.00	27.23	120.78	2.00	0.00	0.54	0.00
27.40	120.44	2.00	0.00	0.54	0.00	27.56	120.16	2.00	0.00	0.53	0.00
27.72	118.94	2.00	0.00	0.53	0.00	27.89	119.67	2.00	0.00	0.53	0.00
28.05	121.33	2.00	0.00	0.52	0.00	28.22	123.92	2.00	0.00	0.52	0.00
28.38	122.71	2.00	0.00	0.52	0.00	28.54	119.82	2.00	0.00	0.52	0.00
28.71	115.02	2.00	0.00	0.51	0.00	28.87	111.29	2.00	0.00	0.51	0.00
29.04	109.61	2.00	0.00	0.51	0.00	29.20	112.15	2.00	0.00	0.51	0.00
29.36	116.02	2.00	0.00	0.50	0.00	29.53	122.43	2.00	0.00	0.50	0.00
29.69	128.66	2.00	0.00	0.50	0.00	29.86	132.51	2.00	0.00	0.49	0.00
30.02	133.32	2.00	0.00	0.49	0.00	30.18	133.01	2.00	0.00	0.49	0.00
30.35	134.24	2.00	0.00	0.49	0.00	30.51	135.73	2.00	0.00	0.48	0.00
30.68	134.98	2.00	0.00	0.48	0.00	30.84	133.52	2.00	0.00	0.48	0.00
31.00	132.42	2.00	0.00	0.47	0.00	31.17	131.76	2.00	0.00	0.47	0.00
31.33	131.41	2.00	0.00	0.47	0.00	31.50	130.79	2.00	0.00	0.47	0.00
31.66	129.46	2.00	0.00	0.46	0.00	31.82	127.40	2.00	0.00	0.46	0.00
31.99	125.47	2.00	0.00	0.46	0.00	32.15	124.76	2.00	0.00	0.46	0.00
32.32	123.94	2.00	0.00	0.45	0.00	32.48	122.71	2.00	0.00	0.45	0.00
32.64	121.40	2.00	0.00	0.45	0.00	32.81	120.70	2.00	0.00	0.44	0.00
32.97	120.37	2.00	0.00	0.44	0.00	33.14	120.33	2.00	0.00	0.44	0.00
33.30	119.72	2.00	0.00	0.44	0.00	33.46	119.43	2.00	0.00	0.43	0.00
33.63	118.76	2.00	0.00	0.43	0.00	33.79	117.66	2.00	0.00	0.43	0.00
33.96	117.16	2.00	0.00	0.42	0.00	34.12	117.75	2.00	0.00	0.42	0.00
34.28	120.54	2.00	0.00	0.42	0.00	34.45	119.94	2.00	0.00	0.42	0.00
34.61	117.36	2.00	0.00	0.41	0.00	34.78	114.03	2.00	0.00	0.41	0.00
34.94	115.06	2.00	0.00	0.41	0.00	35.10	117.56	2.00	0.00	0.41	0.00
35.27	118.09	2.00	0.00	0.40	0.00	35.43	116.84	2.00	0.00	0.40	0.00
35.60	115.80	2.00	0.00	0.40	0.00	35.76	116.35	2.00	0.00	0.39	0.00
35.93	117.12	2.00	0.00	0.39	0.00	36.09	117.39	2.00	0.00	0.39	0.00
36.25	117.58	2.00	0.00	0.39	0.00	36.42	118.84	2.00	0.00	0.38	0.00
36.58	119.93	2.00	0.00	0.38	0.00	36.75	119.47	2.00	0.00	0.38	0.00
36.91	116.76	2.00	0.00	0.37	0.00	37.07	113.06	2.00	0.00	0.37	0.00
37.24	109.88	2.00	0.00	0.37	0.00	37.40	107.43	2.00	0.00	0.37	0.00
37.57	106.75	2.00	0.00	0.36	0.00	37.73	106.32	2.00	0.00	0.36	0.00
37.89	106.17	2.00	0.00	0.36	0.00	38.06	105.28	2.00	0.00	0.35	0.00
38.22	104.58	2.00	0.00	0.35	0.00	38.39	102.50	2.00	0.00	0.35	0.00
38.55	98.98	2.00	0.00	0.35	0.00	38.71	94.70	2.00	0.00	0.34	0.00
38.88	90.90	2.00	0.00	0.34	0.00	39.04	87.39	2.00	0.00	0.34	0.00
39.21	84.59	2.00	0.00	0.34	0.00	39.37	82.78	2.00	0.00	0.33	0.00

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:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
39.53	84.00	2.00	0.00	0.33	0.00	39.70	87.03	2.00	0.00	0.33	0.00
39.86	90.97	2.00	0.00	0.32	0.00	40.03	96.73	2.00	0.00	0.32	0.00
40.19	105.29	2.00	0.00	0.32	0.00	40.35	115.76	2.00	0.00	0.32	0.00
40.52	121.29	2.00	0.00	0.31	0.00	40.68	125.41	2.00	0.00	0.31	0.00
40.85	123.12	2.00	0.00	0.31	0.00	41.01	117.19	2.00	0.00	0.30	0.00
41.17	107.63	2.00	0.00	0.30	0.00	41.34	102.80	2.00	0.00	0.30	0.00
41.50	99.33	2.00	0.00	0.30	0.00	41.67	95.42	2.00	0.00	0.29	0.00
41.83	90.50	2.00	0.00	0.29	0.00	41.99	89.98	2.00	0.00	0.29	0.00
42.16	88.92	2.00	0.00	0.29	0.00	42.32	83.52	2.00	0.00	0.28	0.00
42.49	78.18	2.00	0.00	0.28	0.00	42.65	77.51	2.00	0.00	0.28	0.00
42.81	82.85	2.00	0.00	0.27	0.00	42.98	88.58	2.00	0.00	0.27	0.00
43.14	92.04	2.00	0.00	0.27	0.00	43.31	92.24	2.00	0.00	0.27	0.00
43.47	90.25	2.00	0.00	0.26	0.00	43.64	86.84	2.00	0.00	0.26	0.00
43.80	83.41	2.00	0.00	0.26	0.00	43.96	80.95	2.00	0.00	0.25	0.00
44.13	78.49	2.00	0.00	0.25	0.00	44.29	76.67	2.00	0.00	0.25	0.00
44.46	75.23	2.00	0.00	0.25	0.00	44.62	74.90	2.00	0.00	0.24	0.00
44.78	74.57	2.00	0.00	0.24	0.00	44.95	73.31	2.00	0.00	0.24	0.00
45.11	72.32	2.00	0.00	0.24	0.00	45.28	70.79	2.00	0.00	0.23	0.00
45.44	69.68	2.00	0.00	0.23	0.00	45.60	67.68	2.00	0.00	0.23	0.00
45.77	65.78	2.00	0.00	0.22	0.00	45.93	64.39	2.00	0.00	0.22	0.00
46.10	63.45	2.00	0.00	0.22	0.00	46.26	63.10	2.00	0.00	0.22	0.00
46.42	63.80	2.00	0.00	0.21	0.00	46.59	65.52	2.00	0.00	0.21	0.00
46.75	67.21	2.00	0.00	0.21	0.00	46.92	67.86	2.00	0.00	0.20	0.00
47.08	67.38	2.00	0.00	0.20	0.00	47.24	66.55	2.00	0.00	0.20	0.00
47.41	66.19	2.00	0.00	0.20	0.00	47.57	66.07	2.00	0.00	0.19	0.00
47.74	65.63	2.00	0.00	0.19	0.00	47.90	63.67	2.00	0.00	0.19	0.00
48.06	60.77	2.00	0.00	0.19	0.00	48.23	58.45	2.00	0.00	0.18	0.00
48.39	57.99	2.00	0.00	0.18	0.00	48.56	57.54	2.00	0.00	0.18	0.00
48.72	56.34	2.00	0.00	0.17	0.00	48.88	54.30	2.00	0.00	0.17	0.00
49.05	55.00	2.00	0.00	0.17	0.00	49.21	55.85	2.00	0.00	0.17	0.00
49.38	55.75	2.00	0.00	0.16	0.00	49.54	53.84	2.00	0.00	0.16	0.00
49.70	52.12	2.00	0.00	0.16	0.00	49.87	53.14	2.00	0.00	0.15	0.00
50.03	54.80	2.00	0.00	0.15	0.00						

Total estimated settlement: 0.09

Abbreviations

$Q_{tn,cs}$:	Equivalent clean sand normalized cone resistance
FS:	Factor of safety against liquefaction
e_v (%):	Post-liquefaction volumentric strain
DF:	e_v depth weighting factor
Settlement:	Calculated settlement

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APPENDIX D

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Geotechnical Report

New Turbine Generator and Cooling Tower
Heber 2 Geothermal Plant
Heber, CA

Prepared for:

ORMAT
947 Dogwood Road
Heber, CA 92249



LANDMARK
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January 2005

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January 10, 2005

Mr. Mike Collins
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Geotechnical Investigation
New Turbine Generator and Cooling Tower
Heber 2 Geothermal Plant
Dogwood Road
Heber, California
LCI Report No. LE04354 (2)

Dear Mr. Collins:

This geotechnical report is provided for design and construction of the new turbine generator and cooling tower additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California. Our geotechnical investigation was conducted in response to your request for our services. The enclosed report describes our soil engineering investigation and presents our professional opinions regarding geotechnical conditions at the site to be considered in the design and construction of the project.

This executive summary presents ***selected*** elements of our findings and recommendations only. It ***does not*** present crucial details needed for the proper application of our findings and recommendations. Our findings, recommendations, and application options are related ***only through reading the full report***, and are best evaluated with the active participation of the engineer of record who developed them.

The findings of this study indicate that the site is predominantly underlain by clays of moderate expansion.

The soil are highly corrosive to metals and contain sufficient sulfates and chlorides to require special concrete mixes (4,500 psi with a 0.45 maximum water cement ratio) and protection of embedded steel building components when concrete is placed in contact with native soil. If the native soils are replaced with imported granular soils with low sulfate and chloride content, no special concrete mixes are required.

Evaluation of liquefaction potential at the site indicates that it is unlikely that the subsurface soil will liquefy under seismically induced groundshaking due to the nature of the soil (clays soils predominate). No mitigation is required for liquefaction effects at this site.

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Foundation settlements are indicated on figures 2 thru 5. Differential settlement is estimated to be about of two-thirds of total settlement.

We did not encounter soil conditions that would preclude development of the site for its intended use provided the recommendations contained in this report are implemented in the design and construction of this project.

We appreciate the opportunity to provide our findings and professional opinions regarding geotechnical conditions at the site. If you have any questions or comments regarding our findings, please call our office at (760) 370-3000.

Respectfully Submitted,
Landmark Consultants, Inc.

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Section 1
INTRODUCTION

1.1 Project Description

This report presents the findings of our geotechnical investigation for the proposed additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California (See Vicinity Map, Plate A-1). The proposed development will consist of the addition of one (1) turbine/generator set and one (1) cooling tower. A site plan for the proposed power plant improvements was not made available to us at the time that this report was prepared.

Small structures may be are planned for electrical control panels, consisting of masonry or panelized concrete construction. Expected footing loads are estimated at 1 to 2 kips per lineal foot for the small structures. Expected plant components, cooling tower and turbine/generator columns loads range from 5 to 400 kips. If structural loads exceed those stated above, we should be notified so we may evaluate their impact on foundation settlement and bearing capacity. Site development will include foundation support pad preparation and underground utility installation.

1.2 Purpose and Scope of Work

The purpose of this geotechnical study was to investigate the upper 50 feet of subsurface soil at selected locations within the site for physical/engineering properties. From the subsequent field and laboratory data, professional opinions were developed and are provided in this report regarding geotechnical conditions at this site and the effect on design and construction. The scope of our services consisted of the following:

- Field exploration and in-situ testing of the site soils at selected locations and depths.
- Laboratory testing for physical properties of selected samples.
- A review of the available literature and publications pertaining to local geology, faulting, and seismicity.
- Engineering analysis and evaluation of the data collected.
- Preparation of this report presenting our findings, professional opinions, and recommendations for the geotechnical aspects of project design and construction.

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This report addresses the following geotechnical issues:

- Subsurface soil and groundwater conditions
- Site geology, regional faulting and seismicity, near source factors, and site seismic accelerations
- Liquefaction potential and its mitigation
- Expansive soil and methods of mitigation
- Aggressive soil conditions to metals and concrete

Professional opinions with regard to the above issues are presented for the following:

- Site grading and earthwork
- Foundation subgrade preparation
- Allowable soil bearing pressures and expected settlements
- Concrete slabs-on-grade
- Mitigation of the potential effects of salt concentrations in native soil to concrete mixes and steel reinforcement
- Seismic design parameters

Our scope of work for this report did not include an evaluation of the site for the presence of environmentally hazardous materials or conditions.

1.3 Authorization

Mr. Mike Collins, Project Manager of Ormat for Power Generation Construction provided authorization by written agreement to proceed with our work on December 14, 2004. We conducted our work according to our written proposal dated December 13, 2004.

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Section 2
METHODS OF INVESTIGATION

2.1 Field Exploration

Subsurface exploration was performed on December 20, 2004 using Holguin, Fahan, & Associates, Inc. of Cypress, California to advance three (3) electric cone penetrometer (CPT) soundings to an approximate depth of 50 feet below existing ground surface. The soundings were made at the locations shown on the Site and Exploration Plan (Plate A-2). The approximate sounding locations were established in the field and plotted on the site map by sighting to discernable site features.

CPT soundings provide a continuous profile of the soil stratigraphy with readings every 2.5cm (1 inch) in depth. Direct sampling for visual and physical confirmation of soil properties has been used by our firm to establish direct correlations with CPT exploration in this geographical region.

The CPT exploration was conducted by hydraulically advancing an instrumented Hogentogler 10cm^2 conical probe into the ground at a rate of 2cm per second using a 23-ton truck as a reaction mass. An electronic data acquisition system recorded a nearly continuous log of the resistance of the soil against the cone tip (Qc) and soil friction against the cone sleeve (Fs) as the probe was advanced. Empirical relationships (Robertson and Campanella, 1989) were then applied to the data to give a continuous profile of the soil stratigraphy. Interpretation of CPT data provides correlations for SPT blow count, phi (ϕ) angle (soil friction angle), undrained shear strength (S_u) of clays and over-consolidation ratio (OCR). These correlations may then be used to evaluate vertical and lateral soil bearing capacities and consolidation characteristics of the subsurface soil.

Interpretive logs of the CPT soundings were produced and presented in final form after review of field and laboratory data and are presented on Plates B-1 through B-3 in Appendix B. A key to the interpretation of CPT soundings is presented on Plate B-4. The stratification lines shown on the subsurface logs represent the approximate boundaries between the various strata. However, the transition from one stratum to another may be gradual over some range of depth.

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2.2 Laboratory Testing

Laboratory tests were conducted on selected bulk soil samples obtained from hand auger borings made adjacent to the CPT locations to aid in classification and evaluation of selected engineering properties of the near surface soils. The tests were conducted in general conformance to the procedures of the American Society for Testing and Materials (ASTM) or other standardized methods as referenced below. The laboratory testing program consisted of the following tests:

- Plasticity Index (ASTM D4318) – used for soil classification and expansive soil design criteria.
- Chemical Analyses (soluble sulfates & chlorides, pH, and resistivity) (Caltrans Methods) – used for concrete mix evaluations and corrosion protection requirements.

The laboratory test results are presented on the subsurface logs (Appendix B) and on Plates C-1, C-2 and C-3 in Appendix C.

Engineering parameters of soil strength, compressibility and relative density utilized for developing design criteria provided within this report were either extrapolated from correlations with the subsurface CPT data or from data obtained from the field and laboratory testing program.

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Section 3
DISCUSSION

3.1 Site Conditions

The plant additions are located in the northwest corner of the Heber 2 geothermal plant on the west side of the existing turbine generators and cooling tower. The area is relatively vacant and approximately has the same elevation as the existing plant facilities. An overhead pipe rack is located to the south side of the proposed location.

Adjacent properties outside of the fenced operations yard consist of agricultural land to the north and west. The site is bounded on the east by Dogwood Road and headquarters facilities of a general engineering construction company lie to the south side. Dogwood Road is slated to be a 6-lane north-south arterial from Calexico to Brawley in Imperial County. Adjacent properties are flat-lying and are approximately at the same elevation with this site.

The project site lies at an elevation of approximately 15 feet below mean sea level (MSL) (El. 985 local datum) in the Imperial Valley region of the California low desert. The surrounding properties lie on terrain which is flat (planar), part of a large agricultural valley, which was previously an ancient lake bed covered with fresh water to an elevation of 43± feet above MSL. Annual rainfall in this arid region is less than 4 inches per year with four months of average summertime temperatures above 100 °F. Winter temperatures are mild, seldom reaching freezing.

3.2 Geologic Setting

The project site is located in the Imperial Valley portion of the Salton Trough physiographic province. The Salton Trough is a geologic structural depression resulting from large scale regional faulting. The trough is bounded on the northeast by the San Andreas Fault and Chocolate Mountains and the southwest by the Peninsular Range and faults of the San Jacinto Fault Zone. The Salton Trough represents the northward extension of the Gulf of California, containing both marine and non-marine sediments since the Miocene Epoch. Tectonic activity that formed the trough continues at a high rate as evidenced by deformed young sedimentary deposits and high levels of seismicity. Figure 1 shows the location of the site in relation to regional faults and physiographic features.

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The Imperial Valley is directly underlain by lacustrine deposits, which consist of interbedded lenticular and tabular silt, sand, and clay. The Late Pleistocene to Holocene lake deposits are probably less than 100 feet thick and derived from periodic flooding of the Colorado River which intermittently formed a fresh water lake (Lake Cahuilla). Older deposits consist of Miocene to Pleistocene non-marine and marine sediments deposited during intrusions of the Gulf of California. Basement rock consisting of Mesozoic granite and Paleozoic metamorphic rocks are estimated to exist at depths between 15,000 - 20,000 feet.

3.3 Seismicity and Faulting

Faulting and Seismic Sources: We have performed a computer-aided search of known faults or seismic zones that lie within a 62 mile (100 kilometers) radius of the project site as shown on Figure 1 and Table 1. The search identifies known faults within this distance and computes deterministic ground accelerations at the site based on the maximum credible earthquake expected on each of the faults and the distance from the fault to the site. The Maximum Magnitude Earthquake (Mmax) listed was taken from published geologic information available for each fault (CDMG OFR 96-08 and Jennings, 1994).

Seismic Risk: The project site is located in the seismically active Imperial Valley of southern California and is considered likely to be subjected to moderate to strong ground motion from earthquakes in the region. The proposed site structures should be designed in accordance with the California Building Code (CBC) for near source factors derived from a "Design Basis Earthquake" (DBE). The DBE is defined as the motion having a 10 percent probability of being exceeded in 50 years. The DBE generally corresponds to the Mmax magnitude discussed here.

Seismic Hazards.

- **Groundshaking.** The primary seismic hazard at the project site is the potential for strong groundshaking during earthquakes along the Imperial, Brawley, and Superstition Hills Faults. A further discussion of groundshaking follows in Section 3.4.
- **Surface Rupture.** The project site does not lie within a State of California, Alquist-Priolo Earthquake Fault Zone. Surface fault rupture is considered to be unlikely at the project site because of the well-delineated fault lines through the Imperial Valley as shown on USGS and CGS maps. However, because of the high tectonic activity and deep alluvium of the region, we cannot preclude the potential for surface rupture on undiscovered or new faults that may underlie the site.

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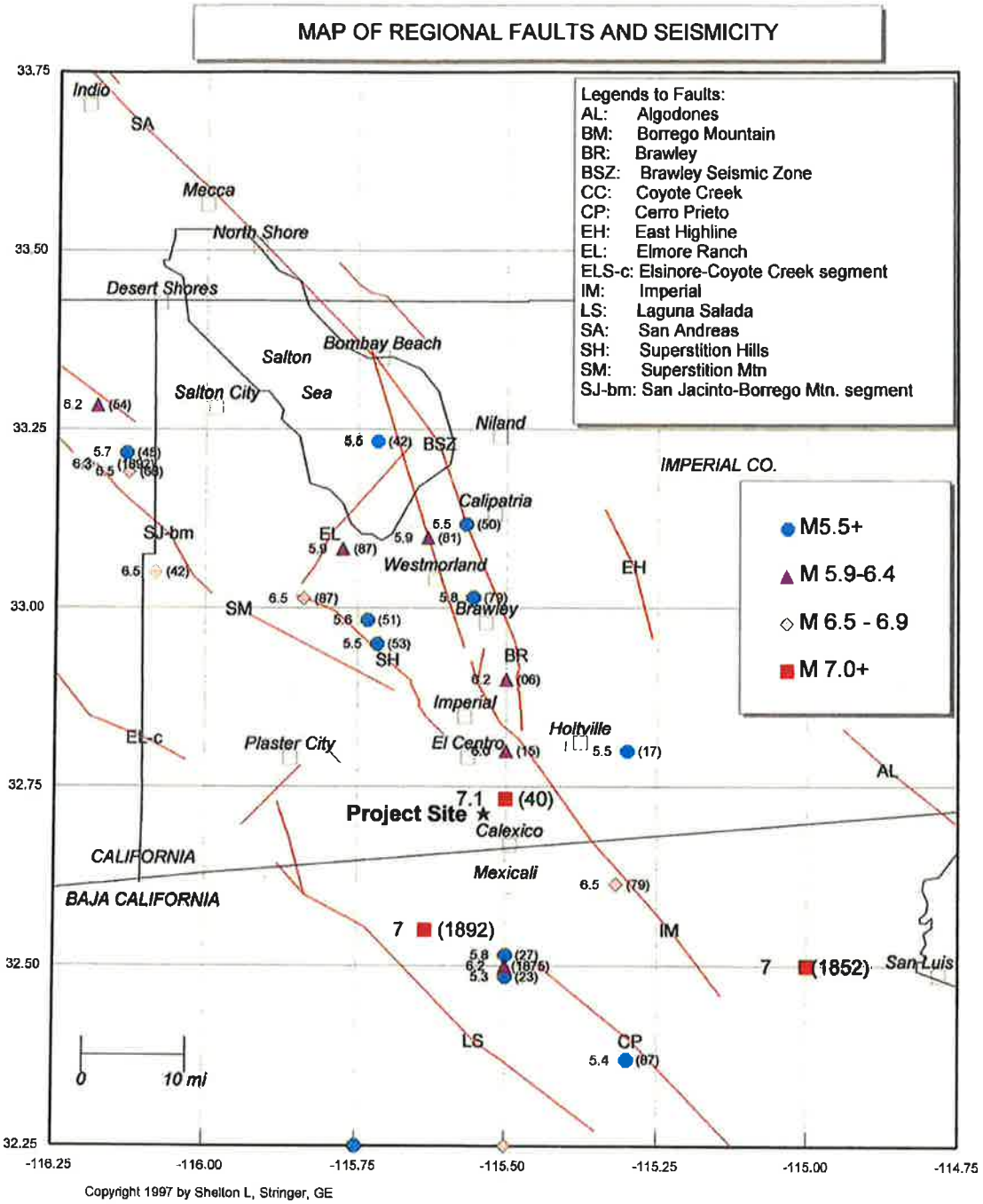

Faults and Seismic Zones from Jennings (1994), Earthquakes modified from Ellsworth (1990) catalog.

Figure 1. Map of Regional Faults and Seismicity

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Table 1
FAULT PARAMETERS & DETERMINISTIC
ESTIMATES OF PEAK GROUND ACCELERATION (PGA)

Fault Name or Seismic Zone	Distance (mi) & Direction from Site	Fault Type		Fault Length (km)	Maximum Magnitude Mmax (Mw)	Avg Slip Rate (mm/yr)	Avg Return Period (yrs)	Date of Last Rupture (year)	Largest Historic Event >5.5M	(year)	Est. Site PGA (g)
Reference Notes: (1)		(2)	(3)	(2)	(4)	(3)	(3)	(3)	(5)		(6)
Imperial Valley Faults											
Imperial	7.0 NE	A	B	62	**7.0**	20	79	1979	7.0	1940	**0.33**
Brawley	8.8 NNE	B	B	14	**7.0**	20	---	1979	5.8	1979	**0.28**
Cerro Prieto	15 SSE	A	B	116	**7.2**	34	50	1980	7.1	1934	**0.21**
Brawley Seismic Zone	16 N	B	B	42	**6.4**	25	24		5.9	1981	**0.13**
East Highline Canal	23 NE	C	C	22	**6.3**	1	774				**0.09**
San Jacinto Fault System											
- Superstition Hills	8.5 NNW	B	A	22	**6.6**	4	250	1987	6.5	1987	**0.23**
- Superstition Mtn.	15 NW	B	A	23	**6.6**	5	500	1440 +/-			**0.16**
- Elmore Ranch	28 NW	B	A	29	**6.6**	1	225	1987	5.9	1987	**0.10**
- Borrego Mtn	34 NW	B	A	29	**6.6**	4	175		6.5	1942	**0.08**
- Anza Segment	51 NW	A	A	90	**7.2**	12	250	1918	6.8	1918	**0.08**
- Coyote Creek	53 NW	B	A	40	**6.8**	4	175	1968	6.5	1968	**0.07**
- Whole Zone	15 NW	A	A	245	**7.5**	---	---				**0.25**
Elsinore Fault System											
- Laguna Salada	16 SW	B	B	67	**7.0**	3.5	336		7.0	1891	**0.18**
- Coyote Segment	29 W	B	A	38	**6.8**	4	625				**0.11**
- Julian Segment	55 WNW	A	A	75	**7.1**	5	340				**0.08**
- Earthquake Valley	57 WNW	B	A	20	**6.5**	2	351				**0.05**
- Whole Zone	29 W	A	A	250	**7.5**	---	---				**0.15**
San Andreas Fault System											
Coachella Valley	45 NNW	A	A	95	**7.4**	25	220	1690 +/-	6.5	1948	**0.10**
- Whole S. Calif. Zone	45 NNW	A	A	458	**7.9**	---	---	1857	7.8	1857	**0.13**
Algodones	36 E	C	C	74	**7.0**	0.1	20,000				**0.10**

Notes:

1. Jennings (1994) and CDMG (1996)
2. CDMG (1996), where Type A faults -- slip rate >5 mm/yr and well constrained paleoseismic data
   Type B faults -- all other faults.
3. WGCEP (1995)
4. CDMG (1996) based on Wells & Coppersmith (1994)
5. Ellsworth Catalog in USGS PP 1515 (1990) and USBR (1976), Mw = moment magnitude,
6. The deterministic estimates of the Site PGA are based on the attenuation relationship of:
   Boore, Joyner, Fumal (1997)

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▸ **Liquefaction.** Liquefaction is unlikely to be a potential hazard at the site due to the lack of saturated granular soil (clay soils predominate).

Other Secondary Hazards.

▸ **Landsliding.** The hazard of landsliding is unlikely due to the regional planar topography. No ancient landslides are shown on geologic maps of the region and no indications of landslides were observed during our site investigation.

▸ **Volcanic hazards.** The site is not located in proximity to any known volcanically active area and the risk of volcanic hazards is considered very low.

▸ **Tsunamis, sieches, and flooding.** The site does not lie near any large bodies of water, so the threat of tsunami, sieches, or other seismically-induced flooding is unlikely.

▸ **Expansive soil.** In general, much of the near surface soils in the Imperial Valley consist of silty clays and clays which are moderate to highly expansive. The expansive soil conditions are discussed in more detail in Section 3.5.

3.4 Site Acceleration and UBC Seismic Coefficients

Deterministic horizontal peak ground accelerations (PGA) from maximum probable earthquakes on regional faults have been estimated and are included in Table 1. Ground motions are dependent primarily on the earthquake magnitude and distance to the seismogenic (rupture) zone. Accelerations also are dependent upon attenuation by rock and soil deposits, direction of rupture and type of fault; therefore, ground motions may vary considerably in the same general area.

We have used the computer program FRISKSP (Blake, 2000) to provide a probabilistic estimate of the site PGA using the attenuation relationship of Boore, Joyner, and Fumal (1997) Soil (250). The PGA estimate for the project site having a 10% probability of being exceeded in 50 years (return period of 475 years) is **0.60g**.

CBC Seismic Coefficients: The CBC seismic coefficients are roughly based on an earthquake ground motion that has a 10% probability of being exceeded in 50 years. The following table lists seismic and site coefficients (near source factors) determined by Chapter 16 of the 2001 CBC. ***This site lies within 11.3 km of a Type A fault overlying S_D (stiff) soil.***

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CBC Seismic Coefficients for Chapter 16 Seismic Provisions

CBC Code Edition	Soil Profile Type	Seismic Source Type	Distance to Critical Source	Near Source Factors		Seismic Coefficients	
				Na	Nv	Ca	Cv
2001	S_D (stiff soil)	A	< 11.3 km	1.00	1.15	0.44	0.74
Ref. Table	16-J	16-U	---	16-S	16-T	16-Q	16-R

3.5 Subsurface Soil

Subsurface soils encountered during the field exploration conducted on December 20, 2004 indicates that 1.0 to 1.5 feet of stiff clay are at ground surface. Dense to very dense silty sands lie below the clays and extend to a depth of 4 to 5 feet. Stiff to very stiff clays extend a depth of 50 feet, the maximum depth of exploration. The subsurface logs (Plates B-1 through B-3) depict the stratigraphic relationships of the various soil types.

The native surface clays exhibit moderate swell potential (Expansion Index, EI = 51 - 90) when correlated to Plasticity index tests (ASTM D4318) performed on the native clays. The clay is expansive when wetted and can shrink with moisture loss (drying). Development of building foundations, concrete flatwork, and asphaltic concrete pavements should include provisions for mitigating potential swelling forces and reduction in soil strength, which can occur from saturation of the soil. Causes for soil saturation include landscape irrigation, broken utility lines, or capillary rise in moisture upon sealing the ground surface to evaporation. Moisture losses can occur with lack of landscape watering, close proximity of structures to downslopes and root system moisture extraction from deep rooted shrubs and trees placed near the foundations. Typical measures used for industrial projects to remediate expansive soil include:

- replacement of silt/clay with non-expansive granular fill,
- moisture conditioning subgrade soils to a minimum of 5% above optimum moisture (ASTM D1557) for the full range in depth of surface soils.
- design of foundations that are resistant to shrink/swell forces of silt/clay soil.

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3.6 Groundwater

Groundwater was not noted on the CPT sounding at the time of exploration, but is typically encountered at approximately 10 to 15 feet below ground surface in the vicinity of the site. There is uncertainty in the accuracy of short-term water level measurements, particularly in fine-grained soil. Groundwater levels may fluctuate with precipitation, irrigation of adjacent properties, drainage, and site grading. The referenced groundwater level should not be interpreted to represent an accurate or permanent condition.

3.7 Liquefaction

Liquefaction occurs when granular soil below the water table is subjected to vibratory motions, such as produced by earthquakes. With strong ground shaking, an increase in pore water pressure develops as the soil tends to reduce in volume. If the increase in pore water pressure is sufficient to reduce the vertical effective stress (suspending the soil particles in water), the soil strength decreases and the soil behaves as a liquid (similar to quicksand). Liquefaction can produce excessive settlement, ground rupture, lateral spreading, or failure of shallow bearing foundations.

Four conditions are generally required for liquefaction to occur:

(1) the soil must be saturated (relatively shallow groundwater);
(2) the soil must be loosely packed (low to medium relative density);
(3) the soil must be relatively cohesionless (not clayey); and
(4) groundshaking of sufficient intensity must occur to function as a trigger mechanism.

All of these conditions exist to some degree at this site.

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Methods of Analysis: Liquefaction potential at the project site was evaluated using the 1997 NCEER Liquefaction Workshop methods that are based on the Seed, et. al. 1985 and Robertson and Campanella (1985) methods. The 1997 NCEER methods utilize direct SPT blow counts or CPT cone readings from site exploration and earthquake magnitude/PGA estimates from the seismic hazard analysis. The resistance to liquefaction is plotted on a chart of cyclic shear stress ratio (CSR) versus a corrected blow count $N_{1(60)}$ or Qc_{1N}. A ground acceleration of 0.60g was used in the analysis with a 12 foot groundwater depth.

Liquefaction induced settlements have been estimated using the 1987 Tokimatsu and Seed method. Fines content of liquefiable sands and silt increase the liquefaction resistance in that more cycles of ground motions are required to fully develop pore pressures. The SPT blow counts were adjusted to an equivalent clean sand blow count, $N_{1(60)}$ prior to calculating settlements using Robertson and Wride (1997) adjustments. A computed factor of safety less than 1.0 indicates a liquefiable condition.

Liquefaction Effects: Based on empirical relationships, liquefaction is not expected to occur at the project site.

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Section 4
RECOMMENDATIONS

4.1 Site Preparation

Clearing and Grubbing: All surface improvements, debris or vegetation including grass and weeds on the site at the time of construction should be removed from the construction area. Organic strippings should be hauled from the site and not used as fill. Any trash, construction debris, concrete slabs, old pavement, landfill, and buried obstructions such as old foundations and utility lines exposed during rough grading should be traced to the limits of the foreign material by the grading contractor and removed under our supervision. Any excavations resulting from site clearing should be dish-shaped to the lowest depth of disturbance and backfilled under observation by the geotechnical engineer's representative with compacted fill as described below.

Structure Subgrade Preparation: The exposed surface soil within the foundation areas should be removed to 12 inches below the foundation elevation or existing grade (whichever is lower). Exposed subgrade should be scarified to a depth of 8 inches, uniformly moisture conditioned to 3 to 8% above optimum moisture content (clays) or 0 to 4% above optimum (silts), and recompacted to at least 90% of the maximum density determined in accordance with ASTM D1557 methods.

The native soil is suitable for use as engineered fill provided it is free from concentrations of organic matter or other deleterious material. The fill soil should be uniformly moisture conditioned by discing and watering to the limits specified above, placed in maximum 8-inch lifts (loose), and compacted to the limits specified above.

Imported fill soil (if required) should have a Plasticity Index less than 15 and sulfates (SO_4) less than 1,000 ppm or non-expansive, granular soil meeting the USCS classifications of SM, SP-SM, or SW-SM with a maximum rock size of 3 inches and 5 to 35% passing the No. 200 sieve. The geotechnical engineer should approve imported fill soil sources before hauling material to the site. Imported granular fill should be placed in lifts no greater than 8 inches in loose thickness and compacted to at least 90% of ASTM D1557 maximum dry density at optimum moisture ±2%.

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In areas other than the structures pad which are to receive area concrete slabs, the ground surface should be presaturated to a minimum depth of 18 inches and then scarified to 6 inches, moisture conditioned to a minimum of 5% over optimum, and recompacted to 83-87% of ASTM D1 557 maximum density just prior to concrete placement.

Trench Backfill: On-site soil free of debris, vegetation, and other deleterious matter may be suitable for use as utility trench backfill, but may be difficult to uniformly maintain at specified moistures and compact to the specified densities. Granular material is often more cost effective for backfill of utility trenches.

Backfill soil within roadways or traffic areas should be placed in layers not more that 6 inches in thickness and mechanically compacted to a minimum of 87% of the ASTM D1557 maximum dry density except for the top 12 inches of the trench which shall be compacted to at least 90%. Native backfill should only be placed and compacted after encapsulating buried pipes with suitable bedding and pipe envelope material. Pipe envelope/bedding should either be clean sand (Sand Equivalent SE>30) or crushed rock when encountering groundwater. A geotextile filter fabric (Mirafi 140N or equivalent) should be used to encapsulate the crushed rock when placed below groundwater to reduce the potential for in-washing of fines into the gravel void space. Precautions should be taken in the compaction of the backfill to avoid damage to the pipes and structures.

Observation and Density Testing: All site preparation and fill placement should be continuously observed and tested by a representative of a qualified geotechnical engineering firm. Full-time observation services during the excavation and scarification process is necessary to detect undesirable materials or conditions and soft areas that may be encountered in the construction area. The geotechnical firm that provides observation and testing during construction shall assume the responsibility of "*geotechnical engineer of record*" and, as such, shall perform additional tests and investigation as necessary to satisfy themselves as to the site conditions and the recommendations for site development.

Auxiliary Structures Foundation Preparation: Auxiliary structures such as free standing or retaining walls should have the existing soil beneath the structure foundation prepared in the manner recommended for the building pad except the preparation needed only to extend 12 inches below and beyond the footing.

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4.2 Foundations and Settlements

Shallow spread footings and continuous wall footings are suitable to support the structures associated with the turbine generator and cooling tower. Footings shall be founded on a layer of properly prepared and compacted soil as described in Section 4.1. The foundations may be designed using an allowable soil bearing pressure of 1,500 psf for compacted native clay soil and 2,000 psf when foundations are supported on imported sands (extending a minimum of 1.0 feet below footings). The allowable soil pressure may be increased by 20% for each foot of embedment depth in excess of 18 inches and by one-third for short term loads induced by winds or seismic events. The maximum allowable soil pressure at increased embedment depths shall not exceed 3,000 psf (clays). Settlements associated with variable loadings and structure/footing sizes are shown on figures 2 thru 5. As an alternative to shallow spread foundations, flat plate structural mats or grade-beam reinforced foundations may be used to mitigate expansive soil heave.

Flat Plate Structural Mats: Structural mats may be designed for a modulus of subgrade reaction (Ks) of 100 pci when placed on compacted clay or a subgrade modulus of 250 pci when placed on 2.5 feet of granular fill. Mats shall overlay 2 inches of sand and a 10-mil polyethylene vapor retarder. The structure support pad shall be moisture conditioned and recompacted as specified in Section 4.1 of this report.

All exterior and interior foundations should be embedded a minimum of 18 inches below the structure support pad or lowest adjacent final grade, whichever is deeper. Continuous wall footings should have a minimum width of 12 inches. Spread footings should have a minimum width of 24 inches. Recommended concrete reinforcement and sizing for all footings should be provided by the structural engineer.

Resistance to horizontal loads will be developed by passive earth pressure on the sides of footings or grade beams and frictional resistance developed along the bases of footings or grade beams and concrete slabs. Passive resistance to lateral earth pressure may be calculated using an equivalent fluid pressure of 250 pcf (300 pcf for sands) to resist lateral loadings. The top one foot of embedment should not be considered in computing passive resistance unless the adjacent area is confined by a slab or pavement. An allowable friction coefficient of 0.25 (0.35 for sands) may also be used at the base of the footings or grade beams to resist lateral loading.

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Total foundation movements under estimated loadings are shown on the load/settlement curves (Figures 2 thru 5). Differential movement is estimated to be about two-thirds of total movement

4.3 Slabs-On-Grade

Thin concrete slabs and flatwork (6 inches or less in thickness) placed over native clay soil should be designed in accordance with Chapter 18, Division III of the 2001 CBC (using an Effective Plasticity Index of 17) and shall be a minimum of 5 inches thick due to expansive soil conditions. Concrete floor slabs shall be monolithically placed with the foundations unless placed on 2.5 feet of granular fill or lime treated soil.

The concrete slabs should be underlain by a minimum of 4 inches of clean sand (Sand Equivalent SE>30) or aggregate base or may be placed directly on a 2.5-foot thick granular fill pad (if used) that has been moistened to approximately optimum moisture just before the concrete placement. A 10-mil visqueen vapor retarder, properly lapped and sealed with a 2-inch sand cover and extended a minimum of 12 inches into the footing, should be placed as a capillary break to prevent moisture migration into the slab section. Concrete slabs may be placed directly over a 15-mil vapor retarder if desired (Stego-Wrap or equivalent).

Concrete slab and flatwork reinforcement should consist of chaired rebar slab reinforcement (minimum of No. 4 bars at 18-inch centers, both horizontal directions) placed at slab mid-height to resist potential swell forces and cracking. Slab thickness and steel reinforcement are minimums only and should be verified by the structural engineer/designer knowing the actual project loadings. All steel components of the foundation system should be protected from corrosion by maintaining a 4-inch minimum concrete cover of densely consolidated concrete at footings (by use of a vibrator). The construction joint between the foundation and any mowstrips/sidewalks placed adjacent to foundations should be sealed with a polyurethane based non-hardening sealant to prevent moisture migration between the joint. Epoxy coated embedded steel components or permanent waterproofing membranes placed at the exterior footing sidewall may also be used to mitigate the corrosion potential of concrete placed in contact with native soil.

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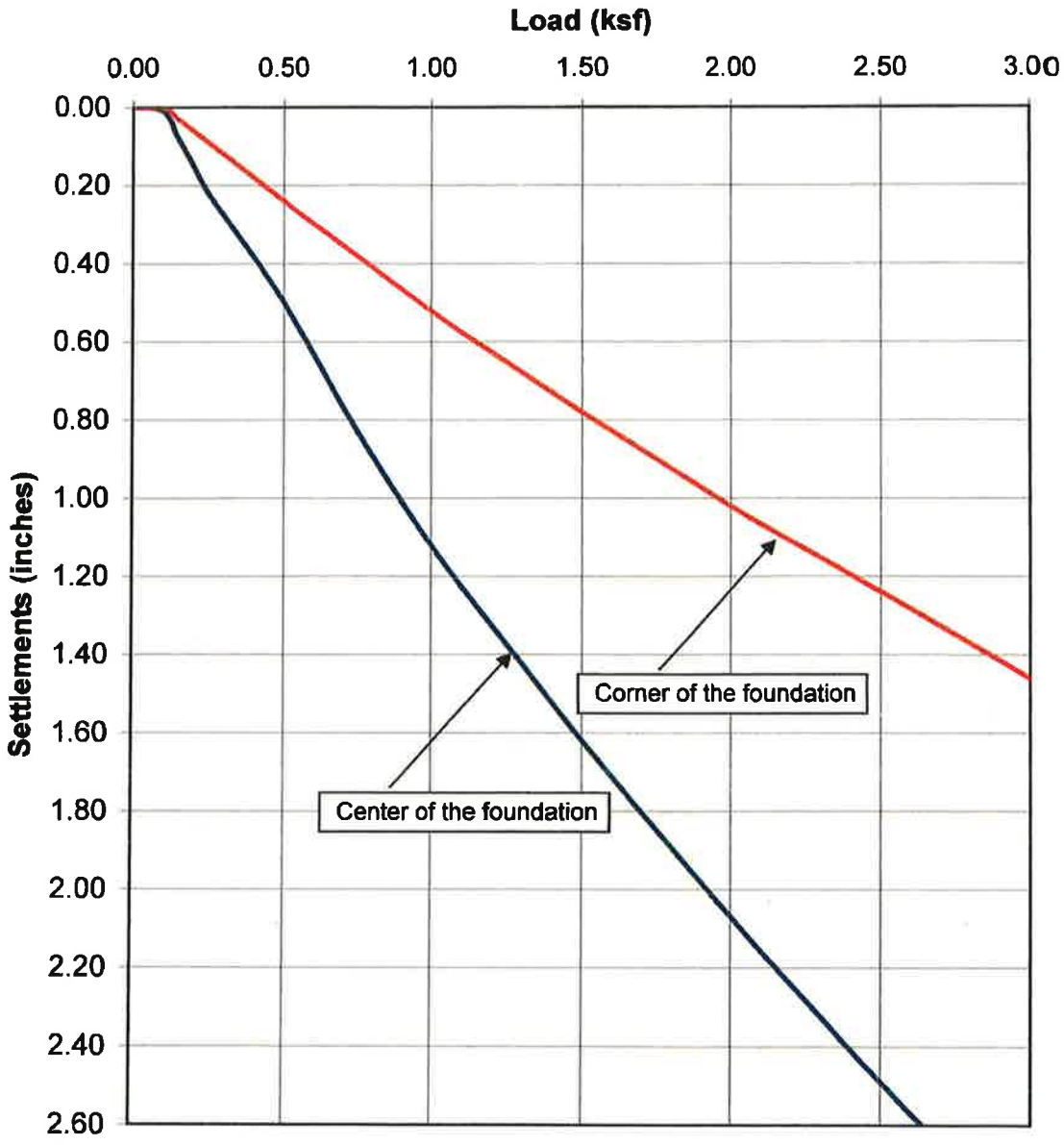

Notes:

1. A 15' x 15' foundation was used for settlement analysis

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Total Settlements for a Turbine Generator Foundation at Heber 2 Geothermal Plant

Figure 2

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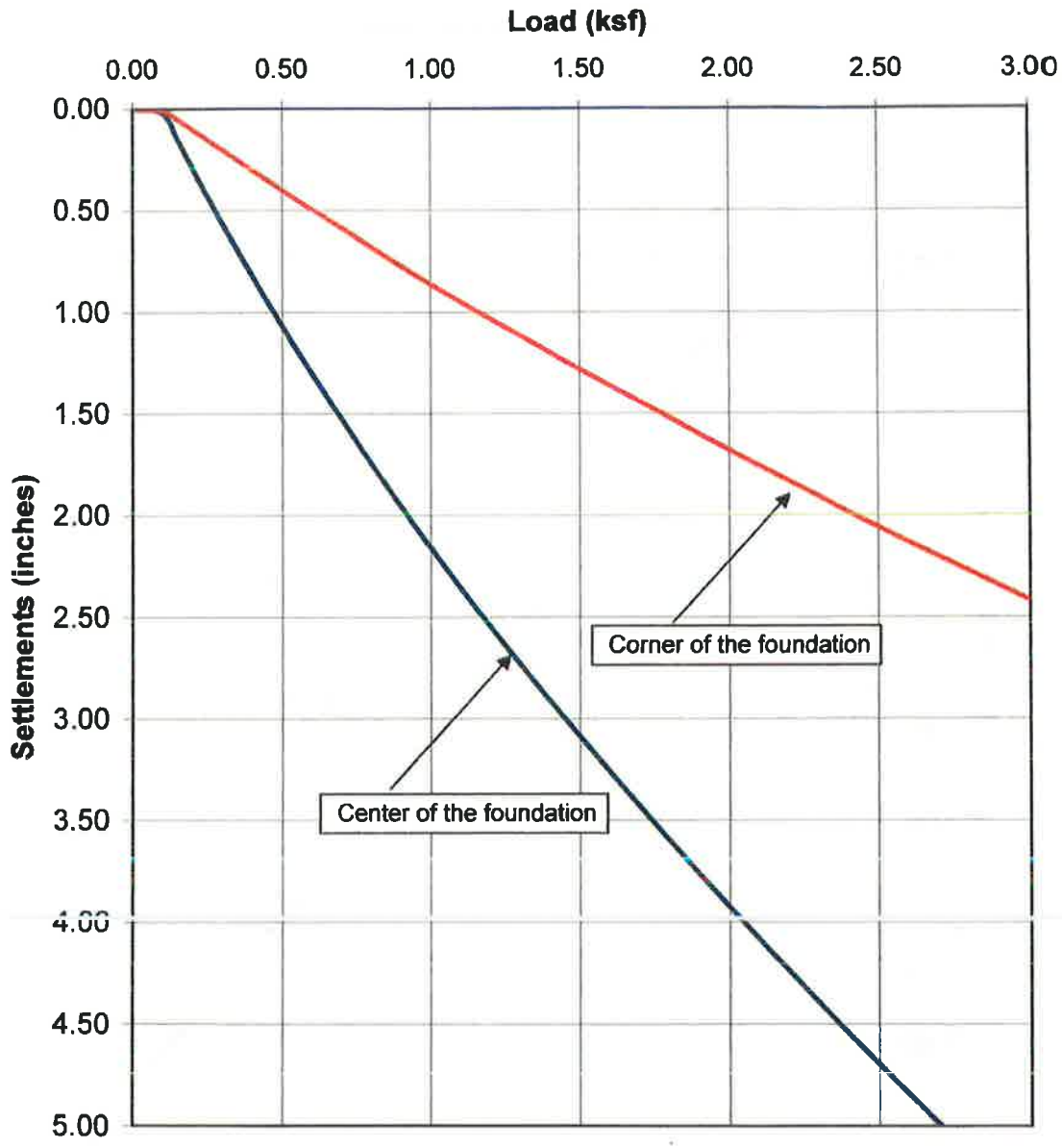

Notes:

1. A 30' x 60' foundation was used for settlement analysis

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Total Settlements for a Turbine Generator Foundation at Heber 2 Geothermal Plant

Figure 3

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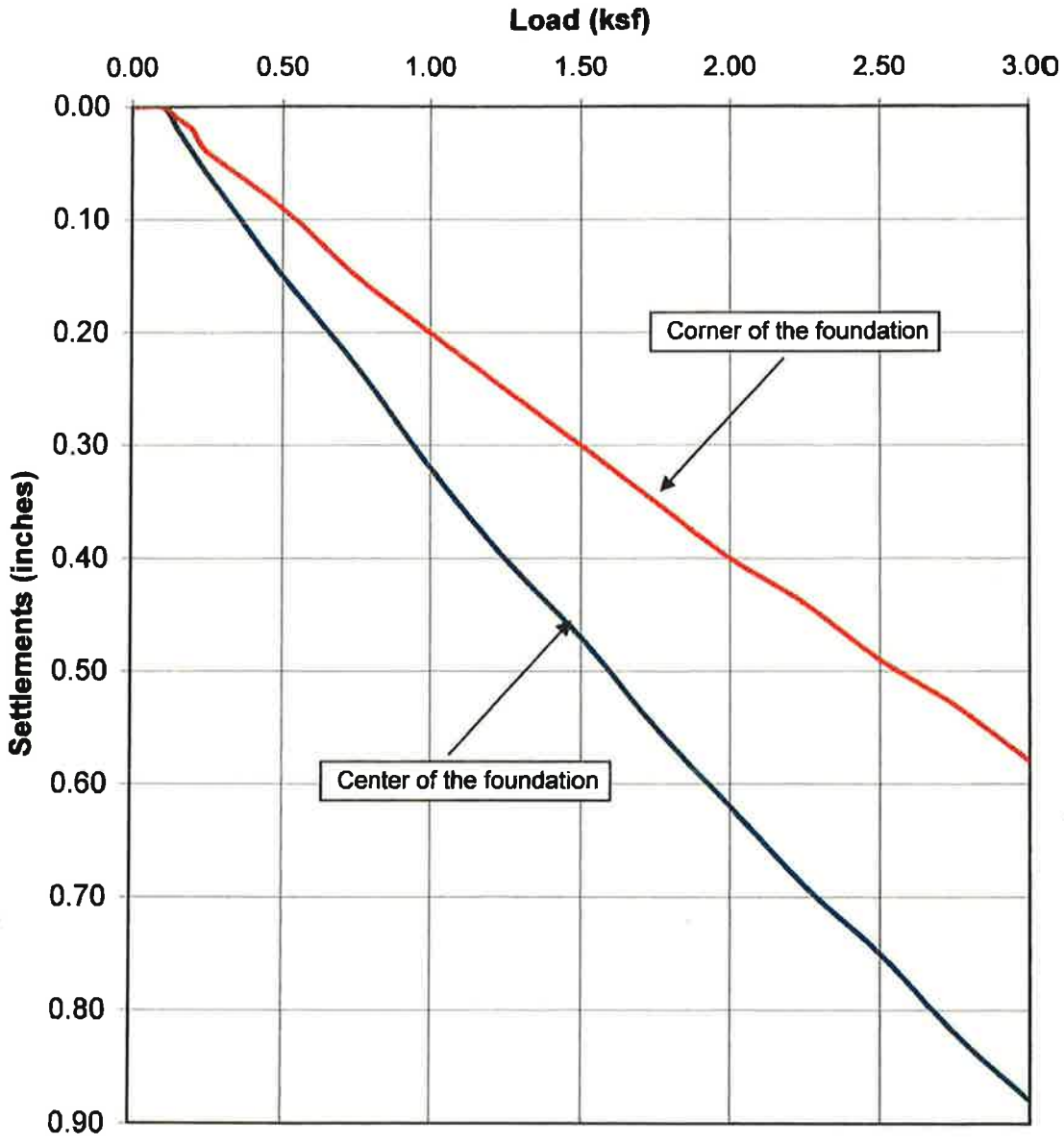

Notes:

1. A 5' x 5' foundation was used for settlement analysis

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Total Settlements for a Cooling Tower Foundation at Heber 2 Geothermal Plant

Figure 4

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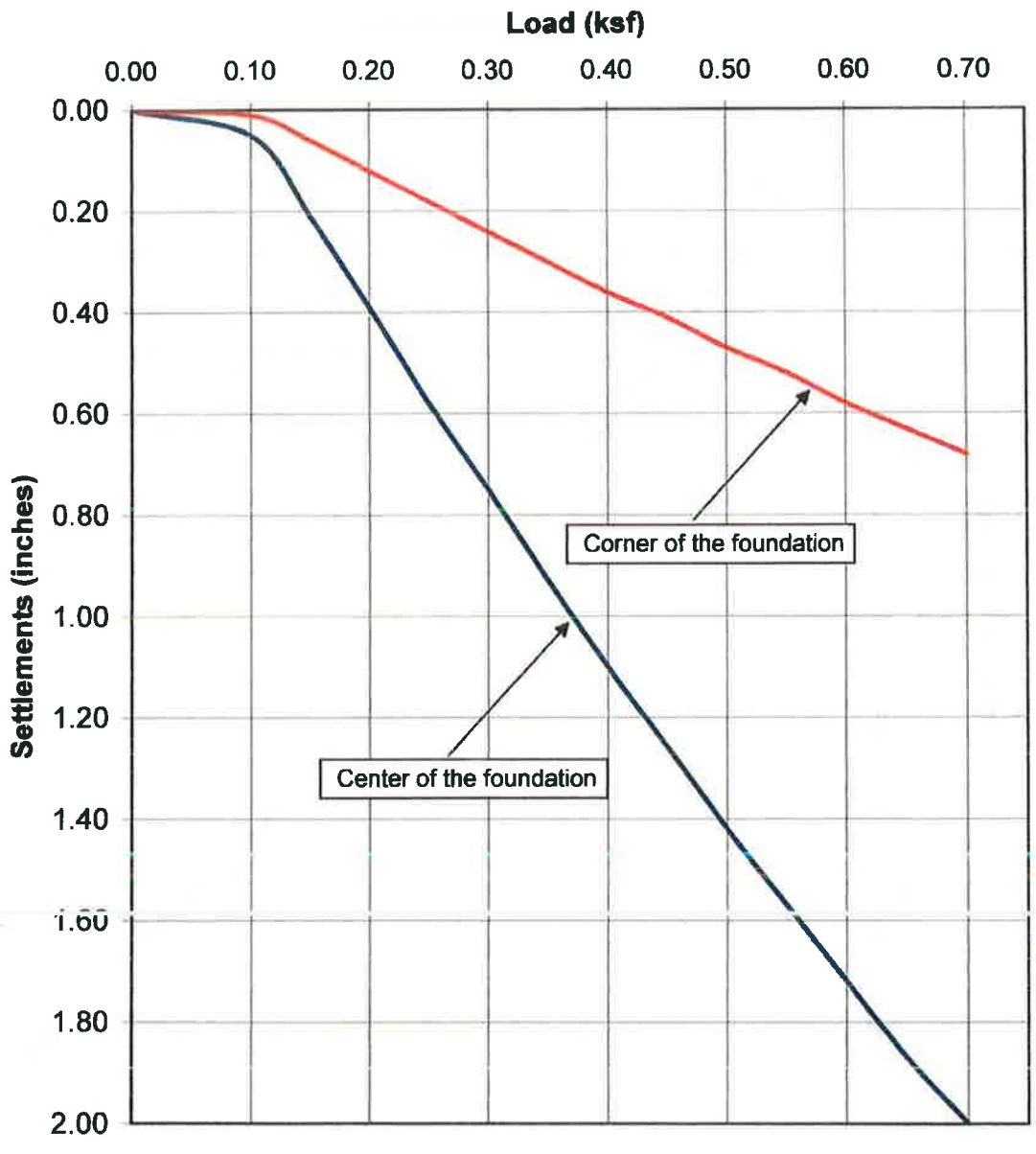

Notes:

1. A 60' x 180' foundation was used for settlement analysis

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Total Settlements for a Cooling Tower Foundation at Heber 2 Geothermal Plant

Figure 5

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Control joints should be provided in all concrete slabs-on-grade at a maximum spacing (in feet) of 2 to 3 times the slab thickness (in inches) as recommended by American Concrete Institute (ACI) guidelines. All joints should form approximately square patterns to reduce randomly oriented contraction cracks. Contraction joints in the slabs should be tooled at the time of the pour or sawcut (¼ of slab depth) within 6 to 8 hours of concrete placement. Construction (cold) joints in foundations and area flatwork should either be thickened butt-joints with dowels or a thickened keyed-joint designed to resist vertical deflection at the joint. All joints in flatwork should be sealed to prevent moisture, vermin, or foreign material intrusion. Precautions should be taken to prevent curling of slabs in this arid desert region (refer to ACI guidelines).

All independent flatwork (sidewalks, housekeeping slabs) should be placed on a minimum of 2 inches of concrete sand or aggregate base, dowelled to the perimeter foundations where adjacent to the structures and sloped 1% or more away from the structure. A minimum of 18 inches of moisture conditioned (3% minimum above optimum) and 8 inches of compacted subgrade (83 to 87%) and a 10-mil (minimum) polyethylene separation sheet should underlie the flatwork. All flatwork should be jointed in square patterns and at irregularities in shape at a maximum spacing of 10 feet or the least width of the sidewalk.

4.4 Concrete Mixes and Corrosivity

Selected chemical analyses for corrosivity were conducted on bulk samples of the near surface soil from the project site (Plates C-2 and C-3). The native soils were found to have moderate to severe levels of sulfate ion concentration (1,052 to 3,006 ppm). Sulfate ions in high concentrations can attack the cementitious material in concrete, causing weakening of the cement matrix and eventual deterioration by raveling. The California Building Code recommends that increased quantities of Type II Portland Cement be used at a low water/cement ratio when concrete is subjected to moderate sulfate concentrations. Type V Portland Cement and/or Type II/V cement with 25% flyash replacement is recommended when the concrete is subjected to soil with severe sulfate concentration.

A minimum of 6.25 sacks per cubic yard of concrete (4,500 psi) of Type V Portland Cement with a maximum water/cement ratio of 0.45 (by weight) should be used for concrete placed in contact with native soil on this project. Admixtures may be required to allow placement of this low water/cement ratio concrete.

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There are no special requirements for concrete mixes when foundations are placed on 2.5 feet of low sulfate content granular fill.

The native soil has moderate to very severe level of chloride ion concentration (210 to 3,040 ppm). Chloride ions can cause corrosion of reinforcing steel, anchor bolts and other buried metallic conduits. Resistivity determinations on the soil indicate very severe potential for metal loss because of electrochemical corrosion processes. Mitigation of the corrosion of steel can be achieved by using steel pipes coated with epoxy corrosion inhibitors, asphaltic and epoxy coatings, cathodic protection or by encapsulating the portion of the pipe lying above groundwater with a minimum of 4 inches of densely consolidated concrete. ***No metallic pipes or conduits should be placed below foundations.***

Foundation designs shall provide a minimum concrete cover of four (4 inches around steel reinforcing or embedded components (anchor bolts, hold-downs, etc.) exposed to native soil or landscape water (to 18 inches above grade). If the 4-inch concrete edge distance cannot be achieved, all embedded steel components (anchor bolts, hold-downs, etc.) shall be epoxy dipped for corrosion protection or a corrosion inhibitor and a permanent waterproofing membrane shall be placed along the exterior face of the exterior footings. Additionally, the concrete should be thoroughly vibrated at footings during placement to decrease the permeability of the concrete.

4.5 Excavations

All site excavations should conform to CalOSHA requirements for Type B soil. The contractor is solely responsible for the safety of workers entering trenches. Temporary excavations with depths of 4 feet or less may be cut nearly vertical for short duration. Excavations deeper than 4 feet will require shoring or slope inclinations in conformance to CAL/OSHA regulations for Type B soil. Surcharge loads of stockpiled soil or construction materials should be set back from the top of the slope a minimum distance equal to the height of the slope. All permanent slopes should not be steeper than 3:1 to reduce wind and rain erosion. Protected slopes with ground cover may be as steep as 2:1. However, maintenance with motorized equipment may not be possible at this inclination.

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4.6 Seismic Design

This site is located in the seismically active southern California area and the site structures are subject to strong ground shaking due to potential fault movements along the Brawley, Superstition Hills, and Imperial Faults. Engineered design and earthquake-resistant construction are the common solutions to increase safety and development of seismic areas. Designs should comply with the latest edition of the CBC for Seismic Zone 4 using the seismic coefficients given in Section 3.4 of this report. ***This site lies within 11.3 km of a Type A fault overlying S_D (stiff) soil.***

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Section 5
LIMITATIONS AND ADDITIONAL SERVICES

5.1 Limitations

The recommendations and conclusions within this report are based on current information regarding the proposed additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California. The conclusions and recommendations of this report are invalid if:

- Structural loads change from those stated or the structures are relocated.
- The Additional Services section of this report is not followed.
- This report is used for adjacent or other property.
- Changes of grade or groundwater occur between the issuance of this report and construction other than those anticipated in this report.
- Any other change that materially alters the project from that proposed at the time this report was prepared.

Findings and recommendations in this report are based on selected points of field exploration, geologic literature, laboratory testing, and our understanding of the proposed project. Our analysis of data and recommendations presented herein are based on the assumption that soil conditions do not vary significantly from those found at specific exploratory locations. Variations in soil conditions can exist between and beyond the exploration points or groundwater elevations may change. If detected, these conditions may require additional studies, consultation, and possible design revisions.

This report contains information that may be useful in the preparation of contract specifications. However, the report is not worded is such a manner that we recommend its use as a construction specification document without proper modification. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.

This report was prepared according to the generally accepted *geotechnical engineering standards of practice* that existed in Imperial County at the time the report was prepared. No express or implied warranties are made in connection with our services. This report should be considered invalid for periods after two years from the report date without a review of the validity of the findings and recommendations by our firm, because of potential changes in the Geotechnical Engineering Standards of Practice.

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APPENDIX A

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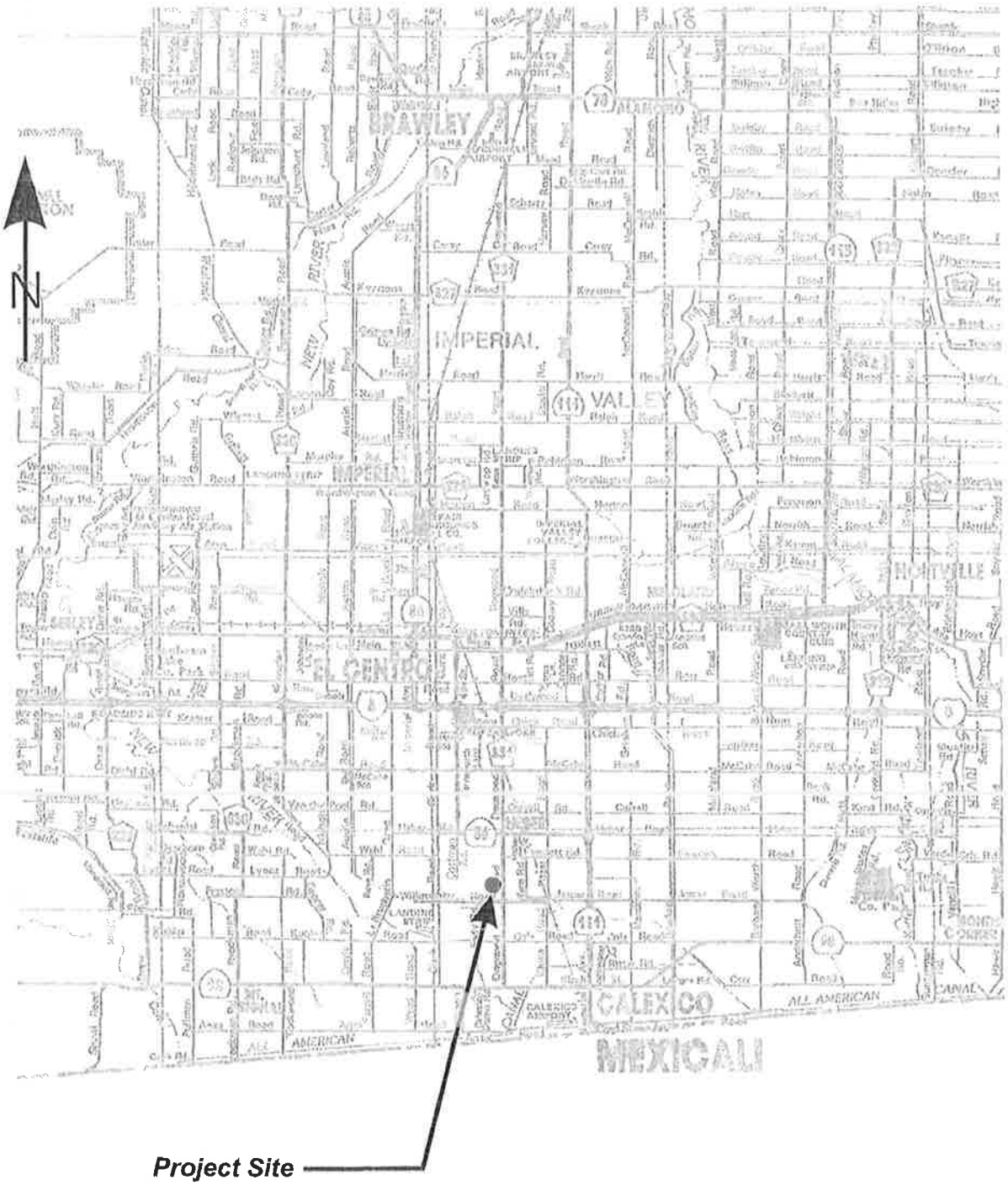

LANDMARK Geo-Engineers and Geologists a DIE/MBE/SBE Company Project No.: LE04354	Vicinity Map	Plate A-1

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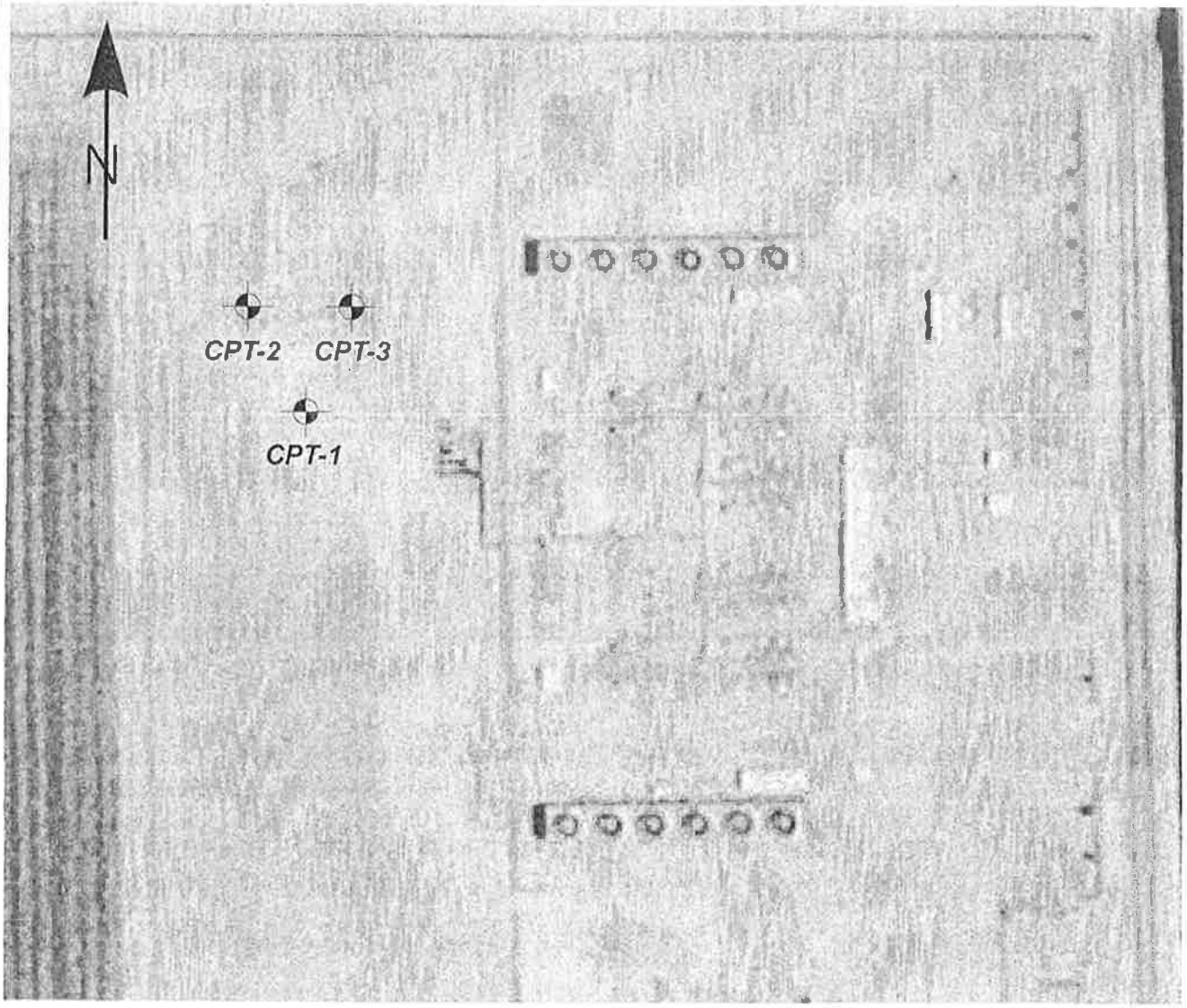

LANDMARK Geo-Engineers and Geologists, a DBE/MBE/SBE Company Project No.: LE04354	Site and Exploration Map	Plate A-2

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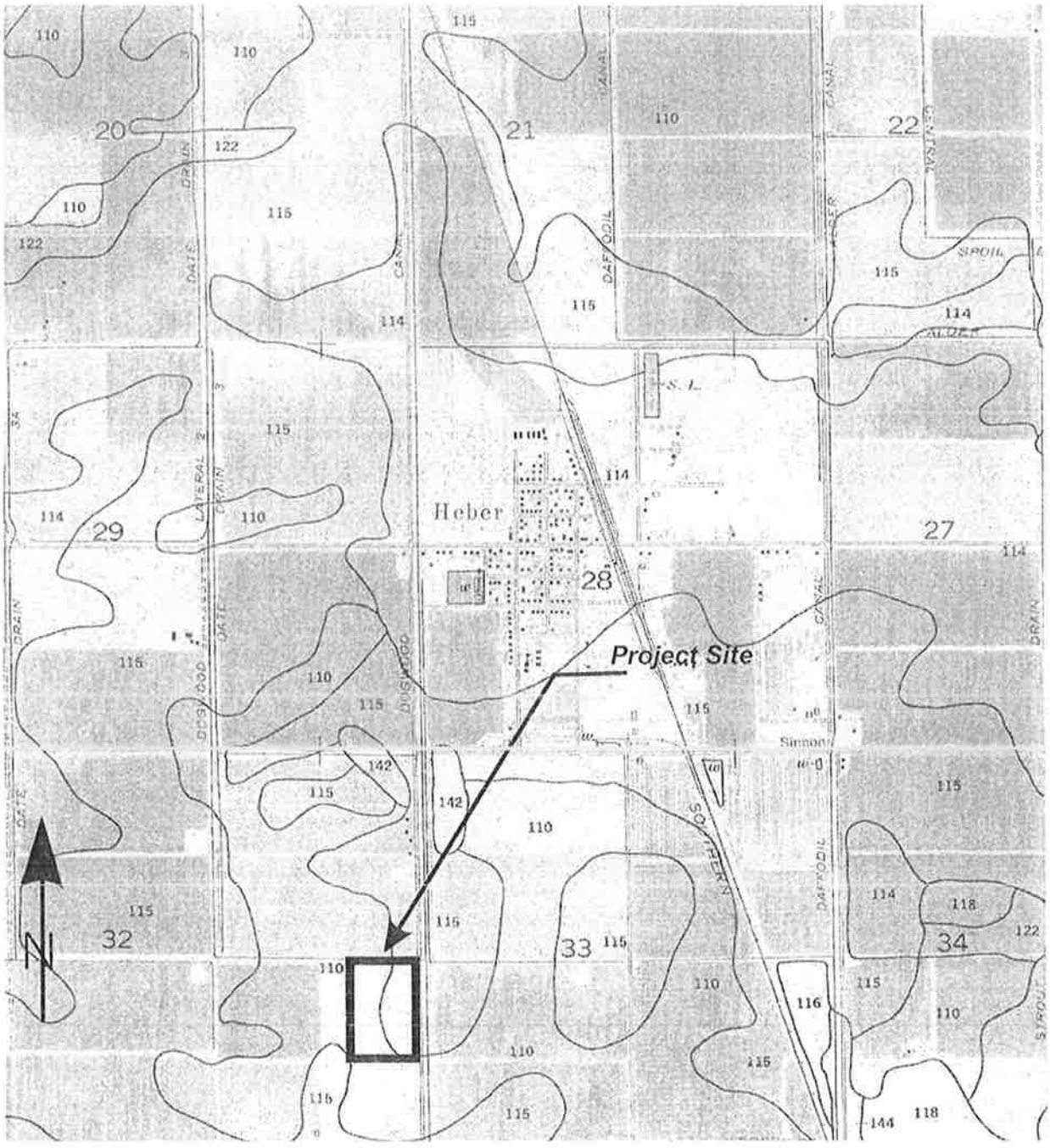

LANDMARK Geo-Engineers and Geologists a DBE/MBE/SBE Company Project No.: LE04354	Soil Survey Map	Plate A-3

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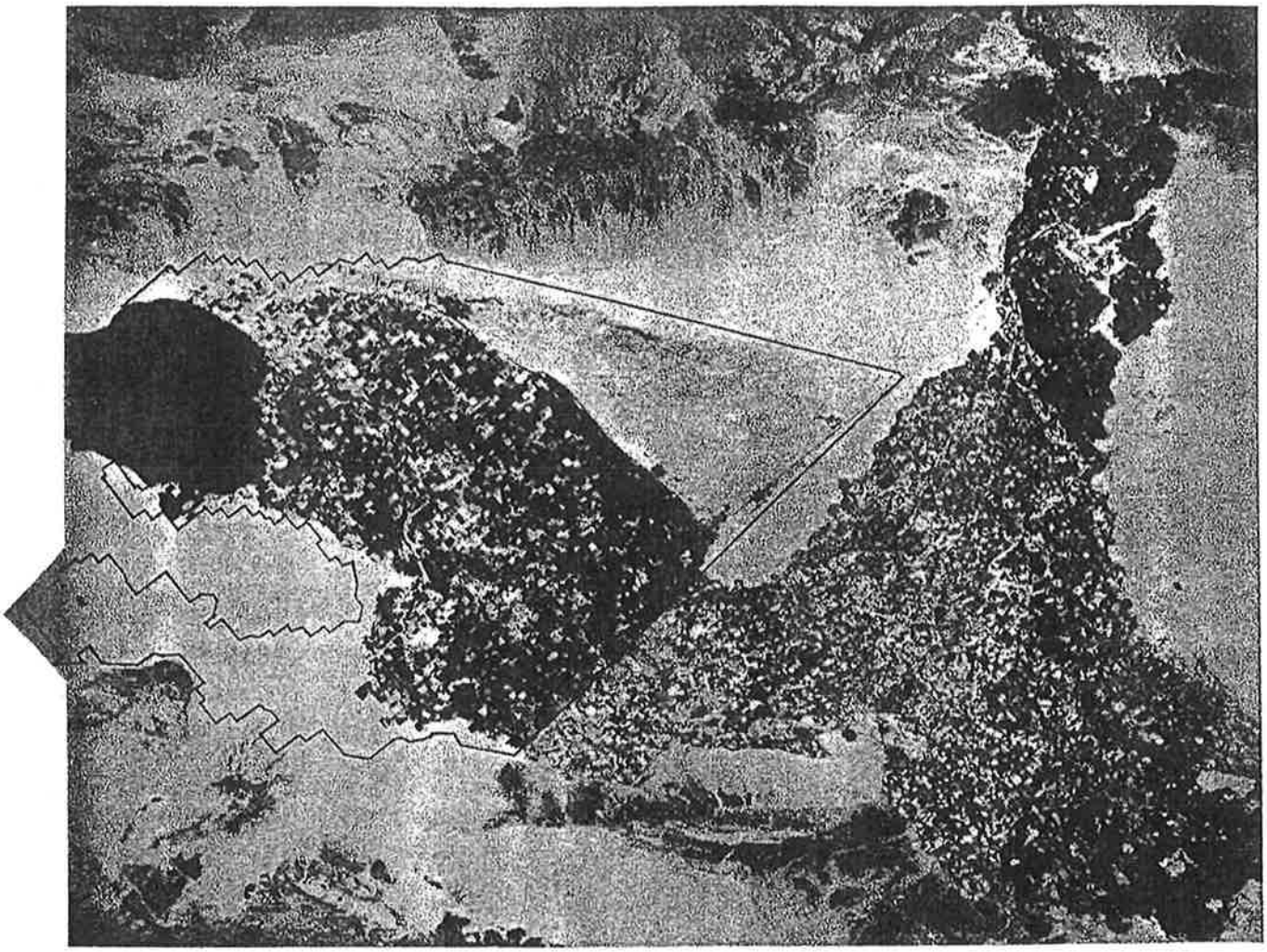
Soil Survey of

IMPERIAL COUNTY CALIFORNIA IMPERIAL VALLEY AREA



United States Department of Agriculture Soil Conservation Service
in cooperation with
University of California Agricultural Experiment Station
and
Imperial Irrigation District

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TABLE 11.--ENGINEERING INDEX PROPERTIES

[The symbol > means more than. Absence of an entry indicates that data were not estimated]

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
100----------	0-13	Loamy fine sand	SM	A-2	0	100	100	75-85	10-30	---	NP
Antho	13-60	Sandy loam, fine sandy loam.	SM	A-2, A-4	0	90-100	75-95	50-60	15-40	---	NP
101*:											
Antho----------	0-8	Loamy fine sand	SM	A-2	0	100	100	75-85	10-30	---	NP
	8-60	Sandy loam, fine sandy loam.	SM	A-2, A-4	0	90-100	75-95	50-60	15-40	---	NP
Superstition------	0-6	Fine sand-------	SM	A-2	0	100	95-100	70-85	15-25	---	NP
	6-60	Loamy fine sand, fine sand, sand.	SM	A-2	0	100	95-100	70-85	15-25	---	NP
102*. Badland											
103----------	0-10	Gravelly sand---	SP, SP-SM	A-1, A-2	0-5	60-90	50-85	30-55	0-10	---	NP
Carsitas	10-60	Gravelly sand, gravelly coarse sand, sand.	SP, SP-SM	A-1	0-5	60-90	50-85	25-50	0-10	---	NP
104* Fluvaquents											
105----------	0-13	Clay loam-------	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
106----------	0-13	Clay loam-------	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
107*----------	0-13	Loam----------	ML, CL-ML, CL	A-4	0	100	100	100	70-80	20-30	NP-10
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	95-100	70-95	35-45	15-30
108----------	0-14	Loam----------	ML	A-4	0	100	100	85-100	55-95	25-35	NP-10
Holtville	14-22	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	22-60	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
109----------	0-17	Silty clay------	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
Holtville	17-24	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	24-35	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
	35-60	Loamy very fine sand, loamy fine sand.	SM, ML	A-2, A-4	0	100	100	75-100	20-55	---	NP
110----------	0-17	Silty clay------	CH, CL	A-7	0	100	100	95-100	85-95	40-65	20-35
Holtville	17-24	Clay, silty clay	CH, CL	A-7	0	100	100	95-100	85-95	40-65	20-35
	24-35	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	55-85	25-35	NP-10
	35-60	Loamy very fine sand, loamy fine sand.	SM, ML	A-2, A-4	0	100	100	75-100	20-55	---	NP

See footnote at end of table.

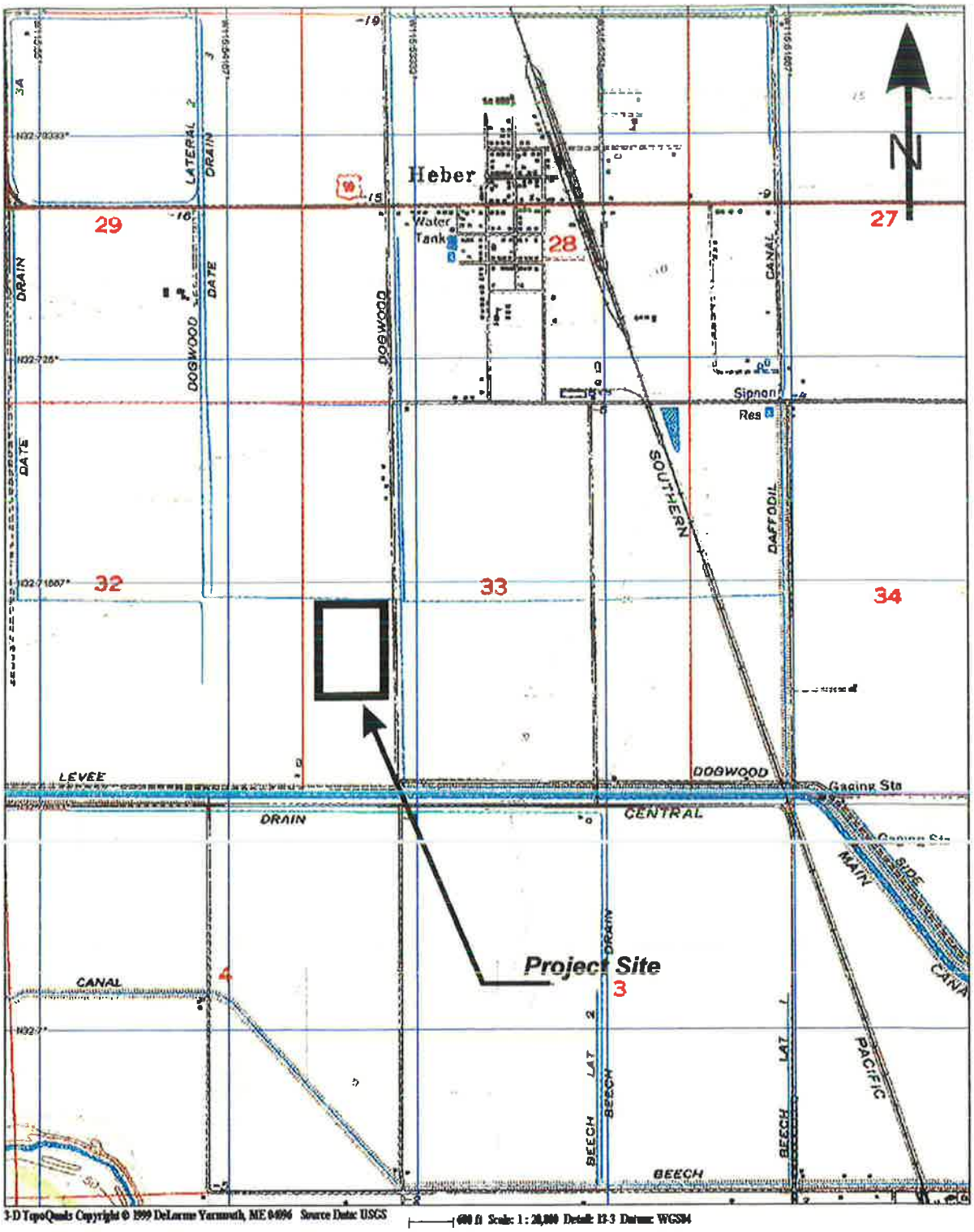
EEC ORIGINAL PKG

TABLE 11.--ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Frag-ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas-ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
111*:											
Holtville	0-10	Silty clay loam	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	10-22	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	22-60	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
Imperial	0-12	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
112	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
113	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay, clay, silty clay loam.	CH	A-7	0	100	100	100	85-95	50-70	25-45
114	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
115*:											
Imperial	0-12	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
Glenbar	0-13	Silty clay loam	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
116*:											
Imperial	0-13	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	13-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
Glenbar	0-13	Silty clay loam	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
	13-60	Clay loam, silty clay loam.	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
117, 118	0-12	Loam	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
Indio	12-72	Stratified loamy very fine sand to silt loam.	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
119*:											
Indio	0-12	Loam	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
	12-72	Stratified loamy very fine sand to silt loam.	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
Vint	0-10	Loamy fine sand	SM	A-2	0	95-100	95-100	70-80	25-35	---	NP
	10-60	Loamy sand, loamy fine sand.	SM	A-2	0	95-100	95-100	70-80	20-30	---	NP
120*	0-12	Loam	ML, CL-ML	A-4	0	100	95-100	75-85	55-65	20-30	NP-10
Laveen	12-60	Loam, very fine sandy loam.	ML, CL-ML	A-4	0	95-100	85-95	70-80	55-65	15-25	NP-10

See footnote at end of table.

EEC ORIGINAL PKG



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Project No.: LE04354

Topographic Map

Plate A-4

EEC ORIGINAL PKG

APPENDIX B

EEC ORIGINAL PKG

CLIENT: ORMAT

PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

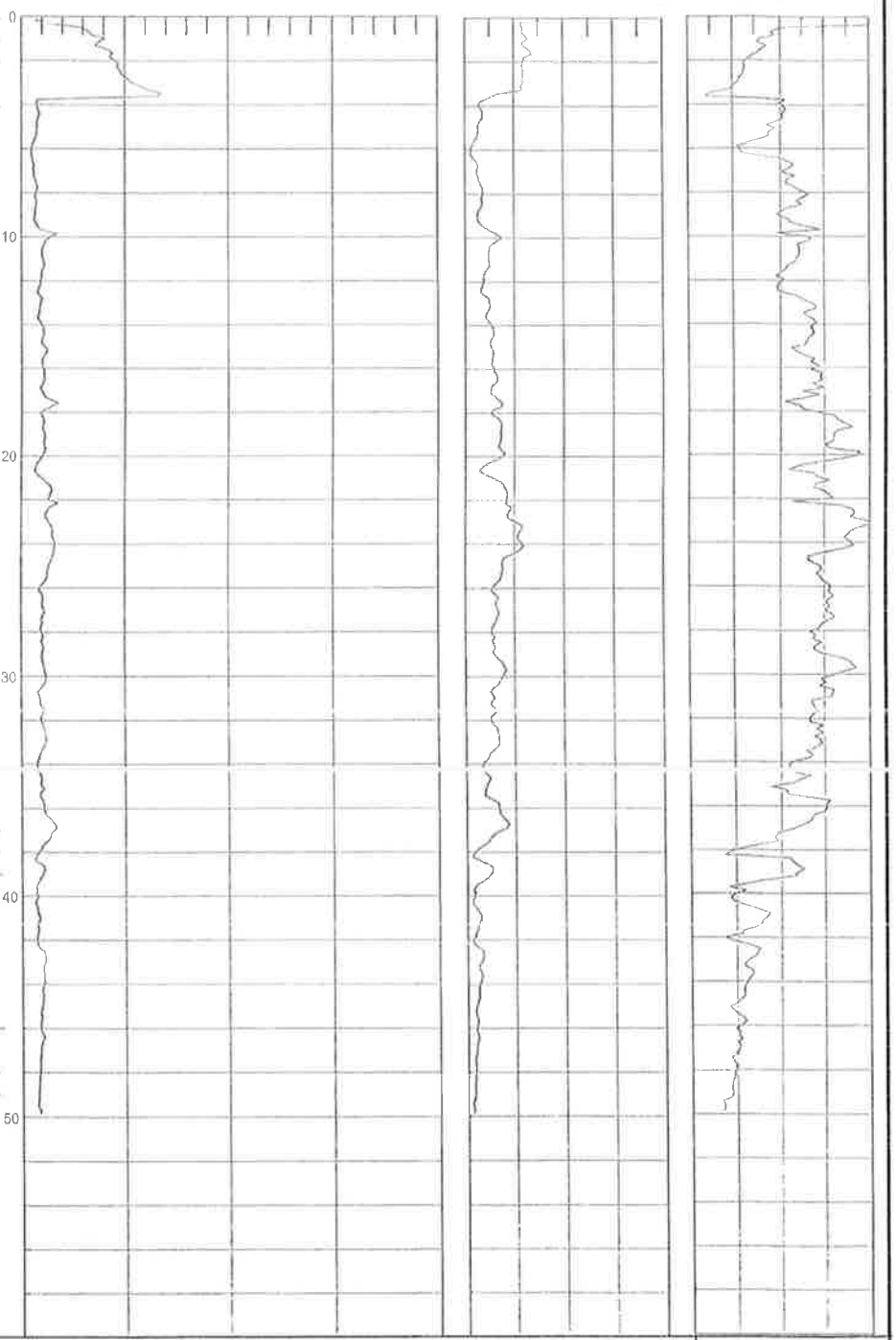
DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-1

INTERPRETED SOIL PROFILE
From Robertson & Campanella (1989)

DEPTH (FEET)			
GROUND EL. +/-			
	Clay	CL/CH	hard
	Sandy Silt to Clayey Silt	ML	very dense
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Silty Clay to Clay	CL	stiff
	Silty Clay to Clay	" "	stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	stiff
10	Clay	" "	very stiff
	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Silty Clay to Clay	CL	stiff
40	Clayey Silt to Silty Clay	ML/CL	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Sandy Silt to Clayey Silt	ML	very loose
	Sandy Silt to Clayey Silt	" "	very loose
	Clayey Silt to Silty Clay	ML/CL	stiff
50			

End of Sounding @ 49.5 ft.



Project No: LE04354

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Plate B-1

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-1

Est. GWT (ft): 12.0

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk; Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	31.82	10.13	3	Clay	CL/CH	very stiff	125	1.3	25	2.00		95			1.87	>10
0.30	1.0	71.19	3.50	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	20	2.00	134.6	45	107	43		
0.45	1.5	76.38	3.27	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	22	2.00	144.4	40	102	42		
0.60	2.0	88.21	2.88	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	25	2.00	166.8	35	101	42		
0.75	2.5	94.19	2.53	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	21	2.00	178.0	30	100	42		
0.93	3.0	101.94	2.35	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	23	2.00	192.7	30	99	42		
1.08	3.5	123.24	1.66	8	Sand to Silty Sand	SP/SM	very dense	115	5.5	22	2.00	233.0	20	102	42		
1.23	4.0	53.93	2.99	6	Sandy Silt to Clayey Silt	ML	dense	115	3.5	15	2.00	101.9	45	76	39		
1.38	4.5	16.43	4.19	3	Clay	CL/CH	stiff	125	1.3	13	2.00		85			0.95	>10
1.53	5.0	15.53	3.80	4	Silty Clay to Clay	CL	stiff	125	1.8	9	1.95		85			0.90	>10
1.68	5.5	13.99	3.48	4	Silty Clay to Clay	CL	stiff	125	1.8	8	1.85		85			0.80	>10
1.83	6.0	10.16	2.42	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	4	1.76		85			0.58	>10
1.98	6.5	10.41	3.55	4	Silty Clay to Clay	CL	stiff	125	1.8	6	1.69		95			0.59	>10
2.13	7.0	11.62	4.38	3	Clay	CL/CH	stiff	125	1.3	9	1.62		100			0.66	>10
2.28	7.5	13.29	4.44	3	Clay	CL/CH	stiff	125	1.3	11	1.56		95			0.76	>10
2.45	8.0	14.55	4.93	3	Clay	CL/CH	stiff	125	1.3	12	1.51		95			0.83	>10
2.60	8.5	13.90	4.96	3	Clay	CL/CH	stiff	125	1.3	11	1.46		100			0.79	>10
2.75	9.0	13.23	4.08	3	Clay	CL/CH	stiff	125	1.3	11	1.42		95			0.75	>10
2.90	9.5	13.66	4.68	3	Clay	CL/CH	stiff	125	1.3	11	1.38		100			0.77	>10
3.05	10.0	26.88	5.00	3	Clay	CL/CH	very stiff	125	1.3	22	1.34		80			1.55	>10
3.20	10.5	21.69	5.01	3	Clay	CL/CH	very stiff	125	1.3	17	1.32		90			1.24	>10
3.35	11.0	19.84	4.85	3	Clay	CL/CH	very stiff	125	1.3	16	1.30		95			1.13	>10
3.50	11.5	21.31	4.45	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	1.29		90			1.22	>10
3.65	12.0	18.97	4.00	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	1.27		90			1.08	>10
3.80	12.5	16.82	3.88	4	Silty Clay to Clay	CL	stiff	125	1.8	10	1.26		95			0.95	>10
3.95	13.0	18.18	4.91	3	Clay	CL/CH	very stiff	125	1.3	15	1.24		100			1.03	>10
4.13	13.5	17.33	5.43	3	Clay	CL/CH	stiff	125	1.3	14	1.23		100			0.98	>10
4.28	14.0	17.04	5.46	3	Clay	CL/CH	stiff	125	1.3	14	1.22		100			0.96	>10
4.43	14.5	21.21	5.45	3	Clay	CL/CH	very stiff	125	1.3	17	1.20		100			1.20	>10
4.58	15.0	19.96	5.21	3	Clay	CL/CH	very stiff	125	1.3	16	1.19		100			1.13	>10
4.73	15.5	23.41	4.80	3	Clay	CL/CH	very stiff	125	1.3	19	1.18		95			1.33	>10
4.88	16.0	20.50	5.51	3	Clay	CL/CH	very stiff	125	1.3	16	1.17		100			1.16	>10
5.03	16.5	21.94	5.88	3	Clay	CL/CH	very stiff	125	1.3	18	1.15		100			1.24	>10
5.18	17.0	19.22	5.48	3	Clay	CL/CH	very stiff	125	1.3	15	1.14		100			1.08	>10
5.33	17.5	27.57	5.03	3	Clay	CL/CH	very stiff	125	1.3	22	1.13		95			1.57	>10
5.48	18.0	23.29	5.22	3	Clay	CL/CH	very stiff	125	1.3	19	1.12		100			1.32	>10
5.65	18.5	20.85	6.67	3	Clay	CL/CH	very stiff	125	1.3	17	1.11		100			1.18	>10
5.80	19.0	21.33	6.77	3	Clay	CL/CH	very stiff	125	1.3	17	1.10		100			1.20	>10
5.95	19.5	21.97	6.29	3	Clay	CL/CH	very stiff	125	1.3	18	1.09		100			1.24	>10
6.10	20.0	21.34	7.09	3	Clay	CL/CH	very stiff	125	1.3	17	1.08		100			1.20	>10
6.25	20.5	15.48	5.72	3	Clay	CL/CH	stiff	125	1.3	12	1.07		100			0.86	5.53
6.40	21.0	15.87	5.20	3	Clay	CL/CH	stiff	125	1.3	13	1.06		100			0.88	5.65
6.55	21.5	26.53	5.79	3	Clay	CL/CH	very stiff	125	1.3	21	1.05		100			1.50	>10
6.70	22.0	27.19	6.21	3	Clay	CL/CH	very stiff	125	1.3	22	1.05		100			1.54	>10
6.85	22.5	29.12	6.18	3	Clay	CL/CH	very stiff	125	1.3	23	1.04		100			1.65	>10
7.00	23.0	24.40	7.41	3	Clay	CL/CH	very stiff	125	1.3	20	1.03		100			1.38	>10
7.18	23.5	29.74	7.65	3	Clay	CL/CH	very stiff	125	1.3	24	1.02		100			1.69	>10
7.33	24.0	31.24	7.01	3	Clay	CL/CH	very stiff	125	1.3	25	1.01		100			1.78	>10
7.48	24.5	31.71	6.74	3	Clay	CL/CH	very stiff	125	1.3	25	1.01		100			1.80	>10
7.63	25.0	28.38	5.36	3	Clay	CL/CH	very stiff	125	1.3	23	1.00		100			1.61	>10
7.78	25.5	25.50	5.79	3	Clay	CL/CH	very stiff	125	1.3	20	0.99		100			1.44	>10
7.93	26.0	21.23	6.01	3	Clay	CL/CH	very stiff	125	1.3	17	0.98		100			1.18	7.00
8.08	26.5	19.41	6.26	3	Clay	CL/CH	very stiff	125	1.3	16	0.98		100			1.08	6.00
8.23	27.0	21.10	6.12	3	Clay	CL/CH	very stiff	125	1.3	17	0.97		100			1.17	6.65
8.38	27.5	20.13	6.30	3	Clay	CL/CH	very stiff	125	1.3	16	0.96		100			1.12	6.00
8.53	28.0	19.23	5.66	3	Clay	CL/CH	very stiff	125	1.3	15	0.96		100			1.06	5.42
8.68	28.5	20.08	5.65	3	Clay	CL/CH	very stiff	125	1.3	16	0.95		100			1.11	5.76
8.85	29.0	20.55	5.67	3	Clay	CL/CH	very stiff	125	1.3	16	0.94		100			1.14	5.88
9.00	29.5	20.76	7.00	3	Clay	CL/CH	very stiff	125	1.3	17	0.94		100			1.15	5.88
9.15	30.0	22.80	6.88	3	Clay	CL/CH	very stiff	125	1.3	18	0.93		100			1.27	6.65

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-1

Est. GWT (ft): 12.0

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PH(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	21.00	5.00	3	Clay	CL/CH	very stiff	125	1.3	17	0.93		100			1.20	6.00
9.45	31.0	17.19	6.36	3	Clay	CL/CH	stiff	125	1.3	14	0.92		100			0.94	4.00
9.60	31.5	20.05	5.47	3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.10	5.10
9.75	32.0	19.47	5.50	3	Clay	CL/CH	very stiff	125	1.3	16	0.91		100			1.07	4.68
9.90	32.5	21.74	5.63	3	Clay	CL/CH	very stiff	125	1.3	17	0.90		100			1.20	5.53
10.05	33.0	23.37	5.76	3	Clay	CL/CH	very stiff	125	1.3	19	0.90		100			1.30	6.10
10.20	33.5	20.39	5.56	3	Clay	CL/CH	very stiff	125	1.3	16	0.89		100			1.12	4.78
10.38	34.0	15.97	5.12	3	Clay	CL/CH	stiff	125	1.3	13	0.89		100			0.86	3.28
10.53	34.5	16.45	4.48	3	Clay	CL/CH	stiff	125	1.3	13	0.88		100			0.89	3.35
10.68	35.0	16.50	4.96	3	Clay	CL/CH	very stiff	125	1.3	15	0.88		100			1.01	3.91
10.83	35.5	19.11	4.05	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.87		100			1.04	5.21
10.98	36.0	20.64	5.86	3	Clay	CL/CH	very stiff	125	1.3	17	0.87		100			1.13	4.47
11.13	36.5	25.44	5.72	3	Clay	CL/CH	very stiff	125	1.3	20	0.86		100			1.41	6.21
11.28	37.0	31.72	4.84	4	Silty Clay to Clay	CL	very stiff	125	1.8	18	0.86		100			1.78	>10
11.43	37.5	25.49	3.77	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.85		100			1.41	>10
11.58	38.0	17.68	2.48	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.85		100			0.95	5.65
11.73	38.5	15.25	3.47	4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.85		100			0.81	3.35
11.88	39.0	20.64	4.84	3	Clay	CL/CH	very stiff	125	1.3	17	0.84		100			1.13	4.00
12.05	39.5	15.50	3.51	4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.84		100			0.82	3.28
12.20	40.0	14.77	2.00	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.83		100			0.78	3.91
12.35	40.5	13.50	2.07	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	5	0.83		100			0.70	3.43
12.50	41.0	15.96	3.29	4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.82		100			0.85	3.28
12.65	41.5	15.32	3.05	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.82		100			0.81	4.00
12.80	42.0	14.74	2.01	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.82		100			0.77	3.66
12.95	42.5	17.48	2.54	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.81		100			0.93	4.78
13.10	43.0	22.47	2.80	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.23	7.13
13.25	43.5	20.78	2.49	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.13	6.21
13.40	44.0	21.29	2.62	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.16	6.43
13.58	44.5	19.71	2.35	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.06	5.53
13.73	45.0	19.60	2.17	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.05	5.42
13.88	45.5	18.05	1.84	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.79	13.5	100	13	30		
14.03	46.0	17.42	2.29	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.79		100			0.92	4.26
14.18	46.5	19.49	2.03	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.79	14.5	100	15	30		
14.33	47.0	17.99	2.10	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.88	3.83
14.48	47.5	16.62	1.85	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.88	3.83
14.63	48.0	16.66	1.91	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.88	3.83
14.78	48.5	15.96	1.83	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.77		100			0.83	3.58
14.93	49.0	15.56	1.78	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.77		100			0.81	3.35
15.10	49.5	14.89	1.48	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	4	0.77	10.8	100	7	29		

EEC ORIGINAL PKG

CLIENT: ORMAT

PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

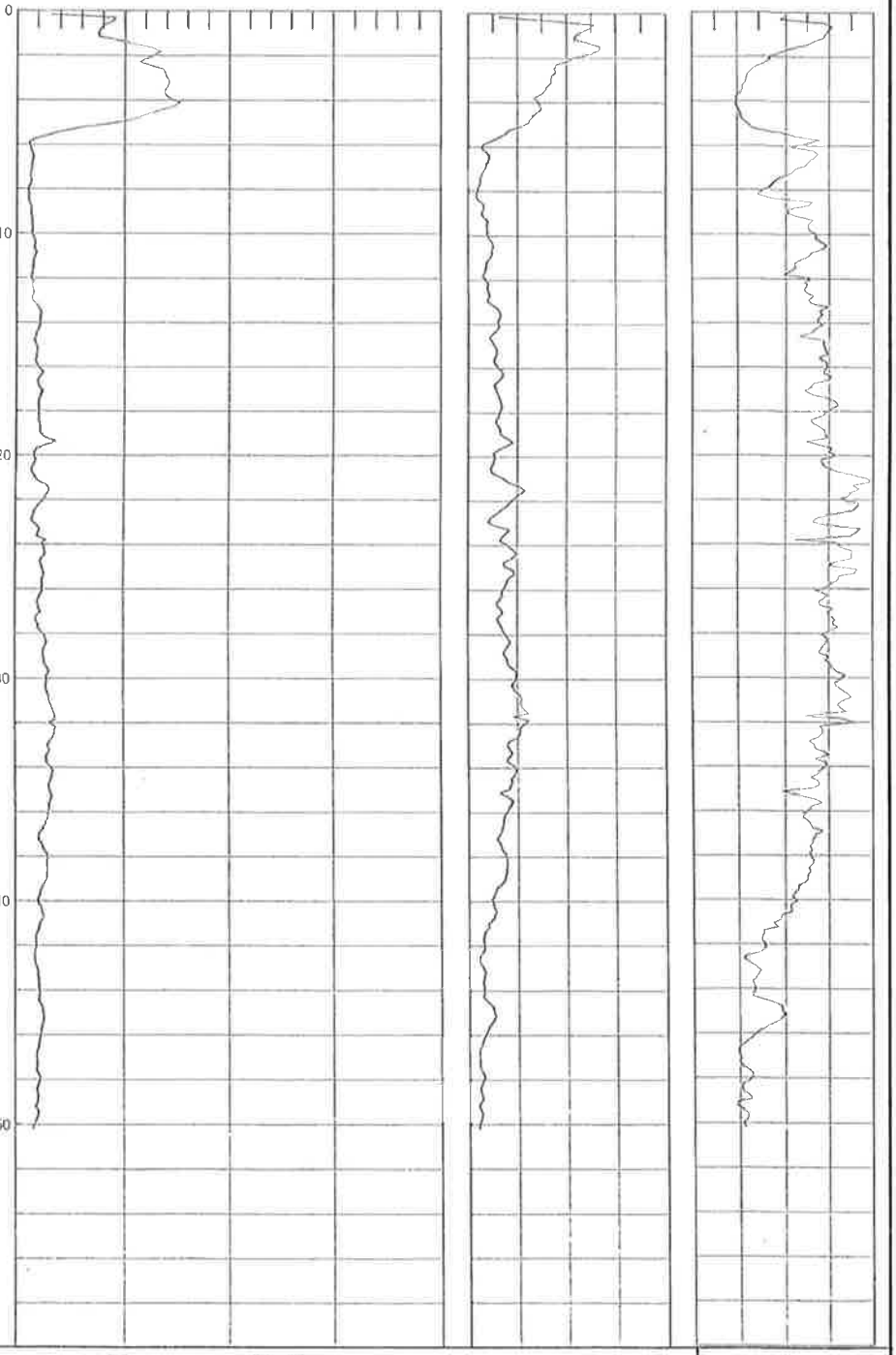
CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-2

DEPTH (FEET)	INTERPRETED SOIL PROFILE From Robertson & Campanella (1989)		
	GROUND EL. +/-		
	Overconsolidated Soil	??	very dense
	Overconsolidated Soil	" "	very dense
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Clayey Silt to Silty Clay	ML/CL	hard
	Clay	CL/CH	stiff
	Silty Clay to Clay	CL	stiff
	Clay	CL/CH	stiff
-10-	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
-20-	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
-30-	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
-40-	Silty Clay to Clay	CL	very stiff
	Silty Clay to Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Sandy Silt to Clayey Silt	ML	very loose
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Sandy Silt to Clayey Silt	ML	very loose
-50-	Sandy Silt to Clayey Silt	" "	very loose

End of Sounding @ 50.0 ft.



Project No: LE04354

LANDMARK
Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Plate B-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-2

Est. GWT (ft): 12.0 Phi Correlation: 0 0:Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %		1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	70.28	4.52	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	28	2.00		50			4.13	>10
0.30	1.0	77.82	5.97	11	11	Overconsolidated Soil	??	very dense	120	1.0	78	2.00	147.1	55	110	43		
0.45	1.5	91.98	5.31	11	11	Overconsolidated Soil	??	very dense	120	1.0	92	2.00	173.9	50	107	43		
0.60	2.0	129.94	3.78	6	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	37	2.00	245.6	35	113	44		
0.75	2.5	119.62	3.11	6	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	34	2.00	226.1	30	107	43		
0.93	3.0	137.68	2.51	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	260.3	25	108	43		
1.08	3.5	140.87	2.30	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	266.3	25	106	43		
1.23	4.0	139.35	2.04	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	263.4	20	104	43		
1.38	4.5	144.85	2.01	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	32	2.00	273.8	20	103	42		
1.53	5.0	113.08	2.24	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	25	1.95	208.9	25	94	41		
1.68	5.5	52.70	3.38	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	1.86		50			3.08	>10
1.83	6.0	13.87	4.91	3	3	Clay	CL/CH	stiff	125	1.3	11	1.77		95			0.80	>10
1.98	6.5	15.08	5.36	3	3	Clay	CL/CH	stiff	125	1.3	12	1.70		95			0.87	>10
2.13	7.0	14.77	4.81	3	3	Clay	CL/CH	stiff	125	1.3	12	1.63		95			0.85	>10
2.28	7.5	13.38	3.90	3	3	Clay	CL/CH	stiff	125	1.3	11	1.57		90			0.76	>10
2.45	8.0	12.25	3.27	4	4	Silty Clay to Clay	CL	stiff	125	1.8	7	1.51		90			0.69	>10
2.60	8.5	11.34	3.86	3	3	Clay	CL/CH	stiff	125	1.3	9	1.46		100			0.64	9.79
2.75	9.0	13.62	4.43	3	3	Clay	CL/CH	stiff	125	1.3	11	1.42		95			0.77	>10
2.90	9.5	14.76	4.97	3	3	Clay	CL/CH	stiff	125	1.3	12	1.38		100			0.84	>10
3.05	10.0	15.04	5.19	3	3	Clay	CL/CH	stiff	125	1.3	12	1.34		100			0.85	>10
3.20	10.5	17.24	5.61	3	3	Clay	CL/CH	stiff	125	1.3	14	1.33		100			0.98	>10
3.35	11.0	17.82	5.31	3	3	Clay	CL/CH	very stiff	125	1.3	14	1.31		100			1.01	>10
3.50	11.5	16.22	4.53	3	3	Clay	CL/CH	stiff	125	1.3	13	1.29		100			0.92	>10
3.65	12.0	14.59	4.45	3	3	Clay	CL/CH	stiff	125	1.3	12	1.28		100			0.82	9.19
3.80	12.5	15.95	4.89	3	3	Clay	CL/CH	stiff	125	1.3	13	1.26		100			0.90	>10
3.95	13.0	16.10	5.07	3	3	Clay	CL/CH	stiff	125	1.3	13	1.25		100			0.91	>10
4.13	13.5	20.52	5.55	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.23		100			1.17	>10
4.28	14.0	22.48	5.55	3	3	Clay	CL/CH	very stiff	125	1.3	18	1.22		100			1.28	>10
4.43	14.5	20.89	5.42	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.21		100			1.19	>10
4.58	15.0	17.79	5.37	3	3	Clay	CL/CH	very stiff	125	1.3	14	1.19		100			1.00	>10
4.73	15.5	19.47	5.86	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.18		100			1.10	>10
4.88	16.0	19.76	5.77	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.17		100			1.12	>10
5.03	16.5	22.50	5.91	3	3	Clay	CL/CH	very stiff	125	1.3	18	1.16		100			1.28	>10
5.18	17.0	21.67	5.09	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.15		100			1.23	>10
5.33	17.5	22.15	5.77	3	3	Clay	CL/CH	very stiff	125	1.3	18	1.13		100			1.25	>10
5.48	18.0	21.43	6.10	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.12		100			1.21	>10
5.65	18.5	21.56	5.34	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.11		100			1.22	>10
5.80	19.0	22.73	5.72	3	3	Clay	CL/CH	very stiff	125	1.3	18	1.10		100			1.29	>10
5.95	19.5	30.63	5.48	3	3	Clay	CL/CH	very stiff	125	1.3	25	1.09		95			1.75	>10
6.10	20.0	17.95	6.14	3	3	Clay	CL/CH	very stiff	125	1.3	14	1.08		100			1.00	7.41
6.25	20.5	17.30	5.70	3	3	Clay	CL/CH	stiff	125	1.3	14	1.07		100			0.96	6.65
6.40	21.0	16.60	6.99	3	3	Clay	CL/CH	stiff	125	1.3	13	1.07		100			0.92	6.10
6.55	21.5	26.75	7.44	3	3	Clay	CL/CH	very stiff	125	1.3	21	1.06		100			1.52	>10
6.70	22.0	28.17	6.81	3	3	Clay	CL/CH	very stiff	125	1.3	23	1.05		100			1.60	>10
6.85	22.5	20.17	7.24	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.04		100			1.13	7.85
7.00	23.0	16.15	5.62	3	3	Clay	CL/CH	stiff	125	1.3	13	1.03		100			0.89	5.21
7.18	23.5	21.37	6.84	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.02		100			1.20	8.27
7.33	24.0	24.23	5.98	3	3	Clay	CL/CH	very stiff	125	1.3	19	1.02		100			1.36	>10
7.48	24.5	27.09	6.88	3	3	Clay	CL/CH	very stiff	125	1.3	22	1.01		100			1.53	>10
7.63	25.0	23.97	6.46	3	3	Clay	CL/CH	very stiff	125	1.3	19	1.00		100			1.35	9.39
7.78	25.5	25.90	6.98	3	3	Clay	CL/CH	very stiff	125	1.3	21	0.99		100			1.46	>10
7.93	26.0	24.80	6.17	3	3	Clay	CL/CH	very stiff	125	1.3	20	0.99		100			1.39	9.59
8.08	26.5	22.94	5.66	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.98		100			1.28	8.00
8.23	27.0	22.28	5.92	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.97		100			1.24	7.27
8.38	27.5	20.15	6.14	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.97		100			1.12	6.10
8.53	28.0	24.13	6.05	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.96		100			1.35	8.14
8.68	28.5	28.28	5.86	3	3	Clay	CL/CH	very stiff	125	1.3	23	0.95		100			1.59	>10
8.85	29.0	26.02	5.73	3	3	Clay	CL/CH	very stiff	125	1.3	21	0.95		100			1.46	8.85
9.00	29.5	28.06	6.01	3	3	Clay	CL/CH	very stiff	125	1.3	22	0.94		100			1.58	>10
9.15	30.0	29.72	6.57	3	3	Clay	CL/CH	very stiff	125	1.3	24	0.93		100			1.68	>10

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-2

Est. GWT (ft): 12.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type		Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	28.55	6.41	3	3	Clay	CL/CH	very stiff	125	1.3	23	0.93		100			1.61	>10
9.45	31.0	31.07	6.84	3	3	Clay	CL/CH	very stiff	125	1.3	25	0.92		100			1.75	>10
9.60	31.5	34.71	6.59	3	3	Clay	CL/CH	very stiff	125	1.3	28	0.92		100			1.97	>10
9.75	32.0	35.27	6.25	3	3	Clay	CL/CH	very stiff	125	1.3	28	0.91		100			2.00	>10
9.90	32.5	37.01	5.65	3	3	Clay	CL/CH	hard	125	1.3	30	0.91		100			2.10	>10
10.05	33.0	32.37	5.31	3	3	Clay	CL/CH	very stiff	125	1.3	26	0.90		100			1.83	>10
10.20	33.5	30.28	5.70	3	3	Clay	CL/CH	very stiff	125	1.3	24	0.89		100			1.70	9.59
10.38	34.0	29.97	5.71	3	3	Clay	CL/CH	very stiff	125	1.3	24	0.89		100			1.68	9.19
10.53	34.5	34.16	5.42	3	3	Clay	CL/CH	very stiff	125	1.3	27	0.88		100			1.93	>10
10.68	35.0	31.53	5.44	3	3	Clay	CL/CH	very stiff	125	1.3	25	0.88		100			1.77	9.79
10.83	35.5	33.18	4.62	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	19	0.87		100			1.87	>10
10.98	36.0	31.41	5.32	3	3	Clay	CL/CH	very stiff	125	1.3	25	0.87		100			1.77	9.19
11.13	36.5	28.95	4.94	3	3	Clay	CL/CH	very stiff	125	1.3	23	0.86		100			1.62	7.70
11.28	37.0	23.74	5.43	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.86		100			1.31	5.42
11.43	37.5	24.03	5.19	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.85		100			1.33	5.42
11.58	38.0	28.73	5.16	3	3	Clay	CL/CH	very stiff	125	1.3	23	0.85		100			1.60	7.13
11.73	38.5	29.89	5.19	3	3	Clay	CL/CH	very stiff	125	1.3	24	0.85		100			1.67	7.56
11.88	39.0	29.55	5.05	3	3	Clay	CL/CH	very stiff	125	1.3	24	0.84		100			1.65	7.27
12.05	39.5	25.32	4.72	3	3	Clay	CL/CH	very stiff	125	1.3	20	0.84		100			1.40	5.53
12.20	40.0	22.19	4.46	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.83		100			1.22	4.37
12.35	40.5	24.43	4.30	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	14	0.83		100			1.35	6.54
12.50	41.0	24.85	3.66	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.82		100			1.37	9.39
12.65	41.5	21.29	3.25	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.16	6.88
12.80	42.0	19.81	3.04	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.82		100			1.07	6.00
12.95	42.5	18.87	2.79	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.02	5.42
13.10	43.0	19.60	2.48	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.06	5.76
13.25	43.5	21.70	2.84	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.18	6.65
13.40	44.0	22.24	2.62	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.21	6.88
13.58	44.5	22.52	2.78	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.23	6.88
13.73	45.0	25.15	3.77	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.80		100			1.38	8.27
13.88	45.5	26.20	3.80	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.44	8.85
14.03	46.0	24.44	3.02	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.34	7.70
14.18	46.5	22.65	2.43	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.79		100			1.23	6.54
14.33	47.0	20.81	1.98	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.78	15.4	100	17	30		
14.48	47.5	20.51	2.12	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.78	15.1	100	17	30		
14.63	48.0	22.61	2.50	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.78		100			1.23	6.32
14.78	48.5	20.83	2.13	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.77	15.2	100	17	30		
14.93	49.0	20.93	2.27	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.77		100			1.13	5.42
15.10	49.5	20.67	2.11	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.77	15.0	100	16	30		
15.25	50.0	19.06	2.25	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.76		100			1.01	4.47

EEC ORIGINAL PKG

CLIENT: ORMAT

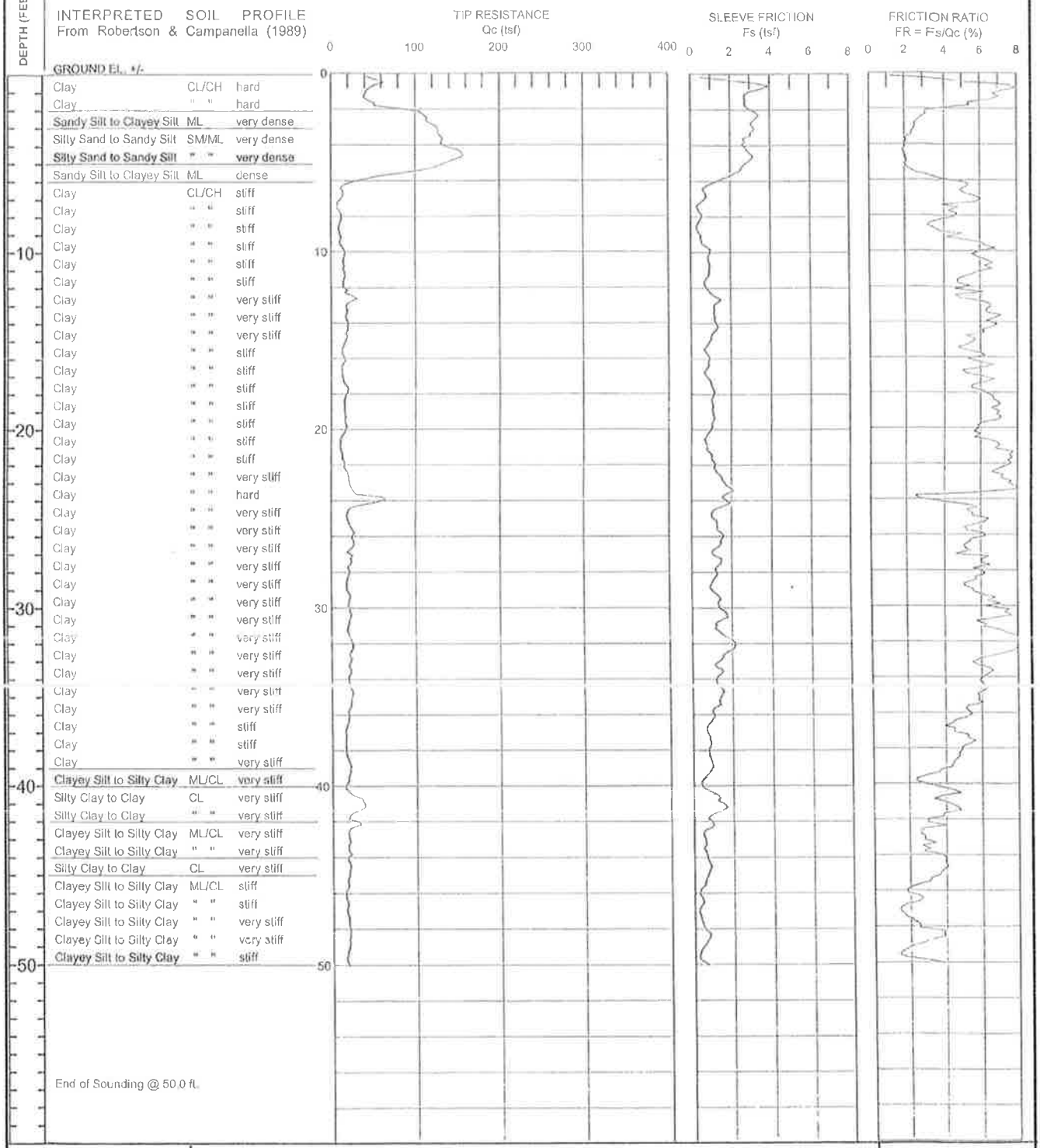
PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-3



Project No: LE04354

LANDMARK Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Plate B-3

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-3

Est. GWT (ft): 12.0

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	I Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: 17.0 Phi (deg.)	Su (tsf)	OCR
0.15	0.5	51.76	3.36	5 5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	2.00		50			3.04	>10
0.30	1.0	46.42	7.56	3 3	Clay	CL/CH	hard	125	1.3	37	2.00		75			2.73	>10
0.45	1.5	40.35	6.79	3 3	Clay	CL/CH	hard	125	1.3	32	2.00		75			2.37	>10
0.60	2.0	61.72	4.80	4 4	Silty Clay to Clay	CL	hard	125	1.8	35	2.00		55			3.62	>10
0.75	2.5	109.67	3.07	6 6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	31	2.00	207.3	35	104	43		
0.93	3.0	118.60	2.64	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	26	2.00	224.2	30	103	42		
1.08	3.5	127.70	2.43	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	28	2.00	241.4	25	103	42		
1.23	4.0	131.15	2.02	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	29	2.00	247.9	25	102	42		
1.38	4.5	147.55	1.96	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	33	2.00	278.9	20	103	42		
1.53	5.0	148.38	2.05	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	33	1.94	271.7	20	102	42		
1.68	5.5	111.44	2.28	7 7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	25	1.85	194.4	25	92	41		
1.83	6.0	40.17	4.02	5 5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	16	1.76		60			2.34	>10
1.98	6.5	13.36	5.18	3 3	Clay	CL/CH	stiff	125	1.3	11	1.69		100			0.76	>10
2.13	7.0	13.22	5.65	3 3	Clay	CL/CH	stiff	125	1.3	11	1.62		100			0.75	>10
2.28	7.5	7.68	4.85	3 3	Clay	CL/CH	firm	125	1.3	6	1.56		100			0.43	6.10
2.45	8.0	11.50	4.55	3 3	Clay	CL/CH	stiff	125	1.3	9	1.51		100			0.65	>10
2.60	8.5	10.61	3.49	4 4	Silty Clay to Clay	CL	stiff	125	1.8	6	1.46		95			0.60	>10
2.75	9.0	9.81	4.10	3 3	Clay	CL/CH	stiff	125	1.3	8	1.42		100			0.55	6.54
2.90	9.5	10.85	5.09	3 3	Clay	CL/CH	stiff	125	1.3	9	1.38		100			0.61	7.00
3.05	10.0	14.61	6.36	3 3	Clay	CL/CH	stiff	125	1.3	12	1.34		100			0.82	>10
3.20	10.5	14.97	5.91	3 3	Clay	CL/CH	stiff	125	1.3	12	1.32		100			0.85	>10
3.35	11.0	14.49	6.53	3 3	Clay	CL/CH	stiff	125	1.3	12	1.31		100			0.82	>10
3.50	11.5	15.94	5.42	3 3	Clay	CL/CH	stiff	125	1.3	13	1.29		100			0.90	>10
3.65	12.0	14.15	5.01	3 3	Clay	CL/CH	stiff	125	1.3	11	1.27		100			0.79	8.56
3.80	12.5	20.31	5.15	3 3	Clay	CL/CH	very stiff	125	1.3	16	1.26		95			1.16	>10
3.95	13.0	23.81	5.79	3 3	Clay	CL/CH	very stiff	125	1.3	19	1.24		95			1.36	>10
4.13	13.5	18.35	6.42	3 3	Clay	CL/CH	very stiff	125	1.3	15	1.23		100			1.04	>10
4.28	14.0	18.13	6.73	3 3	Clay	CL/CH	very stiff	125	1.3	15	1.22		100			1.02	>10
4.43	14.5	19.70	6.56	3 3	Clay	CL/CH	very stiff	125	1.3	16	1.20		100			1.12	>10
4.58	15.0	18.07	5.71	3 3	Clay	CL/CH	very stiff	125	1.3	14	1.19		100			1.02	>10
4.73	15.5	14.86	5.24	3 3	Clay	CL/CH	stiff	125	1.3	12	1.18		100			0.83	7.00
4.88	16.0	14.60	5.69	3 3	Clay	CL/CH	stiff	125	1.3	12	1.17		100			0.81	6.65
5.03	16.5	13.49	6.25	3 3	Clay	CL/CH	stiff	125	1.3	11	1.16		100			0.75	5.65
5.18	17.0	13.31	5.44	3 3	Clay	CL/CH	stiff	125	1.3	11	1.14		100			0.74	5.31
5.33	17.5	16.20	6.21	3 3	Clay	CL/CH	stiff	125	1.3	13	1.13		100			0.90	7.13
5.48	18.0	19.16	5.98	3 3	Clay	CL/CH	very stiff	125	1.3	15	1.12		100			1.08	9.59
5.65	18.5	15.49	6.80	3 3	Clay	CL/CH	stiff	125	1.3	12	1.11		100			0.86	6.32
5.80	19.0	15.81	6.89	3 3	Clay	CL/CH	stiff	125	1.3	13	1.10		100			0.88	6.32
5.95	19.5	16.32	7.00	3 3	Clay	CL/CH	stiff	125	1.3	13	1.09		100			0.91	6.43
6.10	20.0	17.26	5.95	3 3	Clay	CL/CH	stiff	125	1.3	14	1.08		100			0.96	6.88
6.25	20.5	13.28	5.76	3 3	Clay	CL/CH	stiff	125	1.3	11	1.07		100			0.73	4.37
6.40	21.0	11.14	6.84	3 3	Clay	CL/CH	stiff	125	1.3	9	1.06		100			0.60	3.28
6.55	21.5	12.48	7.40	3 3	Clay	CL/CH	stiff	125	1.3	10	1.06		100			0.68	3.74
6.70	22.0	14.92	7.62	3 3	Clay	CL/CH	stiff	125	1.3	12	1.05		100			0.82	4.89
6.85	22.5	17.77	6.98	3 3	Clay	CL/CH	stiff	125	1.3	14	1.04		100			0.99	6.32
7.00	23.0	21.45	7.34	3 3	Clay	CL/CH	very stiff	125	1.3	17	1.03		100			1.20	8.41
7.18	23.5	24.58	7.84	3 3	Clay	CL/CH	very stiff	125	1.3	20	1.02		100			1.39	>10
7.33	24.0	51.65	3.68	5 5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	1.02		70			2.98	>10
7.48	24.5	34.37	4.91	3 3	Clay	CL/CH	very stiff	125	1.3	27	1.01		95			1.96	>10
7.63	25.0	18.84	5.44	3 3	Clay	CL/CH	very stiff	125	1.3	15	1.00		100			1.05	6.10
7.78	25.5	21.09	6.11	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.99		100			1.18	7.13
7.93	26.0	26.12	5.49	3 3	Clay	CL/CH	very stiff	125	1.3	21	0.99		100			1.47	>10
8.08	26.5	26.28	5.55	3 3	Clay	CL/CH	very stiff	125	1.3	21	0.98		100			1.48	>10
8.23	27.0	21.92	5.06	3 3	Clay	CL/CH	very stiff	125	1.3	18	0.97		100			1.22	7.13
8.38	27.5	23.63	6.15	3 3	Clay	CL/CH	very stiff	125	1.3	19	0.97		100			1.32	8.00
8.53	28.0	20.49	6.07	3 3	Clay	CL/CH	very stiff	125	1.3	16	0.96		100			1.14	6.10
8.68	28.5	19.11	5.87	3 3	Clay	CL/CH	very stiff	125	1.3	15	0.95		100			1.06	5.31
8.85	29.0	18.15	5.24	3 3	Clay	CL/CH	stiff	125	1.3	15	0.95		100			1.00	4.78
9.00	29.5	21.72	6.18	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.94		100			1.21	6.32
9.15	30.0	20.63	6.55	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.93		100			1.14	5.65

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-3

Est. GWT (ft): 12.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type		Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk; Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	22.90	7.51	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.93		100			1.27	6.54
9.45	31.0	20.57	6.23	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.14	5.42
9.60	31.5	19.55	6.90	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.08	4.89
9.75	32.0	23.76	8.37	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.91		100			1.32	6.54
9.90	32.5	24.30	8.05	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.90		100			1.35	6.65
10.05	33.0	22.78	6.54	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.90		100			1.26	5.88
10.20	33.5	21.56	5.91	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.89		100			1.19	5.31
10.38	34.0	20.82	6.40	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.89		100			1.15	4.89
10.53	34.5	21.17	6.04	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.88		100			1.17	4.89
10.68	35.0	24.71	6.05	3	3	Clay	CL/CH	very stiff	125	1.3	20	0.88		100			1.37	6.21
10.83	35.5	23.14	5.91	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.87		100			1.28	5.53
10.98	36.0	19.96	5.21	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.87		100			1.09	4.28
11.13	36.5	19.03	4.88	3	3	Clay	CL/CH	very stiff	125	1.3	15	0.86		100			1.04	3.91
11.28	37.0	16.19	4.33	3	3	Clay	CL/CH	stiff	125	1.3	13	0.86		100			0.87	3.07
11.43	37.5	16.02	5.36	3	3	Clay	CL/CH	stiff	125	1.3	13	0.85		100			0.86	3.00
11.58	38.0	16.15	5.06	3	3	Clay	CL/CH	stiff	125	1.3	13	0.85		100			0.86	3.00
11.73	38.5	17.81	4.75	3	3	Clay	CL/CH	stiff	125	1.3	14	0.85		100			0.96	3.35
11.88	39.0	21.66	4.41	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	0.84		100			1.19	5.65
12.05	39.5	20.18	3.42	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.84		100			1.10	6.65
12.20	40.0	17.00	2.62	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.83		100			0.91	5.00
12.35	40.5	20.64	4.32	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	0.83		100			1.12	5.00
12.50	41.0	36.57	3.70	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	15	0.82		95			2.06	>10
12.65	41.5	31.64	4.64	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	18	0.82		100			1.77	>10
12.80	42.0	23.58	3.56	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.29	8.14
12.95	42.5	24.97	3.28	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.81		100			1.37	8.85
13.10	43.0	19.07	2.71	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.03	5.42
13.25	43.5	18.86	2.98	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.01	5.31
13.40	44.0	19.54	3.20	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.05	5.53
13.58	44.5	19.29	3.97	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.80		100			1.04	3.91
13.73	45.0	19.79	3.86	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.80		100			1.07	4.00
13.88	45.5	17.66	3.31	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.79		100			0.94	4.47
14.03	46.0	16.42	2.18	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.79		100			0.87	3.91
14.18	46.5	15.61	2.35	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.78		100			0.82	3.58
14.33	47.0	10.00	1.00	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.78	12.3	100	11	29		
14.48	47.5	18.25	1.80	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.78	13.4	100	13	30		
14.63	48.0	19.39	2.43	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.78		100			1.04	4.89
14.78	48.5	19.39	3.87	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.77		100			1.04	3.58
14.93	49.0	19.13	2.69	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.77		100			1.02	4.57
15.10	49.5	16.46	1.59	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.77	11.9	100	10	29		
15.25	50.0	16.91	2.83	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.76		100			0.89	3.74

EEC ORIGINAL PKG

APPENDIX C

EEC ORIGINAL PKG

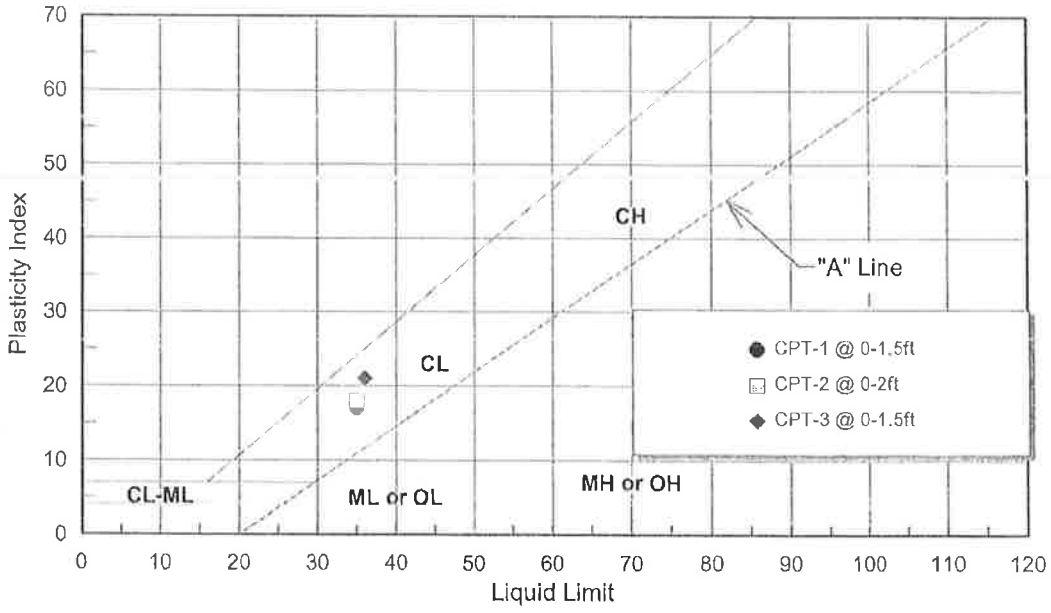
LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

ATTERBERG LIMITS (ASTM D4318)

Sample Location	Sample Depth (ft)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	USCS Classif-ation
CPT-1	0-1.5	35	18	17	CL
CPT-2	0-2	35	17	18	CL
CPT-3	0-1.5	36	15	21	CL

PLASTICITY CHART



LANDMARK Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Project No: LE04354

Atterberg Limits Test Results

Plate C-1

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

CHEMICAL ANALYSES

Boring:	CPT-1	CPT-1	CPT-2	CPT-2	CalTrans
Sample Depth, ft:	0-1.5	1.5-3	0-2	2-3	Method
pH:	7.9	7.9	7.8	7.9	643
Electrical Conductivity (mmhos):	2.5	1.7	1.8	0.9	424
Resistivity (ohm-cm):	260	1000	300	1000	643
Chloride (Cl), ppm:	3,040	230	1,490	220	422
Sulfate (SO4), ppm:	2,812	3,006	1,500	1,106	417

General Guidelines for Soil Corrosivity

Material Affected	Chemical Agent	Amount in Soil (ppm)	Degree of Corrosivity
Concrete	Soluble Sulfates	0 -1000	Low
		1000 - 2000	Moderate
		2000 - 20,000	Severe
		> 20,000	Very Severe
Normal Grade Steel	Soluble Chlorides	0 - 200	Low
		200 - 700	Moderate
		700 - 1500	Severe
		> 1500	Very Severe
Normal Grade Steel	Resistivity	1-1000	Very Severe
		1000-2000	Severe
		2000-10,000	Moderate
		10,000+	Low

LANDMARK Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Project No: LE04354

Selected Chemical Analyses Results

Plate C-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

CHEMICAL ANALYSES

Boring:	CPT-3	CPT-3	CalTrans
Sample Depth, ft:	0-1.5	1.5-3	Method
pH:	7.9	7.8	643
Electrical Conductivity (mmhos):	1.5	1.3	424
Resistivity (ohm-cm):	450	1000	643
Chloride (Cl), ppm:	570	210	422
Sulfate (SO4), ppm:	1,785	1,052	417

General Guidelines for Soil Corrosivity

Material Affected	Chemical Agent	Amount in Soil (ppm)	Degree of Corrosivity
Concrete	Soluble Sulfates	0 -1000	Low
		1000 - 2000	Moderate
		2000 - 20,000	Severe
		> 20,000	Very Severe
Normal Grade Steel	Soluble Chlorides	0 - 200	Low
		200 - 700	Moderate
		700 - 1500	Severe
		> 1500	Very Severe
Normal Grade Steel	Resistivity	1-1000	Very Severe
		1000-2000	Severe
		2000-10,000	Moderate
		10,000+	Low

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Project No: LE04354

Selected Chemical Analyses Results

Plate C-3

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APPENDIX D

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APPENDIX E

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May 9, 2007

Mr. Yuri Gal
ORMAT Nevada, Inc.
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Geotechnical Investigation
Proposed Heber South Geothermal Plant
Dogwood Road
Heber, California
LCI Project No. L07178

Dear Mr. Gal:

Landmark Consultants, Inc. is pleased to present this geotechnical report update for design and construction of the Heber South Geothermal Plant facility located on Dogwood Road south of Heber, California. The project site is located in the southwest corner of the existing Heber geothermal plant site. The proposed plant will consist of one OEC unit, one cooling tower, and various ancillary structures including pumps, filters, and shelter.

This update report presents selected elements of our findings and recommendations only. For the proper application of our findings and recommendations, reading of the full geotechnical report (LCI Report No. LE04354, dated January 5, 2005) is required, and are best evaluated with the active participation of the engineer of record who developed them.

The scope of work consisted of conducting two (2) electronic CPT soundings within the OEC and cooling tower footprints and review of the existing geotechnical report for the Heber 2 plant expansion (Landmark, 2005) to determine suitability of the prior geotechnical report for use with the design and construction of the proposed Heber South plant.

Small structures are planned for electrical control panels, consisting of masonry or panelized concrete construction. Expected footing loads are estimated at 1 to 2 kips per lineal foot for the small structures. Expected plant components, cooling tower and turbine/generator columns loads range from 5 to 400 kips. If structural loads exceed those stated above, we should be notified so we may evaluate their impact on foundation settlement and bearing capacity. Site development will include foundation support pad preparation and underground utility installation.

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Subsurface Exploration

Subsurface exploration was performed on May 2, 2007 using Holguin, Fahan, & Associates, Inc. of Cypress, California to advance three (3) electric cone penetrometer (CPT) soundings to an approximate depth of 50 feet below existing ground surface. The soundings were made at the locations shown on the Site and Exploration Plan (Plate A-2). The approximate sounding locations were established in the field and plotted on the site map by sighting to discernable site features.

Interpretive logs of the CPT soundings were produced and presented in final form after review of field and laboratory data and are presented on Plates B-1 and B-2 in Appendix B. A key to the interpretation of CPT soundings is presented on Plate B-3. The stratification lines shown on the subsurface logs represent the approximate boundaries between the various strata. However, the transition from one stratum to another may be gradual over some range of depth.

Subsurface soils encountered during the field exploration conducted on May 2, 2007 consist of medium dense to dense silty sands extend to a depth of 4 to 5 feet below ground surface. Stiff to very stiff clays extend from 4 feet to a depth of 50 feet, the maximum depth of exploration. The subsurface logs (Plates B-1 and B-2) depict the stratigraphic relationships of the various soil types.

Groundwater Elevation

Groundwater was not noted in the CPT soundings at the time of exploration, but is typically encountered at approximately 10 to 15 feet below ground surface in the vicinity of the site. There is uncertainty in the accuracy of short-term water level measurements, particularly in fine-grained soil. Groundwater levels may fluctuate with precipitation, irrigation of adjacent properties, drainage, and site grading. The referenced groundwater level should not be interpreted to represent an accurate or permanent condition.

Seismic Parameters

The project site is located in the seismically active Imperial Valley in Southern California, and is considered likely to be subjected to moderate to strong ground shaking from earthquakes in the region. The project site lies approximately 11.3 km southwest of the Imperial Fault. Strong ground shaking can be expected for magnitudes of 6.0 to 7.2 events on the Imperial Fault with a recurrence interval for 6.0 magnitude events at about 29 years. We have used the computer program FRISKSP (Blake, 2000) to provide a probabilistic estimate of the site Peak Ground Acceleration (PGA) using the attenuation relationship of Boore, Joyner, and Fumal (1997) NEHRP D (250). The PGA estimate for the project site having a 10% probability of being exceeded in 50 years (return period of 475 years) is **0.60g**.

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CBC Seismic Coefficients: The California Building Code (CBC) seismic response coefficients are calculated from the near-source factors for Seismic Zone 4. The near-source factors are based on the distance from the fault and the seismic source type. The following table lists seismic and site coefficients (near source factors) determined by Chapter 16 of the 2001 CBC. ***This site lies within 11.3 km of a Type A fault overlying S_D (stiff) soil.***

CBC Seismic Coefficients for Chapter 16 Seismic Provisions

CBC Code Edition	Soil Profile Type	Seismic Source Type	Distance to Critical Source	Near Source Factors		Seismic Coefficients	
				Na	Nv	Ca	Cv
2001	S_D (stiff soil)	A	< 11.3 km	1.00	1.15	0.44	0.74
Ref. Table	16-J	16-U	---	16-S	16-T	16-Q	16-R

Liquefaction Potential

Evaluation of liquefaction potential at the site indicates that it is unlikely that the subsurface soil will liquefy under seismically induced groundshaking due to the predominance of cohesive clay (non-liquefiable) subsurface soil below the groundwater depth. No mitigation is required for liquefaction effects at this site.

Lateral Earth Pressures

Earth retaining structures, such as retaining walls, should be designed to resist the soil pressure imposed by the retained soil mass. Walls with granular drained backfill may be designed for an assumed static earth pressure equivalent to that exerted by a fluid weighing 55 pcf for unrestrained (active) conditions (able to rotate 0.1% of wall height), and 70 pcf for restrained (at-rest) conditions.

Surcharge loads should be considered if loads are applied within a zone between the face of the wall and a plane projected behind the wall 45 degrees upward from the base of the wall. The increase in lateral earth pressure acting uniformly against the back of the wall should be taken as 50% of the surcharge load within this zone. Areas of the retaining wall subjected to traffic loads should be designed for a uniform surcharge load equivalent to two feet of native soil.

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Walls should be provided with backdrains to reduce the potential for the buildup of hydrostatic pressure. The drainage system should consist of a composite HDPE drainage panel or a 2-foot wide zone of free draining crushed rock placed adjacent to the wall and extending 2/3 the height of the wall. The gravel should be completely enclosed in an approved filter fabric to separate the gravel and backfill soil. A perforated pipe should be placed perforations down at the base of the permeable material at least six inches below finished floor elevations. The pipe should be sloped to drain to an appropriate outlet that is protected against erosion. Walls should be properly waterproofed. The project geotechnical engineer should approve any alternative drain system.

Structure Support Pads/Foundation

The subsurface exploration conducted in May 2007 identified engineering properties of the soil nearly identical to the Landmark, 2005 geotechnical report. The findings and recommendations within the 2005 geotechnical report may be used for the Heber South project. A copy of the Landmark 2005 geotechnical report is provide in Appendix C.

Closure

We appreciate the opportunity to provide our findings and professional opinions regarding geotechnical conditions at the site. If you have any questions or comments regarding our findings, please call our office at (760) 370-3000.

Respectfully Submitted,
Landmark Consultants, Inc.

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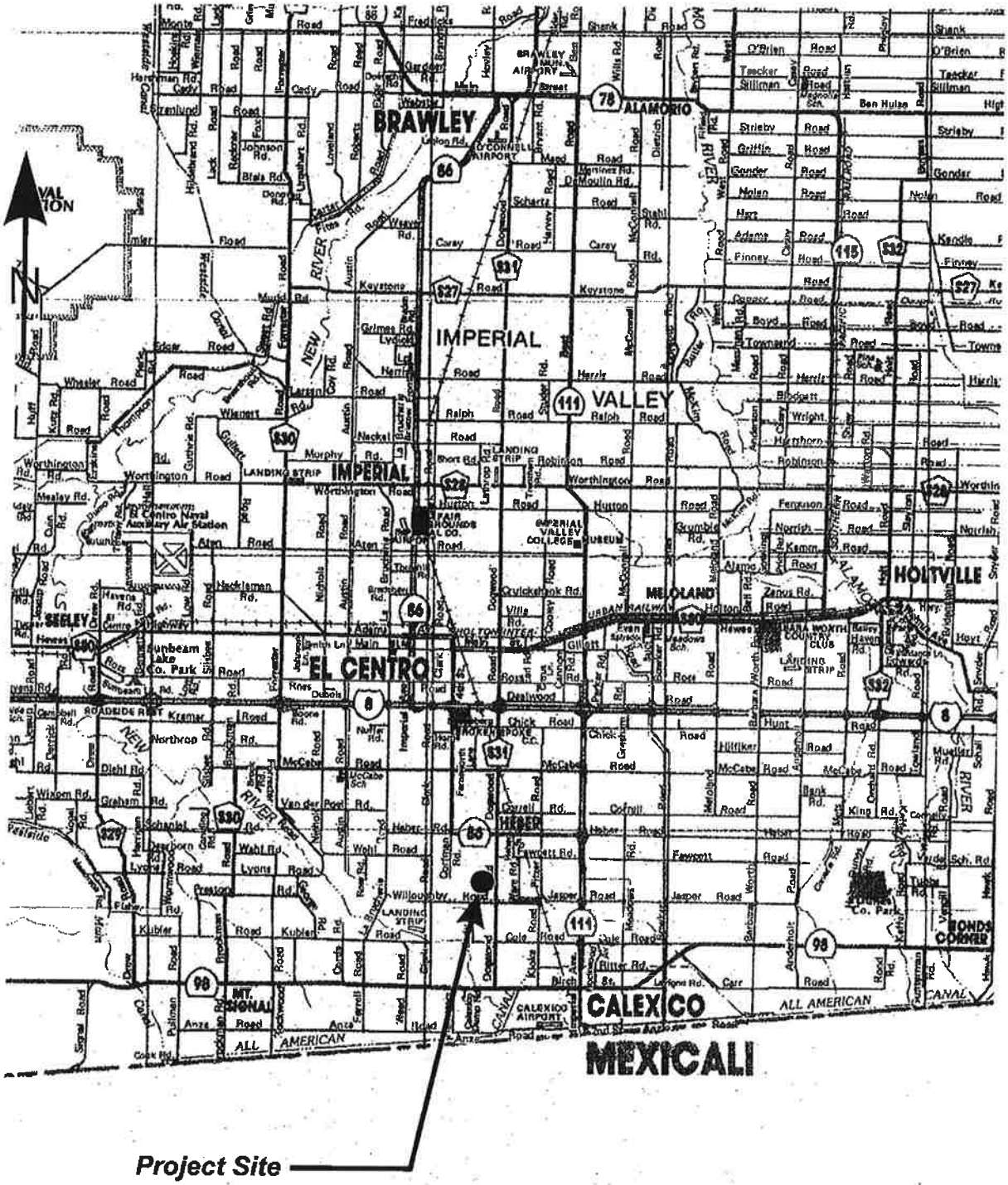
APPENDIX A

EEC ORIGINAL PKG



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Vicinity Map

Plate
A-1

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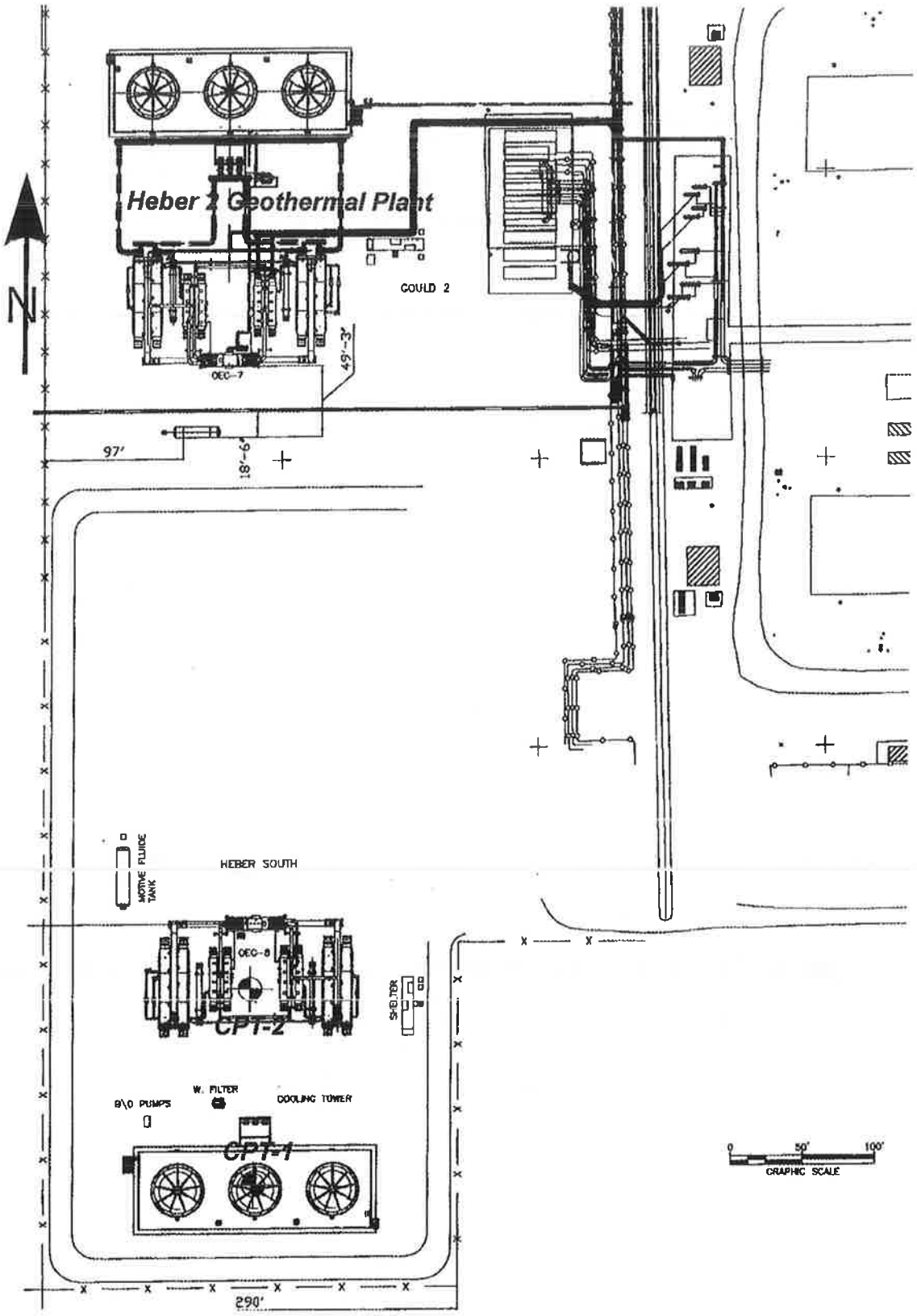

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Project No.: LE07178

Site and Exploration Map

Plate
A-2

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APPENDIX B

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CLIENT: Ormat Nevada

PROJECT: Heber South Geothermal Plant -- Heber, CA

LOCATION: See Site and Boring Location Plan

CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

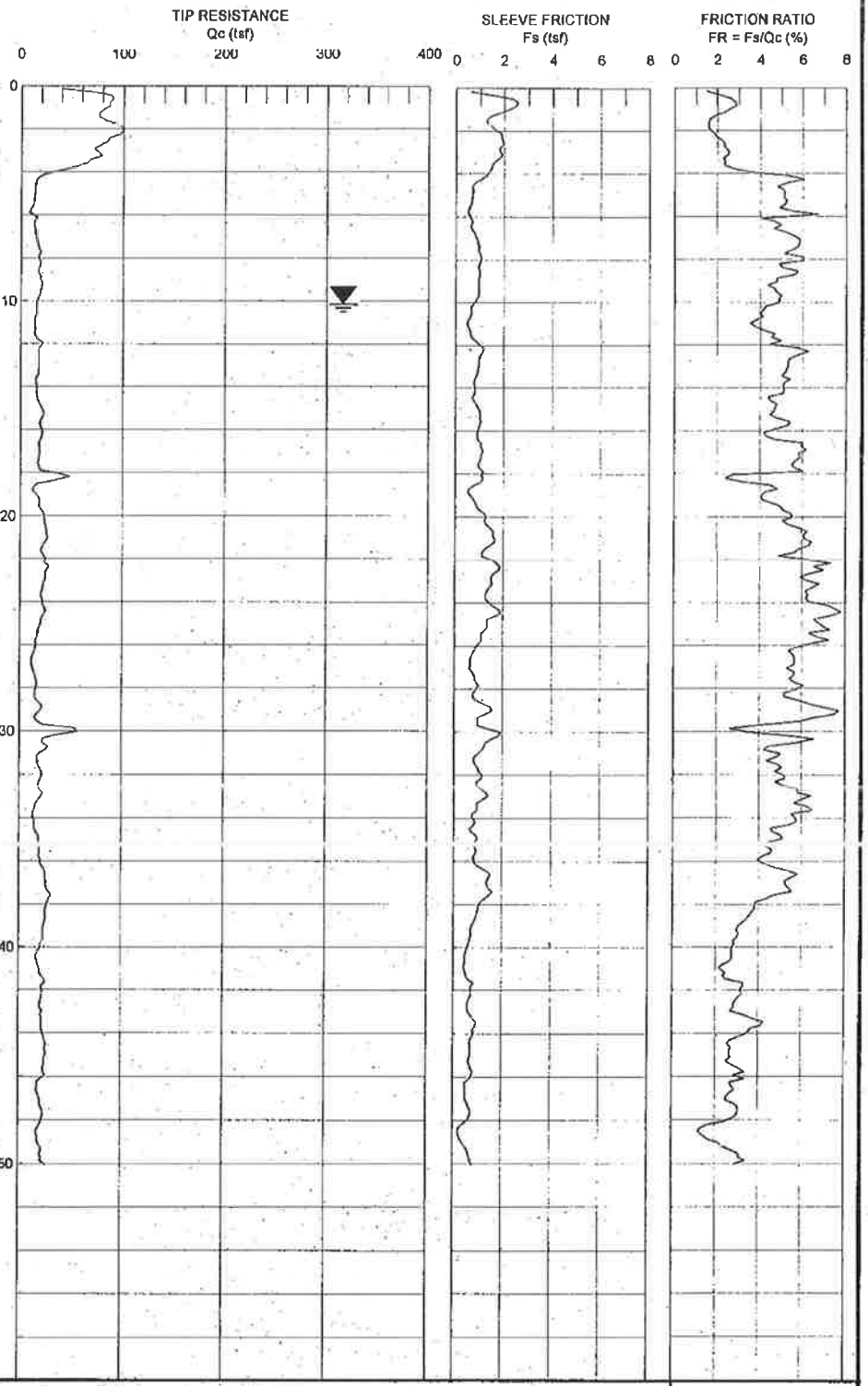
DATE: 05/02/07

LOG OF CONE SOUNDING DATA CPT-1

DEPTH (FEET)	INTERPRETED SOIL PROFILE From Robertson & Campanella (1989)		
	GROUND EL. +/-		
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Sandy Silt to Clayey Silt	ML	dense
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
10	Clay	" "	very stiff
	Silty Clay to Clay	CL	stiff
	Clay	CL/CH	stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
20	Clay	CL/CH	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Silty Clay to Clay	CL	very stiff
	Clay	CL/CH	very stiff
	Silty Clay to Clay	CL	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
40	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Sandy Silt to Clayey Silt	ML	very loose
50	Clayey Silt to Silty Clay	ML/CL	very stiff

End of Sounding @ 50.0 ft.

Anticipated groundwater @ 10.0 ft.



Project No: LE07178

LANDMARK
Geo-Engineers and Geologists

Plate B-1

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LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber South Plant -- Heber, CA Project No: LE07178 Date: 05/02/07

CONE SOUNDING: CPT-1

Est. GWT (ft): 10.0

Phi Correlation: 0 (0-Schm(78),1-R&C(83),2-PHT(74))

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	I Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	66.25	2.04	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	15	2.00	125.2	35	122	45		
0.30	1.0	88.18	2.75	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	25	2.00	166.7	35	114	44		
0.45	1.5	77.73	1.95	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	17	2.00	146.9	30	103	42		
0.60	2.0	92.53	1.60	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	21	2.00	174.9	25	103	42		
0.75	2.5	93.95	2.02	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	21	2.00	177.6	25	100	42		
0.93	3.0	77.68	2.40	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	17	2.00	146.8	35	91	41		
1.08	3.5	74.47	2.39	6	Sandy Silt to Clayey Silt	ML	dense	115	3.5	21	2.00	140.8	35	88	40		
1.23	4.0	52.73	2.83	6	Sandy Silt to Clayey Silt	ML	dense	115	3.5	15	2.00	99.7	45	75	39		
1.38	4.5	18.49	5.55	3	Clay	CL/CH	very stiff	125	1.3	15	2.00		90			1.07	>10
1.53	5.0	13.75	5.02	3	Clay	CL/CH	stiff	125	1.3	11	1.95		100			0.79	>10
1.68	5.5	12.39	5.11	3	Clay	CL/CH	stiff	125	1.3	10	1.85		100			0.71	>10
1.83	6.0	10.98	5.45	3	Clay	CL/CH	stiff	125	1.3	9	1.77		100			0.63	>10
1.98	6.5	13.51	4.77	3	Clay	CL/CH	stiff	125	1.3	11	1.69		95			0.77	>10
2.13	7.0	14.72	5.56	3	Clay	CL/CH	stiff	125	1.3	12	1.62		100			0.84	>10
2.28	7.5	16.58	5.71	3	Clay	CL/CH	stiff	125	1.3	13	1.56		95			0.95	>10
2.45	8.0	17.99	5.72	3	Clay	CL/CH	very stiff	125	1.3	14	1.51		95			1.03	>10
2.60	8.5	18.67	5.21	3	Clay	CL/CH	very stiff	125	1.3	15	1.46		90			1.07	>10
2.75	9.0	19.02	5.07	3	Clay	CL/CH	very stiff	125	1.3	15	1.42		90			1.09	>10
2.90	9.5	20.56	4.59	3	Clay	CL/CH	very stiff	125	1.3	16	1.38		85			1.18	>10
3.05	10.0	17.46	4.91	3	Clay	CL/CH	stiff	125	1.3	14	1.34		95			0.99	>10
3.20	10.5	15.45	4.14	3	Clay	CL/CH	stiff	125	1.3	12	1.32		95			0.87	>10
3.35	11.0	13.93	3.83	4	Silty Clay to Clay	CL	stiff	125	1.8	8	1.31		100			0.78	>10
3.50	11.5	13.83	4.23	3	Clay	CL/CH	stiff	125	1.3	11	1.29		100			0.78	8.56
3.65	12.0	18.01	4.65	3	Clay	CL/CH	very stiff	125	1.3	14	1.27		95			1.02	>10
3.80	12.5	18.70	5.93	3	Clay	CL/CH	very stiff	125	1.3	15	1.26		100			1.06	>10
3.95	13.0	18.01	5.35	3	Clay	CL/CH	very stiff	125	1.3	14	1.24		100			1.02	>10
4.13	13.5	17.39	5.15	3	Clay	CL/CH	stiff	125	1.3	14	1.23		100			0.98	>10
4.28	14.0	14.93	5.20	3	Clay	CL/CH	stiff	125	1.3	12	1.22		100			0.84	8.00
4.43	14.5	15.49	4.86	3	Clay	CL/CH	stiff	125	1.3	12	1.20		100			0.87	8.27
4.58	15.0	18.22	4.65	3	Clay	CL/CH	very stiff	125	1.3	15	1.19		100			1.03	>10
4.73	15.5	22.11	4.64	3	Clay	CL/CH	very stiff	125	1.3	18	1.18		95			1.26	>10
4.88	16.0	19.85	4.92	3	Clay	CL/CH	very stiff	125	1.3	16	1.17		100			1.12	>10
5.03	16.5	19.77	4.96	3	Clay	CL/CH	very stiff	125	1.3	16	1.16		100			1.12	>10
5.18	17.0	18.38	5.96	3	Clay	CL/CH	very stiff	125	1.3	15	1.14		100			1.03	9.39
5.33	17.5	17.64	5.69	3	Clay	CL/CH	stiff	125	1.3	14	1.13		100			0.99	8.41
5.48	18.0	25.50	4.80	3	Clay	CL/CH	very stiff	125	1.3	20	1.12		95			1.45	>10
5.65	18.5	32.47	3.36	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	13	1.11		75			1.86	>10
5.80	19.0	13.48	4.36	3	Clay	CL/CH	stiff	125	1.3	11	1.10		100			0.74	4.89
5.95	19.5	18.41	4.55	3	Clay	CL/CH	very stiff	125	1.3	15	1.09		100			1.03	8.00
6.10	20.0	22.07	5.36	3	Clay	CL/CH	very stiff	125	1.3	18	1.08		100			1.25	>10
6.25	20.5	24.57	5.40	3	Clay	CL/CH	very stiff	125	1.3	20	1.07		100			1.39	>10
6.40	21.0	26.18	6.13	3	Clay	CL/CH	very stiff	125	1.3	21	1.07		100			1.49	>10
6.55	21.5	23.24	6.19	3	Clay	CL/CH	very stiff	125	1.3	19	1.06		100			1.31	>10
6.70	22.0	22.66	5.55	3	Clay	CL/CH	very stiff	125	1.3	18	1.05		100			1.28	>10
6.85	22.5	26.25	6.97	3	Clay	CL/CH	very stiff	125	1.3	21	1.04		100			1.49	>10
7.00	23.0	25.11	6.17	3	Clay	CL/CH	very stiff	125	1.3	20	1.03		100			1.42	>10
7.18	23.5	22.18	6.48	3	Clay	CL/CH	very stiff	125	1.3	18	1.02		100			1.25	8.70
7.33	24.0	21.09	6.24	3	Clay	CL/CH	very stiff	125	1.3	17	1.02		100			1.18	7.85
7.48	24.5	23.54	7.51	3	Clay	CL/CH	very stiff	125	1.3	19	1.01		100			1.32	9.39
7.63	25.0	21.31	6.90	3	Clay	CL/CH	very stiff	125	1.3	17	1.00		100			1.19	7.56
7.78	25.5	18.21	6.67	3	Clay	CL/CH	very stiff	125	1.3	15	0.99		100			1.01	5.65
7.93	26.0	15.91	6.78	3	Clay	CL/CH	stiff	125	1.3	13	0.99		100			0.87	4.37
8.08	26.5	13.54	5.59	3	Clay	CL/CH	stiff	125	1.3	11	0.98		100			0.73	3.43
8.23	27.0	11.78	5.53	3	Clay	CL/CH	stiff	125	1.3	9	0.97		100			0.63	2.73
8.38	27.5	14.49	5.56	3	Clay	CL/CH	stiff	125	1.3	12	0.97		100			0.79	3.58
8.53	28.0	16.02	5.84	3	Clay	CL/CH	stiff	125	1.3	13	0.96		100			0.87	4.09
8.68	28.5	15.04	5.37	3	Clay	CL/CH	stiff	125	1.3	12	0.95		100			0.82	3.66
8.85	29.0	20.59	6.98	3	Clay	CL/CH	very stiff	125	1.3	16	0.95		100			1.14	5.88
9.00	29.5	16.05	6.66	3	Clay	CL/CH	stiff	125	1.3	13	0.94		100			0.87	3.83
9.15	30.0	44.48	3.37	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	18	0.93		80			2.54	>10
9.30	30.5	27.03	5.86	3	Clay	CL/CH	very stiff	125	1.3	22	0.93		100			1.52	8.85

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber South Plant -- Heber, CA Project No: LE07178 Date: 05/02/07

CONE SOUNDING: CPT-1

Est. GWT (ft): 10.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.45	31.0	24.88	4.56	3	Clay	CL/CH	very stiff	125	1.3	20	0.92		100			1.39	7.41
9.60	31.5	17.85	4.68	3	Clay	CL/CH	stiff	125	1.3	14	0.92		100			0.98	4.18
9.75	32.0	21.43	4.98	3	Clay	CL/CH	very stiff	125	1.3	17	0.91		100			1.19	5.53
9.90	32.5	19.94	5.01	3	Clay	CL/CH	very stiff	125	1.3	16	0.91		100			1.10	4.78
10.05	33.0	21.67	6.03	3	Clay	CL/CH	very stiff	125	1.3	17	0.90		100			1.20	5.42
10.20	33.5	17.09	5.96	3	Clay	CL/CH	stiff	125	1.3	14	0.89		100			0.93	3.66
10.38	34.0	13.75	5.92	3	Clay	CL/CH	stiff	125	1.3	11	0.89		100			0.73	2.65
10.53	34.5	14.75	5.27	3	Clay	CL/CH	stiff	125	1.3	12	0.88		100			0.79	2.91
10.68	35.0	17.80	4.91	3	Clay	CL/CH	stiff	125	1.3	14	0.88		100			0.97	3.66
10.83	35.5	19.50	4.45	3	Clay	CL/CH	very stiff	125	1.3	16	0.87		100			1.07	4.18
10.98	36.0	20.06	4.23	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.87		100			1.10	5.53
11.13	36.5	23.73	5.01	3	Clay	CL/CH	very stiff	125	1.3	19	0.86		100			1.31	5.53
11.28	37.0	26.37	5.33	3	Clay	CL/CH	very stiff	125	1.3	21	0.86		100			1.47	6.43
11.43	37.5	29.22	5.23	3	Clay	CL/CH	very stiff	125	1.3	23	0.85		100			1.63	7.56
11.58	38.0	28.26	4.00	4	Silty Clay to Clay	CL	very stiff	125	1.8	16	0.85		100			1.58	9.39
11.73	38.5	26.29	3.66	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	11	0.85		100			1.46	>10
11.88	39.0	24.98	3.19	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.84		100			1.38	>10
12.05	39.5	23.62	3.00	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.84		100			1.30	9.00
12.20	40.0	21.78	2.80	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.83		100			1.19	7.56
12.35	40.5	17.57	2.75	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.83		100			0.94	5.21
12.50	41.0	19.10	2.36	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.83		100			1.03	5.88
12.65	41.5	22.54	2.42	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.23	7.70
12.80	42.0	23.41	3.23	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.28	8.14
12.95	42.5	22.05	3.08	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.20	7.13
13.10	43.0	21.46	2.78	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.17	6.65
13.25	43.5	22.21	3.76	4	Silty Clay to Clay	CL	very stiff	125	1.8	13	0.81		100			1.21	5.10
13.40	44.0	22.69	3.76	4	Silty Clay to Clay	CL	very stiff	125	1.8	13	0.80		100			1.24	5.21
13.58	44.5	25.69	2.81	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.80		100			1.41	8.85
13.73	45.0	26.50	2.66	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	11	0.80		100			1.46	9.19
13.88	45.5	25.22	2.66	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.38	8.27
14.03	46.0	24.63	3.10	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.36	7.85
14.18	46.5	18.88	2.93	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.79		100			1.01	4.89
14.33	47.0	19.43	2.84	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.78		100			1.04	5.00
14.48	47.5	22.40	3.03	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.78		100			1.22	6.32
14.63	48.0	23.12	2.75	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.78		100			1.26	6.54
14.78	48.5	18.94	1.38	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.77	13.8	100	14	30		
14.93	49.0	18.77	1.78	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.77	13.7	100	14	30		
15.09	49.5	21.59	2.73	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.77		100			1.16	5.65
15.25	50.0	23.82	3.12	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.76		100			1.29	6.54

EEC ORIGINAL PKG

CLIENT: Ormat Nevada

PROJECT: Heber South Plant -- Heber, CA

LOCATION: See Site and Boring Location Plan

CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

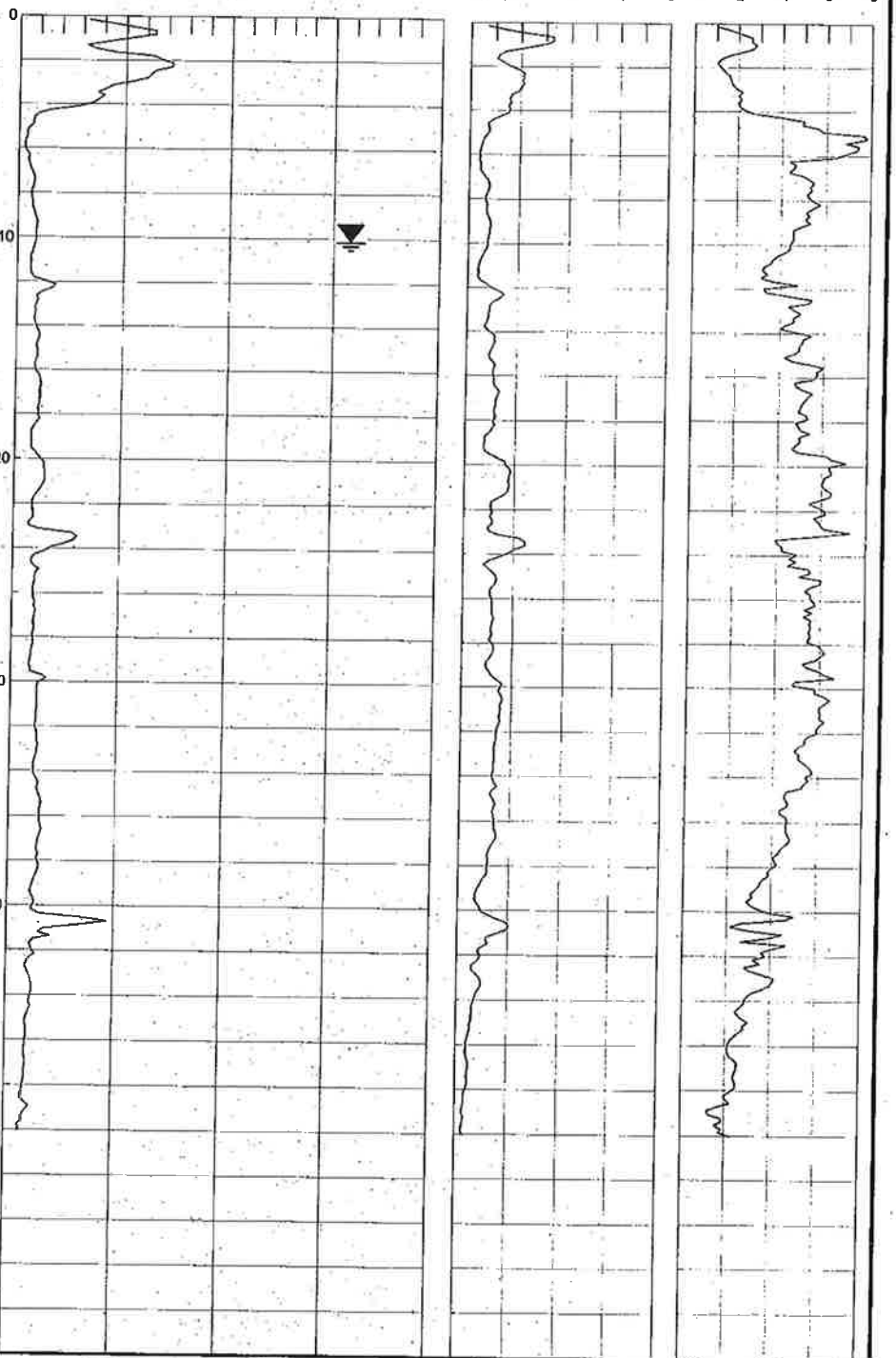
DATE: 05/02/07

LOG OF CONE SOUNDING DATA CPT-2

DEPTH (FEET)	INTERPRETED SOIL PROFILE From Robertson & Campanella (1989)		
	GROUND EL. +/-		
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Sand to Silty Sand	SP/SM	very dense
	Silty Sand to Sandy Silt	SM/ML	dense
	Clay	CL/CH	very stiff
	Clay	" "	firm
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
10	Clay	" "	very stiff
	Silty Clay to Clay	CL	stiff
	Silty Clay to Clay	" "	stiff
	Silty Clay to Clay	" "	very stiff
	Clay	CL/CH	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Silty Clay to Clay	CL	hard
	Clay	CL/CH	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Silty Clay to Clay	" "	very stiff
	Silty Clay to Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
40	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	hard
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Sandy Silt to Clayey Silt	ML	very loose
50	Clayey Silt to Silty Clay	ML/CL	stiff

End of Sounding @ 50.0 ft.

Anticipated groundwater @ 10.0 ft.



Project No: LE07178

LANDMARK
Geo-Engineers and Geologists

Plate B-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber South Plant – Heber, CA Project No: LE07178 Date: 05/02/07

CONE SOUNDING: CPT-2

Est. GWT (ft): 10.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	85.14	1.61	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	19	2.00	161.0	25	130	46		
0.30	1.0	120.36	2.66	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	27	2.00	227.5	30	124	45		
0.45	1.5	72.28	2.13	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	16	2.00	136.6	30	101	42		
0.60	2.0	116.67	1.12	8	Sand to Silty Sand	SP/SM	very dense	115	5.5	21	2.00	220.6	15	110	43		
0.75	2.5	138.05	1.48	8	Sand to Silty Sand	SP/SM	very dense	115	5.5	25	2.00	261.0	15	111	44		
0.93	3.0	117.13	1.76	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	26	2.00	221.4	20	104	42		
1.08	3.5	81.23	2.12	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	18	2.00	153.5	30	90	41		
1.23	4.0	74.63	2.12	7	Silty Sand to Sandy Silt	SM/ML	dense	115	4.5	17	2.00	141.1	30	86	40		
1.38	4.5	34.90	3.90	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	14	2.00		60			2.04	>10
1.53	5.0	13.76	5.45	3	Clay	CL/CH	stiff	125	1.3	11	1.96		100			0.79	>10
1.68	5.5	7.57	7.44	3	Clay	CL/CH	firm	125	1.3	6	1.86		100			0.43	>10
1.83	6.0	5.99	6.88	3	Clay	CL/CH	firm	125	1.3	5	1.77		100			0.33	6.10
1.98	6.5	9.47	4.51	3	Clay	CL/CH	stiff	125	1.3	8	1.69		100			0.54	>10
2.13	7.0	11.69	4.84	3	Clay	CL/CH	stiff	125	1.3	9	1.63		100			0.66	>10
2.28	7.5	14.81	5.37	3	Clay	CL/CH	stiff	125	1.3	12	1.57		95			0.85	>10
2.45	8.0	13.05	5.26	3	Clay	CL/CH	stiff	125	1.3	10	1.51		100			0.74	>10
2.60	8.5	13.41	5.40	3	Clay	CL/CH	stiff	125	1.3	11	1.46		100			0.76	>10
2.75	9.0	15.40	5.21	3	Clay	CL/CH	stiff	125	1.3	12	1.42		100			0.88	>10
2.90	9.5	18.24	4.66	3	Clay	CL/CH	very stiff	125	1.3	15	1.38		90			1.04	>10
3.05	10.0	17.49	4.50	3	Clay	CL/CH	stiff	125	1.3	14	1.34		95			0.99	>10
3.20	10.5	16.07	4.15	3	Clay	CL/CH	stiff	125	1.3	13	1.32		95			0.91	>10
3.35	11.0	13.34	3.48	4	Silty Clay to Clay	CL	stiff	125	1.8	8	1.31		95			0.75	>10
3.50	11.5	12.52	3.24	4	Silty Clay to Clay	CL	stiff	125	1.8	7	1.29		100			0.70	9.79
3.65	12.0	18.93	3.91	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	1.28		90			1.08	>10
3.80	12.5	31.15	4.38	4	Silty Clay to Clay	CL	very stiff	125	1.8	18	1.26		75			1.79	>10
3.95	13.0	19.46	4.78	3	Clay	CL/CH	very stiff	125	1.3	16	1.25		95			1.10	>10
4.13	13.5	17.74	4.74	3	Clay	CL/CH	very stiff	125	1.3	14	1.23		100			1.00	>10
4.28	14.0	17.58	4.34	3	Clay	CL/CH	stiff	125	1.3	14	1.22		100			0.99	>10
4.43	14.5	21.21	5.18	3	Clay	CL/CH	very stiff	125	1.3	17	1.20		100			1.20	>10
4.58	15.0	20.43	4.83	3	Clay	CL/CH	very stiff	125	1.3	16	1.19		100			1.16	>10
4.73	15.5	20.79	4.75	3	Clay	CL/CH	very stiff	125	1.3	17	1.18		100			1.18	>10
4.88	16.0	18.89	5.75	3	Clay	CL/CH	very stiff	125	1.3	15	1.17		100			1.07	>10
5.03	16.5	23.41	4.88	3	Clay	CL/CH	very stiff	125	1.3	19	1.16		95			1.33	>10
5.18	17.0	23.59	5.34	3	Clay	CL/CH	very stiff	125	1.3	19	1.14		100			1.34	>10
5.33	17.5	23.27	4.98	3	Clay	CL/CH	very stiff	125	1.3	19	1.13		100			1.32	>10
5.48	18.0	22.19	5.13	3	Clay	CL/CH	very stiff	125	1.3	18	1.12		100			1.26	>10
5.65	18.5	20.81	5.10	3	Clay	CL/CH	very stiff	125	1.3	17	1.11		100			1.17	>10
5.80	19.0	15.76	4.92	3	Clay	CL/CH	stiff	125	1.3	13	1.10		100			0.88	6.32
5.95	19.5	16.06	5.23	3	Clay	CL/CH	stiff	125	1.3	13	1.09		100			0.89	6.32
6.10	20.0	22.81	6.58	3	Clay	CL/CH	very stiff	125	1.3	18	1.08		100			1.29	>10
6.25	20.5	28.53	6.30	3	Clay	CL/CH	very stiff	125	1.3	23	1.07		100			1.62	>10
6.40	21.0	28.99	6.06	3	Clay	CL/CH	very stiff	125	1.3	23	1.07		100			1.65	>10
6.55	21.5	24.82	6.28	3	Clay	CL/CH	very stiff	125	1.3	20	1.06		100			1.40	>10
6.70	22.0	18.48	5.79	3	Clay	CL/CH	very stiff	125	1.3	15	1.05		100			1.03	6.88
6.85	22.5	18.41	5.89	3	Clay	CL/CH	very stiff	125	1.3	15	1.04		100			1.03	6.65
7.00	23.0	15.96	6.46	3	Clay	CL/CH	stiff	125	1.3	13	1.03		100			0.88	5.10
7.18	23.5	46.63	4.62	4	Silty Clay to Clay	CL	hard	125	1.8	27	1.02		80			2.68	>10
7.33	24.0	47.09	4.48	4	Silty Clay to Clay	CL	hard	125	1.8	27	1.02		80			2.71	>10
7.48	24.5	23.27	4.67	3	Clay	CL/CH	very stiff	125	1.3	19	1.01		100			1.31	9.00
7.63	25.0	21.09	5.34	3	Clay	CL/CH	very stiff	125	1.3	17	1.00		100			1.18	7.41
7.78	25.5	21.71	5.85	3	Clay	CL/CH	very stiff	125	1.3	17	0.99		100			1.21	7.56
7.93	26.0	19.90	5.47	3	Clay	CL/CH	very stiff	125	1.3	16	0.99		100			1.11	6.32
8.08	26.5	20.78	5.59	3	Clay	CL/CH	very stiff	125	1.3	17	0.98		100			1.16	6.65
8.23	27.0	21.98	5.44	3	Clay	CL/CH	very stiff	125	1.3	18	0.97		100			1.23	7.13
8.38	27.5	20.73	5.53	3	Clay	CL/CH	very stiff	125	1.3	17	0.97		100			1.15	6.32
8.53	28.0	20.36	5.62	3	Clay	CL/CH	very stiff	125	1.3	16	0.96		100			1.13	6.00
8.68	28.5	19.99	6.11	3	Clay	CL/CH	very stiff	125	1.3	16	0.95		100			1.11	5.76
8.85	29.0	18.33	5.49	3	Clay	CL/CH	very stiff	125	1.3	15	0.95		100			1.01	4.89
9.00	29.5	17.78	6.27	3	Clay	CL/CH	stiff	125	1.3	14	0.94		100			0.98	4.47
9.15	30.0	29.76	5.16	3	Clay	CL/CH	very stiff	125	1.3	24	0.93		100			1.68	>10
9.30	30.5	25.36	6.14	3	Clay	CL/CH	very stiff	125	1.3	20	0.93		100			1.42	7.85

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: Heber South Plant – Heber, CA Project No: LE07178 Date: 05/02/07

CONE SOUNDING: CPT-2

Est. GWT (ft): 10.0 Phi Correlation: 0 (0-Schm(78),1-R&C(83),2-PHT(74))

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.45	31.0	25.65	6.08	3	Clay	CL/CH	very stiff	125	1.3	21	0.92		100			1.44	7.85
9.60	31.5	24.99	6.11	3	Clay	CL/CH	very stiff	125	1.3	20	0.92		100			1.40	7.27
9.75	32.0	24.42	5.93	3	Clay	CL/CH	very stiff	125	1.3	20	0.91		100			1.36	6.88
9.90	32.5	25.69	5.42	3	Clay	CL/CH	very stiff	125	1.3	21	0.90		100			1.43	7.27
10.05	33.0	26.43	5.06	3	Clay	CL/CH	very stiff	125	1.3	21	0.90		100			1.48	7.56
10.20	33.5	24.95	5.31	3	Clay	CL/CH	very stiff	125	1.3	20	0.89		100			1.39	6.65
10.36	34.0	22.88	5.62	3	Clay	CL/CH	very stiff	125	1.3	18	0.89		100			1.27	5.65
10.53	34.5	25.51	5.40	3	Clay	CL/CH	very stiff	125	1.3	20	0.88		100			1.42	6.65
10.68	35.0	27.31	4.56	4	Silty Clay to Clay	CL	very stiff	125	1.8	16	0.88		100			1.53	>10
10.83	35.5	30.04	4.55	4	Silty Clay to Clay	CL	very stiff	125	1.8	17	0.87		100			1.69	>10
10.98	36.0	29.52	4.52	4	Silty Clay to Clay	CL	very stiff	125	1.8	17	0.87		100			1.65	>10
11.13	36.5	30.25	4.64	4	Silty Clay to Clay	CL	very stiff	125	1.8	17	0.86		100			1.70	>10
11.28	37.0	29.39	4.68	4	Silty Clay to Clay	CL	very stiff	125	1.8	17	0.86		100			1.64	>10
11.43	37.5	27.60	4.22	4	Silty Clay to Clay	CL	very stiff	125	1.8	16	0.85		100			1.54	9.00
11.58	38.0	27.92	4.11	4	Silty Clay to Clay	CL	very stiff	125	1.8	16	0.85		100			1.56	9.00
11.73	38.5	28.57	3.77	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	11	0.85		100			1.59	>10
11.88	39.0	24.62	3.37	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.84		100			1.36	>10
12.05	39.5	22.28	3.04	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.84		100			1.22	8.00
12.20	40.0	24.64	3.45	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.83		100			1.36	9.59
12.35	40.5	41.78	4.14	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	17	0.83		95			2.37	>10
12.50	41.0	64.96	3.22	6	Sandy Silt to Clayey Silt	ML	medium dense	115	3.5	19	0.83	50.7	70	52	35		
12.65	41.5	32.37	3.75	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	13	0.82		100			1.81	>10
12.80	42.0	22.75	3.82	4	Silty Clay to Clay	CL	very stiff	125	1.8	13	0.82		100			1.25	5.53
12.95	42.5	22.78	3.20	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.25	7.56
13.10	43.0	19.79	3.62	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.81		100			1.07	4.28
13.25	43.5	23.86	3.91	4	Silty Clay to Clay	CL	very stiff	125	1.8	14	0.81		100			1.31	5.76
13.40	44.0	24.93	3.00	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.80		100			1.37	8.41
13.58	44.5	23.46	2.65	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.28	7.41
13.73	45.0	21.13	2.78	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.14	6.10
13.88	45.5	19.10	2.73	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.79		100			1.02	5.10
14.03	46.0	19.63	2.23	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.79		100			1.06	5.31
14.18	46.5	18.74	2.12	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	7	0.79		100			1.00	4.78
14.33	47.0	18.93	2.49	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.78		100			1.01	4.78
14.48	47.5	18.85	2.42	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.78		100			1.01	4.68
14.63	48.0	17.53	2.38	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.93	4.09
14.78	48.5	16.01	2.08	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.77		100			0.84	3.58
14.93	49.0	20.91	1.36	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.77	15.2	100	17	30		
15.09	49.5	17.29	1.76	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.77	12.5	100	11	30		
15.25	50.0	13.85	1.98	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.76		100			0.71	2.82

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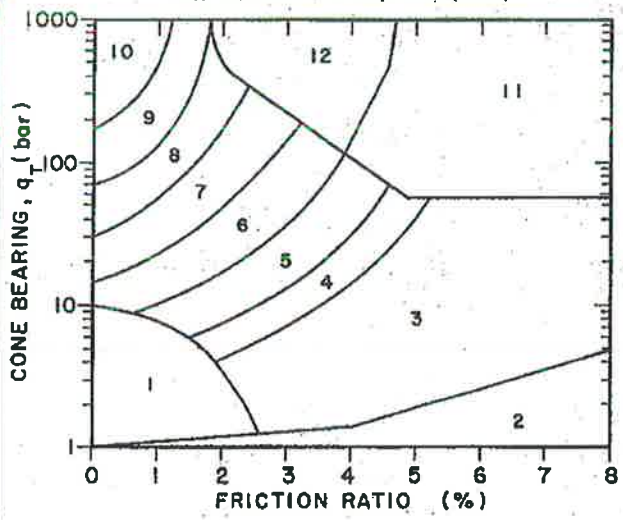
Simplified Soil Classification Chart

After Robertson & Campanella (1989)



Geotechnical Parameters from CPT Data:

Equivalent SPT N(60) blow count = Qc/(Qc/N Ratio)

N1(60) = Cn*N(60) Normalized SPT blow count

Cn = 1/(p'o)^0.5 < 1.6 max. from Liao & Whitman (1986)

p'o = effective overburden pressure (tsf) using unit densities given below and estimated groundwater table.

Dr = Relative density (%) from Jamiolkowski et. al. (1986) relationship

= -98 +68*log(Qc/p'o^0.5) where Qc, p'o in tonne/sqm

Note: 1 tonne/sqm = 0.1024 tsf, 1 bar =1.0443 tsf

Phi = Friction Angle estimated from either:

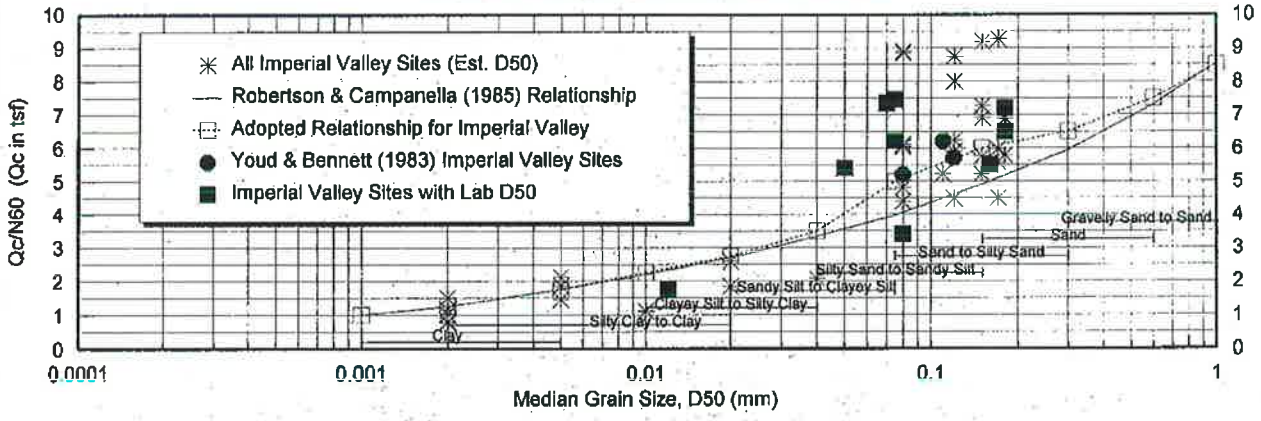
1. Roberton & Campanella (1983) chart:
   Phi = 5.3 + 24*(log(Qc/p'o))+3(log(Qc/p'o))^2
2. Peck, Hansen & Thornburn (1974) N-Phi Correlation
3. Schmertman (1978) chart [Phi = 28+0.14*Dr for fine uniform sands]

Su = undrained shear strength (tsf)

= (Qc-p'o)/Nk where Nk varies from 10 to 22, 17 for OC clays

OCR = Overconsolidation Ratio estimated from Schmertman (1978) chart using Su/p'o ratio and estimated normal consolidated Su/p'o

Variation of Qc/N Ratio with Grain Size



Note: Assumed Properties and Adopted Qc/N Ratio based on correlations from Imperial Valley, California soils

Table of Soil Types and Assumed Properties

Zone	Soil Classification	UCS	Density (pcf)	R&C Qc/N	Adopted Qc/N	Est. PI	Fines (%)	D50 (mm)	Su (tsf)	Consistency
1	Sensitive fine grained	ML	120	2	2	NP-15	65-100	0.020	0-0.13	very soft
2	Organic Material	OL/OH	120	1	1	--	--	--	0.13-.25	soft
3	Clay	CL/CH	125	1	1.25	25-40+	90-100	0.002	0.25-0.5	firm
4	Silty Clay to Clay	CL	125	1.5	2	15-40	90-100	0.010	0.5-1.0	stiff
5	Clayey Silt to Silty Clay	ML/CL	120	2	2.75	5-25	90-100	0.020	1.0-2.0	very stiff
6	Sandy Silt to Clayey Silt	ML	115	2.5	3.5	NP-10	65-100	0.040	>2.0	hard
7	Silty Sand to Sandy Silt	SM/ML	115	3	5	NP	35-75	0.075	Dr (%)	Relative Density
8	Sand to Silty Sand	SP/SM	115	4	6	NP	5-35	0.150	0-15	very loose
9	Sand	SP	110	5	6.5	NP	0-5	0.300	15-35	loose
10	Gravelly Sand to Sand	SW	115	6	7.5	NP	0-5	0.600	35-65	medium dense
11	Overconsolidated Soil	--	120	1	1	NP	90-100	0.010	65-85	dense
12	Sand to Clayey Sand	SP/SC	115	2	2	NP-5	--	---	>85	very dense

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Project No: LE07178

Key to CPT Interpretation of Logs

Plate B-3

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APPENDIX C

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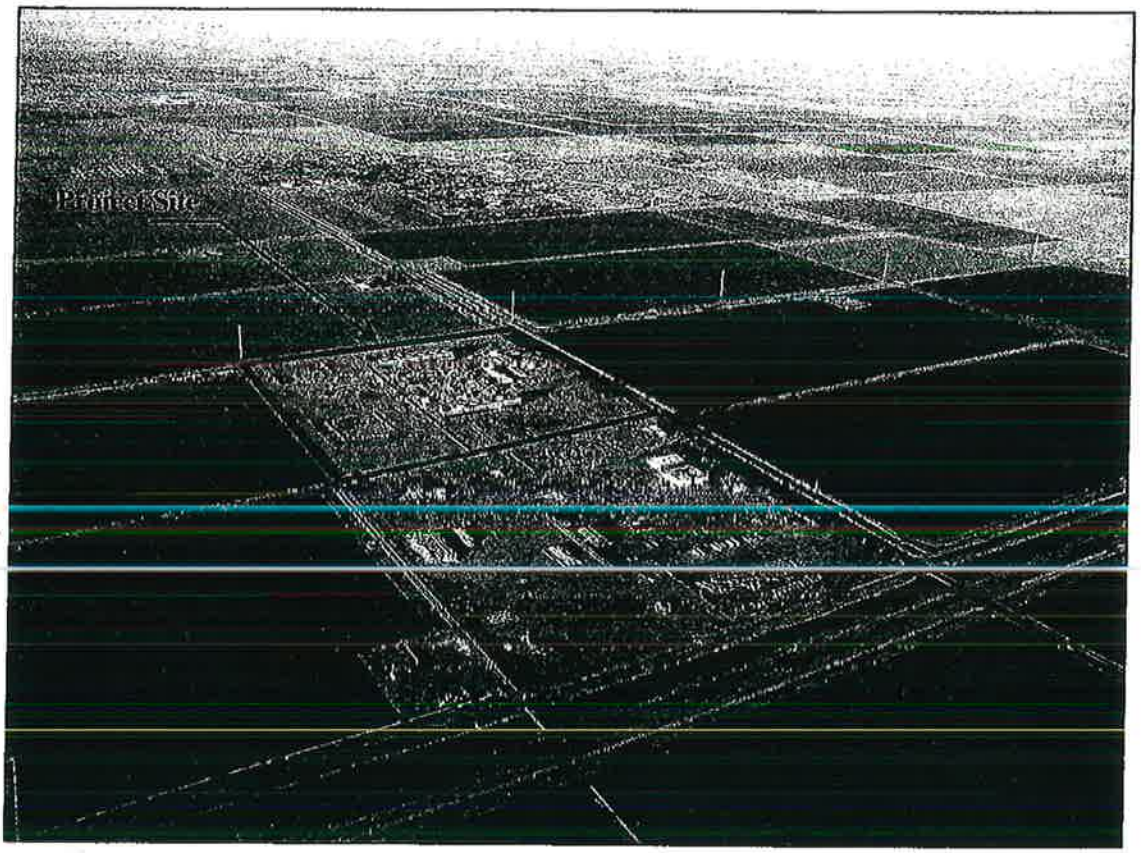
Geotechnical Report

New Turbine Generator and Cooling Tower
Heber 2 Geothermal Plant
Heber, CA

Prepared for:

ORMAT
947 Dogwood Road
Heber, CA 92249



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January 2005

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Geotechnical Investigation
New Turbine Generator and Cooling Tower
Heber 2 Geothermal Plant
Dogwood Road
Heber, California
LCI Report No. LE04354 (2)

Dear Mr. Collins:

This geotechnical report is provided for design and construction of the new turbine generator and cooling tower additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California. Our geotechnical investigation was conducted in response to your request for our services. The enclosed report describes our soil engineering investigation and presents our professional opinions regarding geotechnical conditions at the site to be considered in the design and construction of the project.

This executive summary presents ***selected*** elements of our findings and recommendations only. It ***does not*** present crucial details needed for the proper application of our findings and recommendations. Our findings, recommendations, and application options are related ***only through reading the full report***, and are best evaluated with the active participation of the engineer of record who developed them.

The findings of this study indicate that the site is predominantly underlain by clays of moderate expansion.

The soil are highly corrosive to metals and contain sufficient sulfates and chlorides to require special concrete mixes (4,500 psi with a 0.45 maximum water cement ratio) and protection of embedded steel building components when concrete is placed in contact with native soil. If the native soils are replaced with imported granular soils with low sulfate and chloride content, no special concrete mixes are required.

Evaluation of liquefaction potential at the site indicates that it is unlikely that the subsurface soil will liquefy under seismically induced groundshaking due to the nature of the soil (clays soils predominate). No mitigation is required for liquefaction effects at this site.

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Foundation settlements are indicated on figures 2 thru 5. Differential settlement is estimated to be about of two-thirds of total settlement.

We did not encounter soil conditions that would preclude development of the site for its intended use provided the recommendations contained in this report are implemented in the design and construction of this project.

We appreciate the opportunity to provide our findings and professional opinions regarding geotechnical conditions at the site. If you have any questions or comments regarding our findings, please call our office at (760) 370-3000.

Respectfully Submitted,
Landmark Consultants, Inc.

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Section 1
INTRODUCTION

1.1 Project Description

This report presents the findings of our geotechnical investigation for the proposed additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California (See Vicinity Map, Plate A-1). The proposed development will consist of the addition of one (1) turbine/generator set and one (1) cooling tower. A site plan for the proposed power plant improvements was not made available to us at the time that this report was prepared.

Small structures may be are planned for electrical control panels, consisting of masonry or panelized concrete construction. Expected footing loads are estimated at 1 to 2 kips per lineal foot for the small structures. Expected plant components, cooling tower and turbine/generator columns loads range from 5 to 400 kips. If structural loads exceed those stated above, we should be notified so we may evaluate their impact on foundation settlement and bearing capacity. Site development will include foundation support pad preparation and underground utility installation.

1.2 Purpose and Scope of Work

The purpose of this geotechnical study was to investigate the upper 50 feet of subsurface soil at selected locations within the site for physical/engineering properties. From the subsequent field and laboratory data, professional opinions were developed and are provided in this report regarding geotechnical conditions at this site and the effect on design and construction. The scope of our services consisted of the following:

- Field exploration and in-situ testing of the site soils at selected locations and depths.
- Laboratory testing for physical properties of selected samples.
- A review of the available literature and publications pertaining to local geology, faulting, and seismicity.
- Engineering analysis and evaluation of the data collected.
- Preparation of this report presenting our findings, professional opinions, and recommendations for the geotechnical aspects of project design and construction.

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This report addresses the following geotechnical issues:

- Subsurface soil and groundwater conditions
- Site geology, regional faulting and seismicity, near source factors, and site seismic accelerations
- Liquefaction potential and its mitigation
- Expansive soil and methods of mitigation
- Aggressive soil conditions to metals and concrete

Professional opinions with regard to the above issues are presented for the following:

- Site grading and earthwork
- Foundation subgrade preparation
- Allowable soil bearing pressures and expected settlements
- Concrete slabs-on-grade
- Mitigation of the potential effects of salt concentrations in native soil to concrete mixes and steel reinforcement
- Seismic design parameters

Our scope of work for this report did not include an evaluation of the site for the presence of environmentally hazardous materials or conditions.

1.3 Authorization

Mr. Mike Collins, Project Manager of Ormat for Power Generation Construction provided authorization by written agreement to proceed with our work on December 14, 2004. We conducted our work according to our written proposal dated December 13, 2004.

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Section 2
METHODS OF INVESTIGATION

2.1 Field Exploration

Subsurface exploration was performed on December 20, 2004 using Holguin, Fahan, & Associates, Inc. of Cypress, California to advance three (3) electric cone penetrometer (CPT) soundings to an approximate depth of 50 feet below existing ground surface. The soundings were made at the locations shown on the Site and Exploration Plan (Plate A-2). The approximate sounding locations were established in the field and plotted on the site map by sighting to discernable site features.

CPT soundings provide a continuous profile of the soil stratigraphy with readings every 2.5cm (1 inch) in depth. Direct sampling for visual and physical confirmation of soil properties has been used by our firm to establish direct correlations with CPT exploration in this geographical region.

The CPT exploration was conducted by hydraulically advancing an instrumented Hogentogler 10cm^2 conical probe into the ground at a rate of 2cm per second using a 23-ton truck as a reaction mass. An electronic data acquisition system recorded a nearly continuous log of the resistance of the soil against the cone tip (Qc) and soil friction against the cone sleeve (Fs) as the probe was advanced. Empirical relationships (Robertson and Campanella, 1989) were then applied to the data to give a continuous profile of the soil stratigraphy. Interpretation of CPT data provides correlations for SPT blow count, phi (ϕ) angle (soil friction angle), undrained shear strength (S_u) of clays and over-consolidation ratio (OCR). These correlations may then be used to evaluate vertical and lateral soil bearing capacities and consolidation characteristics of the subsurface soil.

Interpretive logs of the CPT soundings were produced and presented in final form after review of field and laboratory data and are presented on Plates B-1 through B-3 in Appendix B. A key to the interpretation of CPT soundings is presented on Plate B-4. The stratification lines shown on the subsurface logs represent the approximate boundaries between the various strata. However, the transition from one stratum to another may be gradual over some range of depth.

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2.2 Laboratory Testing

Laboratory tests were conducted on selected bulk soil samples obtained from hand auger borings made adjacent to the CPT locations to aid in classification and evaluation of selected engineering properties of the near surface soils. The tests were conducted in general conformance to the procedures of the American Society for Testing and Materials (ASTM) or other standardized methods as referenced below. The laboratory testing program consisted of the following tests:

- Plasticity Index (ASTM D4318) – used for soil classification and expansive soil design criteria.
- Chemical Analyses (soluble sulfates & chlorides, pH, and resistivity) (Caltrans Methods) – used for concrete mix evaluations and corrosion protection requirements.

The laboratory test results are presented on the subsurface logs (Appendix B) and on Plates C-1, C-2 and C-3 in Appendix C.

Engineering parameters of soil strength, compressibility and relative density utilized for developing design criteria provided within this report were either extrapolated from correlations with the subsurface CPT data or from data obtained from the field and laboratory testing program.

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Section 3
DISCUSSION

3.1 Site Conditions

The plant additions are located in the northwest corner of the Heber 2 geothermal plant on the west side of the existing turbine generators and cooling tower. The area is relatively vacant and approximately has the same elevation as the existing plant facilities. An overhead pipe rack is located to the south side of the proposed location.

Adjacent properties outside of the fenced operations yard consist of agricultural land to the north and west. The site is bounded on the east by Dogwood Road and headquarters facilities of a general engineering construction company lie to the south side. Dogwood Road is slated to be a 6-lane north-south arterial from Calexico to Brawley in Imperial County. Adjacent properties are flat-lying and are approximately at the same elevation with this site.

The project site lies at an elevation of approximately 15 feet below mean sea level (MSL) (El. 985 local datum) in the Imperial Valley region of the California low desert. The surrounding properties lie on terrain which is flat (planar), part of a large agricultural valley, which was previously an ancient lake bed covered with fresh water to an elevation of 43± feet above MSL. Annual rainfall in this arid region is less than 4 inches per year with four months of average summertime temperatures above 100 °F. Winter temperatures are mild, seldom reaching freezing.

3.2 Geologic Setting

The project site is located in the Imperial Valley portion of the Salton Trough physiographic province. The Salton Trough is a geologic structural depression resulting from large scale regional faulting. The trough is bounded on the northeast by the San Andreas Fault and Chocolate Mountains and the southwest by the Peninsular Range and faults of the San Jacinto Fault Zone. The Salton Trough represents the northward extension of the Gulf of California, containing both marine and non-marine sediments since the Miocene Epoch. Tectonic activity that formed the trough continues at a high rate as evidenced by deformed young sedimentary deposits and high levels of seismicity. Figure 1 shows the location of the site in relation to regional faults and physiographic features.

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The Imperial Valley is directly underlain by lacustrine deposits, which consist of interbedded lenticular and tabular silt, sand, and clay. The Late Pleistocene to Holocene lake deposits are probably less than 100 feet thick and derived from periodic flooding of the Colorado River which intermittently formed a fresh water lake (Lake Cahuilla). Older deposits consist of Miocene to Pleistocene non-marine and marine sediments deposited during intrusions of the Gulf of California. Basement rock consisting of Mesozoic granite and Paleozoic metamorphic rocks are estimated to exist at depths between 15,000 - 20,000 feet.

3.3 Seismicity and Faulting

Faulting and Seismic Sources: We have performed a computer-aided search of known faults or seismic zones that lie within a 62 mile (100 kilometers) radius of the project site as shown on Figure 1 and Table 1. The search identifies known faults within this distance and computes deterministic ground accelerations at the site based on the maximum credible earthquake expected on each of the faults and the distance from the fault to the site. The Maximum Magnitude Earthquake (Mmax) listed was taken from published geologic information available for each fault (CDMG OFR 96-08 and Jennings, 1994).

Seismic Risk: The project site is located in the seismically active Imperial Valley of southern California and is considered likely to be subjected to moderate to strong ground motion from earthquakes in the region. The proposed site structures should be designed in accordance with the California Building Code (CBC) for near source factors derived from a "Design Basis Earthquake" (DBE). The DBE is defined as the motion having a 10 percent probability of being exceeded in 50 years. The DBE generally corresponds to the Mmax magnitude discussed here.

Seismic Hazards.

- **Groundshaking.** The primary seismic hazard at the project site is the potential for strong groundshaking during earthquakes along the Imperial, Brawley, and Superstition Hills Faults. A further discussion of groundshaking follows in Section 3.4.
- **Surface Rupture.** The project site does not lie within a State of California, Alquist-Priolo Earthquake Fault Zone. Surface fault rupture is considered to be unlikely at the project site because of the well-delineated fault lines through the Imperial Valley as shown on USGS and CGS maps. However, because of the high tectonic activity and deep alluvium of the region, we cannot preclude the potential for surface rupture on undiscovered or new faults that may underlie the site.

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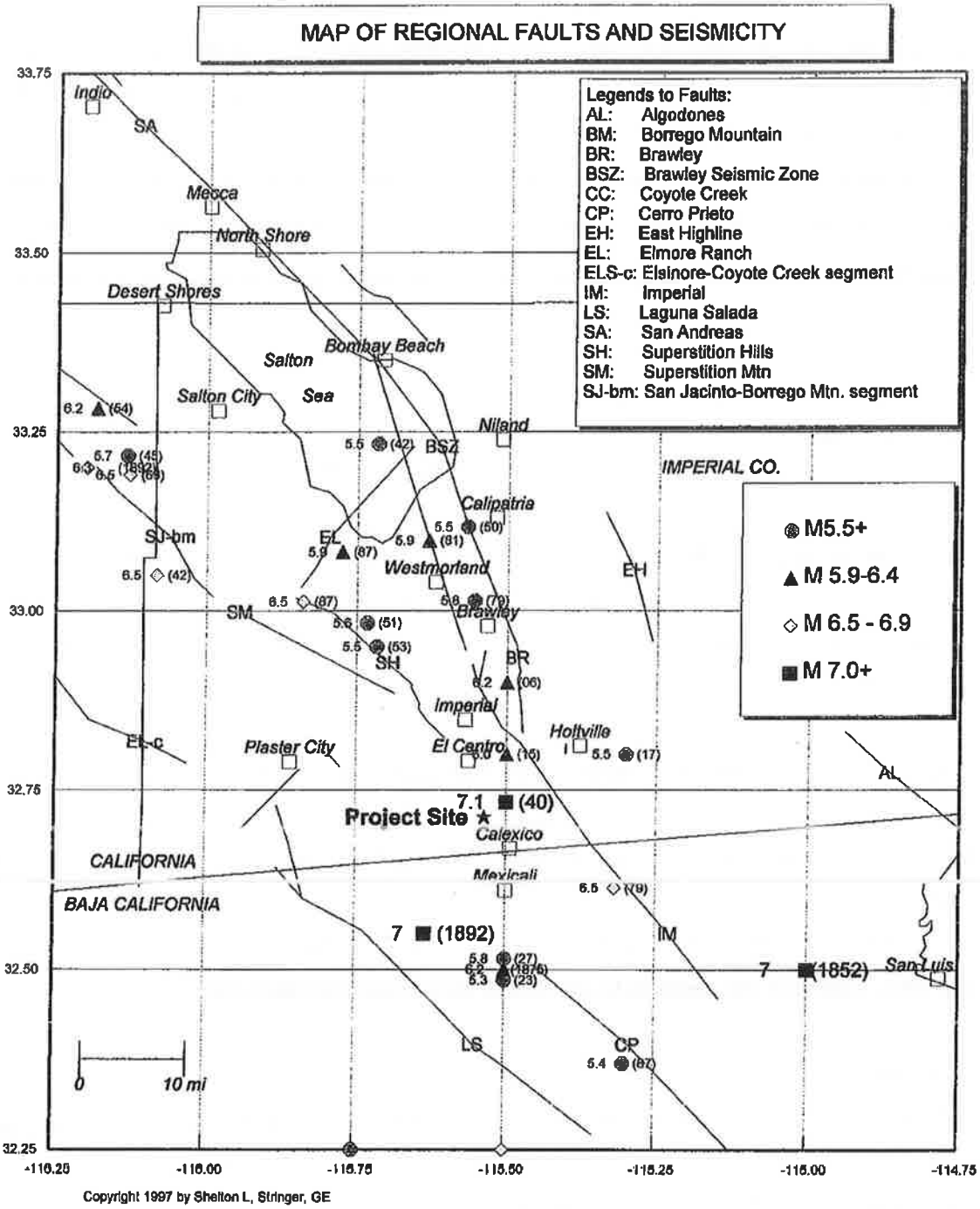

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Faults and Seismic Zones from Jennings (1994), Earthquakes modified from Ellsworth (1990) catalog.

Figure 1. Map of Regional Faults and Seismicity

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Table 1
FAULT PARAMETERS & DETERMINISTIC
ESTIMATES OF PEAK GROUND ACCELERATION (PGA)

Fault Name or Seismic Zone	Distance (mi) & Direction from Site	Fault Type		Fault Length (km)	Maximum Magnitude Mmax (Mw)	Avg Slip Rate (mm/yr)	Avg Return Period (yrs)	Date of Last Rupture (year)	Largest Historic Event >5.5M (year)	Est. Site PGA (g)
Reference Notes: (1)		(2)	(3)	(2)	(4)	(3)	(3)	(3)	(5)	(6)
Imperial Valley Faults										
Imperial	7.0 NE	A	B	62	**7.0**	20	79	1979	7.0 1940	**0.33**
Brawley	8.8 NNE	B	B	14	**7.0**	20	—	1979	5.8 1979	**0.28**
Cerro Prieto	15 SSE	A	B	116	**7.2**	34	50	1980	7.1 1934	**0.21**
Brawley Seismic Zone	16 N	B	B	42	**6.4**	25	24		5.9 1981	**0.13**
East Highline Canal	23 NE	C	C	22	**6.3**	1	774			**0.09**
San Jacinto Fault System										
- Superstition Hills	8.5 NNW	B	A	22	**6.6**	4	250	1987	6.5 1987	**0.23**
- Superstition Mtn.	15 NW	B	A	23	**6.6**	5	500	1440 +/-		**0.16**
- Elmore Ranch	28 NW	B	A	29	**6.6**	1	225	1987	5.9 1987	**0.10**
- Borrego Mtn	34 NW	B	A	29	**6.6**	4	175		6.5 1942	**0.08**
- Anza Segment	51 NW	A	A	90	**7.2**	12	250	1918	6.8 1918	**0.08**
- Coyote Creek	53 NW	B	A	40	**6.8**	4	175	1968	6.5 1968	**0.07**
- Whole Zone	15 NW	A	A	245	**7.5**	—	—			**0.25**
Elsinore Fault System										
- Laguna Salada	16 SW	B	B	67	**7.0**	3.5	336		7.0 1891	**0.18**
- Coyote Segment	29 W	B	A	38	**6.8**	4	625			**0.11**
- Julian Segment	55 WNW	A	A	75	**7.1**	5	340			**0.08**
- Earthquake Valley	57 WNW	B	A	20	**6.5**	2	351			**0.05**
- Whole Zone	29 W	A	A	250	**7.5**	—	—			**0.15**
San Andreas Fault System										
- Coachella Valley	45 NNW	A	A	95	**7.4**	25	220	1690+/-	6.5 1948	**0.10**
- Whole S. Calif. Zone	45 NNW	A	A	458	**7.9**	—	—	1857	7.8 1857	**0.13**
Algodones	36 E	C	C	74	**7.0**	0.1	20,000			**0.10**

Notes:

1. Jennings (1994) and CDMG (1996)
2. CDMG (1996), where Type A faults -- slip rate >5 mm/yr and well constrained paleoseismic data
   Type B faults -- all other faults.
3. WGCEP (1995)
4. CDMG (1996) based on Wells & Coppersmith (1994)
5. Ellsworth Catalog in USGS PP 1515 (1990) and USBR (1976), Mw = moment magnitude,
6. The deterministic estimates of the Site PGA are based on the attenuation relationship of:
   Boore, Joyner, Fumal (1997)

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▸ **Liquefaction.** Liquefaction is unlikely to be a potential hazard at the site due to the lack of saturated granular soil (clay soils predominate).

Other Secondary Hazards.

▸ **Landsliding.** The hazard of landsliding is unlikely due to the regional planar topography. No ancient landslides are shown on geologic maps of the region and no indications of landslides were observed during our site investigation.

▸ **Volcanic hazards.** The site is not located in proximity to any known volcanically active area and the risk of volcanic hazards is considered very low.

▸ **Tsunamis, sieches, and flooding.** The site does not lie near any large bodies of water, so the threat of tsunami, sieches, or other seismically-induced flooding is unlikely.

▸ **Expansive soil.** In general, much of the near surface soils in the Imperial Valley consist of silty clays and clays which are moderate to highly expansive. The expansive soil conditions are discussed in more detail in Section 3.5.

3.4 Site Acceleration and UBC Seismic Coefficients

Deterministic horizontal peak ground accelerations (PGA) from maximum probable earthquakes on regional faults have been estimated and are included in Table 1. Ground motions are dependent primarily on the earthquake magnitude and distance to the seismogenic (rupture) zone. Accelerations also are dependent upon attenuation by rock and soil deposits, direction of rupture and type of fault; therefore, ground motions may vary considerably in the same general area.

We have used the computer program FRISKSP (Blake, 2000) to provide a probabilistic estimate of the site PGA using the attenuation relationship of Boore, Joyner, and Fumal (1997) Soil (250). The PGA estimate for the project site having a 10% probability of being exceeded in 50 years (return period of 475 years) is **0.60g**.

CBC Seismic Coefficients: The CBC seismic coefficients are roughly based on an earthquake ground motion that has a 10% probability of being exceeded in 50 years. The following table lists seismic and site coefficients (near source factors) determined by Chapter 16 of the 2001 CBC. ***This site lies within 11.3 km of a Type A fault overlying S_D (stiff) soil.***

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CBC Seismic Coefficients for Chapter 16 Seismic Provisions

CBC Code Edition	Soil Profile Type	Seismic Source Type	Distance to Critical Source	Near Source Factors		Seismic Coefficients	
				Na	Nv	Ca	Cv
2001	S_D (stiff soil)	A	< 11.3 km	1.00	1.15	0.44	0.74
Ref. Table	16-J	16-U	---	16-S	16-T	16-Q	16-R

3.5 Subsurface Soil

Subsurface soils encountered during the field exploration conducted on December 20, 2004 indicates that 1.0 to 1.5 feet of stiff clay are at ground surface. Dense to very dense silty sands lie below the clays and extend to a depth of 4 to 5 feet. Stiff to very stiff clays extend a depth of 50 feet, the maximum depth of exploration. The subsurface logs (Plates B-1 through B-3) depict the stratigraphic relationships of the various soil types.

The native surface clays exhibit moderate swell potential (Expansion Index, EI = 51 - 90) when correlated to Plasticity index tests (ASTM D4318) performed on the native clays. The clay is expansive when wetted and can shrink with moisture loss (drying). Development of building foundations, concrete flatwork, and asphaltic concrete pavements should include provisions for mitigating potential swelling forces and reduction in soil strength, which can occur from saturation of the soil. Causes for soil saturation include landscape irrigation, broken utility lines, or capillary rise in moisture upon sealing the ground surface to evaporation. Moisture losses can occur with lack of landscape watering, close proximity of structures to downslopes and root system moisture extraction from deep rooted shrubs and trees placed near the foundations. Typical measures used for industrial projects to remediate expansive soil include:

- replacement of silt/clay with non-expansive granular fill,
- moisture conditioning subgrade soils to a minimum of 5% above optimum moisture (ASTM D1557) for the full range in depth of surface soils.
- design of foundations that are resistant to shrink/swell forces of silt/clay soil.

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3.6 Groundwater

Groundwater was not noted on the CPT sounding at the time of exploration, but is typically encountered at approximately 10 to 15 feet below ground surface in the vicinity of the site. There is uncertainty in the accuracy of short-term water level measurements, particularly in fine-grained soil. Groundwater levels may fluctuate with precipitation, irrigation of adjacent properties, drainage, and site grading. The referenced groundwater level should not be interpreted to represent an accurate or permanent condition.

3.7 Liquefaction

Liquefaction occurs when granular soil below the water table is subjected to vibratory motions, such as produced by earthquakes. With strong ground shaking, an increase in pore water pressure develops as the soil tends to reduce in volume. If the increase in pore water pressure is sufficient to reduce the vertical effective stress (suspending the soil particles in water), the soil strength decreases and the soil behaves as a liquid (similar to quicksand). Liquefaction can produce excessive settlement, ground rupture, lateral spreading, or failure of shallow bearing foundations.

Four conditions are generally required for liquefaction to occur:

(1) the soil must be saturated (relatively shallow groundwater);
(2) the soil must be loosely packed (low to medium relative density);
(3) the soil must be relatively cohesionless (not clayey); and
(4) groundshaking of sufficient intensity must occur to function as a trigger mechanism.

All of these conditions exist to some degree at this site.

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Methods of Analysis: Liquefaction potential at the project site was evaluated using the 1997 NCEER Liquefaction Workshop methods that are based on the Seed, et. al. 1985 and Robertson and Campanella (1985) methods. The 1997 NCEER methods utilize direct SPT blow counts or CPT cone readings from site exploration and earthquake magnitude/PGA estimates from the seismic hazard analysis. The resistance to liquefaction is plotted on a chart of cyclic shear stress ratio (CSR) versus a corrected blow count $N_{1(60)}$ or Qc_{IN}. A ground acceleration of 0.60g was used in the analysis with a 12 foot groundwater depth.

Liquefaction induced settlements have been estimated using the 1987 Tokimatsu and Seed method. Fines content of liquefiable sands and silt increase the liquefaction resistance in that more cycles of ground motions are required to fully develop pore pressures. The SPT blow counts were adjusted to an equivalent clean sand blow count, $N_{1(60)}$ prior to calculating settlements using Robertson and Wride (1997) adjustments. A computed factor of safety less than 1.0 indicates a liquefiable condition.

Liquefaction Effects: Based on empirical relationships, liquefaction is not expected to occur at the project site.

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Section 4
RECOMMENDATIONS

4.1 Site Preparation

Clearing and Grubbing: All surface improvements, debris or vegetation including grass and weeds on the site at the time of construction should be removed from the construction area. Organic strippings should be hauled from the site and not used as fill. Any trash, construction debris, concrete slabs, old pavement, landfill, and buried obstructions such as old foundations and utility lines exposed during rough grading should be traced to the limits of the foreign material by the grading contractor and removed under our supervision. Any excavations resulting from site clearing should be dish-shaped to the lowest depth of disturbance and backfilled under observation by the geotechnical engineer's representative with compacted fill as described below.

Structure Subgrade Preparation: The exposed surface soil within the foundation areas should be removed to 12 inches below the foundation elevation or existing grade (whichever is lower). Exposed subgrade should be scarified to a depth of 8 inches, uniformly moisture conditioned to 3 to 8% above optimum moisture content (clays) or 0 to 4% above optimum (silts), and recompacted to at least 90% of the maximum density determined in accordance with ASTM D1557 methods.

The native soil is suitable for use as engineered fill provided it is free from concentrations of organic matter or other deleterious material. The fill soil should be uniformly moisture conditioned by discing and watering to the limits specified above, placed in maximum 8-inch lifts (loose), and compacted to the limits specified above.

Imported fill soil (if required) should have a Plasticity Index less than 15 and sulfates (SO_4) less than 1,000 ppm or non-expansive, granular soil meeting the USCS classifications of SM, SP-SM, or SW-SM with a maximum rock size of 3 inches and 5 to 35% passing the No. 200 sieve. The geotechnical engineer should approve imported fill soil sources before hauling material to the site. Imported granular fill should be placed in lifts no greater than 8 inches in loose thickness and compacted to at least 90% of ASTM D1557 maximum dry density at optimum moisture ±2%.

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In areas other than the structures pad which are to receive area concrete slabs, the ground surface should be presaturated to a minimum depth of 18 inches and then scarified to 6 inches, moisture conditioned to a minimum of 5% over optimum, and recompacted to 83-87% of ASTM D1557 maximum density just prior to concrete placement.

Trench Backfill: On-site soil free of debris, vegetation, and other deleterious matter may be suitable for use as utility trench backfill, but may be difficult to uniformly maintain at specified moistures and compact to the specified densities. Granular material is often more cost effective for backfill of utility trenches.

Backfill soil within roadways or traffic areas should be placed in layers not more that 6 inches in thickness and mechanically compacted to a minimum of 87% of the ASTM D1557 maximum dry density except for the top 12 inches of the trench which shall be compacted to at least 90%. Native backfill should only be placed and compacted after encapsulating buried pipes with suitable bedding and pipe envelope material. Pipe envelope/bedding should either be clean sand (Sand Equivalent SE>30) or crushed rock when encountering groundwater. A geotextile filter fabric (Mirafi 140N or equivalent) should be used to encapsulate the crushed rock when placed below groundwater to reduce the potential for in-washing of fines into the gravel void space. Precautions should be taken in the compaction of the backfill to avoid damage to the pipes and structures.

Observation and Density Testing: All site preparation and fill placement should be continuously observed and tested by a representative of a qualified geotechnical engineering firm. Full-time observation services during the excavation and scarification process is necessary to detect undesirable materials or conditions and soft areas that may be encountered in the construction area. The geotechnical firm that provides observation and testing during construction shall assume the responsibility of "*geotechnical engineer of record*" and, as such, shall perform additional tests and investigation as necessary to satisfy themselves as to the site conditions and the recommendations for site development.

Auxiliary Structures Foundation Preparation: Auxiliary structures such as free standing or retaining walls should have the existing soil beneath the structure foundation prepared in the manner recommended for the building pad except the preparation needed only to extend 12 inches below and beyond the footing.

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4.2 Foundations and Settlements

Shallow spread footings and continuous wall footings are suitable to support the structures associated with the turbine generator and cooling tower. Footings shall be founded on a layer of properly prepared and compacted soil as described in Section 4.1. The foundations may be designed using an allowable soil bearing pressure of 1,500 psf for compacted native clay soil and 2,000 psf when foundations are supported on imported sands (extending a minimum of 1.0 feet below footings). The allowable soil pressure may be increased by 20% for each foot of embedment depth in excess of 18 inches and by one-third for short term loads induced by winds or seismic events. The maximum allowable soil pressure at increased embedment depths shall not exceed 3,000 psf (clays). Settlements associated with variable loadings and structure/footing sizes are shown on figures 2 thru 5. As an alternative to shallow spread foundations, flat plate structural mats or grade-beam reinforced foundations may be used to mitigate expansive soil heave.

Flat Plate Structural Mats: Structural mats may be designed for a modulus of subgrade reaction (Ks) of 100 pci when placed on compacted clay or a subgrade modulus of 250 pci when placed on 2.5 feet of granular fill. Mats shall overlay 2 inches of sand and a 10-mil polyethylene vapor retarder. The structure support pad shall be moisture conditioned and recompacted as specified in Section 4.1 of this report.

All exterior and interior foundations should be embedded a minimum of 18 inches below the structure support pad or lowest adjacent final grade, whichever is deeper. Continuous wall footings should have a minimum width of 12 inches. Spread footings should have a minimum width of 24 inches. Recommended concrete reinforcement and sizing for all footings should be provided by the structural engineer.

Resistance to horizontal loads will be developed by passive earth pressure on the sides of footings or grade beams and frictional resistance developed along the bases of footings or grade beams and concrete slabs. Passive resistance to lateral earth pressure may be calculated using an equivalent fluid pressure of 250 pcf (300 pcf for sands) to resist lateral loadings. The top one foot of embedment should not be considered in computing passive resistance unless the adjacent area is confined by a slab or pavement. An allowable friction coefficient of 0.25 (0.35 for sands) may also be used at the base of the footings or grade beams to resist lateral loading.

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Total foundation movements under estimated loadings are shown on the load/settlement curves (Figures 2 thru 5). Differential movement is estimated to be about two-thirds of total movement

4.3 Slabs-On-Grade

Thin concrete slabs and flatwork (6 inches or less in thickness) placed over native clay soil should be designed in accordance with Chapter 18, Division III of the 2001 CBC (using an Effective Plasticity Index of 17) and shall be a minimum of 5 inches thick due to expansive soil conditions. Concrete floor slabs shall be monolithically placed with the foundations unless placed on 2.5 feet of granular fill or lime treated soil.

The concrete slabs should be underlain by a minimum of 4 inches of clean sand (Sand Equivalent SE>30) or aggregate base or may be placed directly on a 2.5-foot thick granular fill pad (if used) that has been moistened to approximately optimum moisture just before the concrete placement. A 10-mil visqueen vapor retarder, properly lapped and sealed with a 2-inch sand cover and extended a minimum of 12 inches into the footing, should be placed as a capillary break to prevent moisture migration into the slab section. Concrete slabs may be placed directly over a 15-mil vapor retarder if desired (Stego-Wrap or equivalent).

Concrete slab and flatwork reinforcement should consist of chaired rebar slab reinforcement (minimum of No. 4 bars at 18-inch centers, both horizontal directions) placed at slab mid-height to resist potential swell forces and cracking. Slab thickness and steel reinforcement are minimums only and should be verified by the structural engineer/designer knowing the actual project loadings. All steel components of the foundation system should be protected from corrosion by maintaining a 4-inch minimum concrete cover of densely consolidated concrete at footings (by use of a vibrator). The construction joint between the foundation and any mowstrips/sidewalks placed adjacent to foundations should be sealed with a polyurethane based non-hardening sealant to prevent moisture migration between the joint. Epoxy coated embedded steel components or permanent waterproofing membranes placed at the exterior footing sidewall may also be used to mitigate the corrosion potential of concrete placed in contact with native soil.

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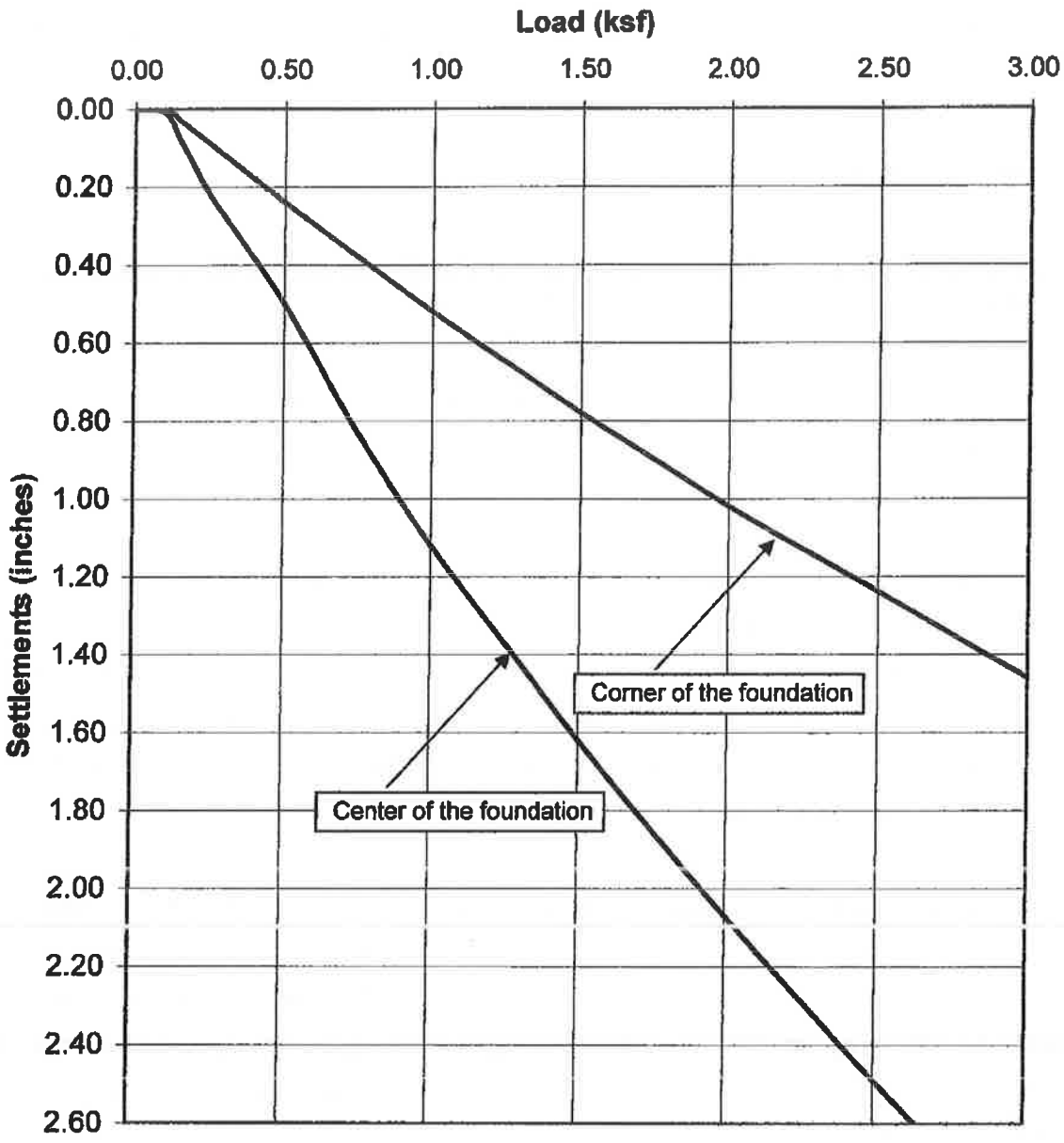

Notes:

1. A 15' x 15' foundation was used for settlement analysis

LANDMARK Geo-Engineers and Geologists *a DBE/MBE/SBE Company* **Project No.: LE04354**	**Total Settlements for a Turbine Generator Foundation at Heber 2 Geothermal Plant**	**Figure 2**

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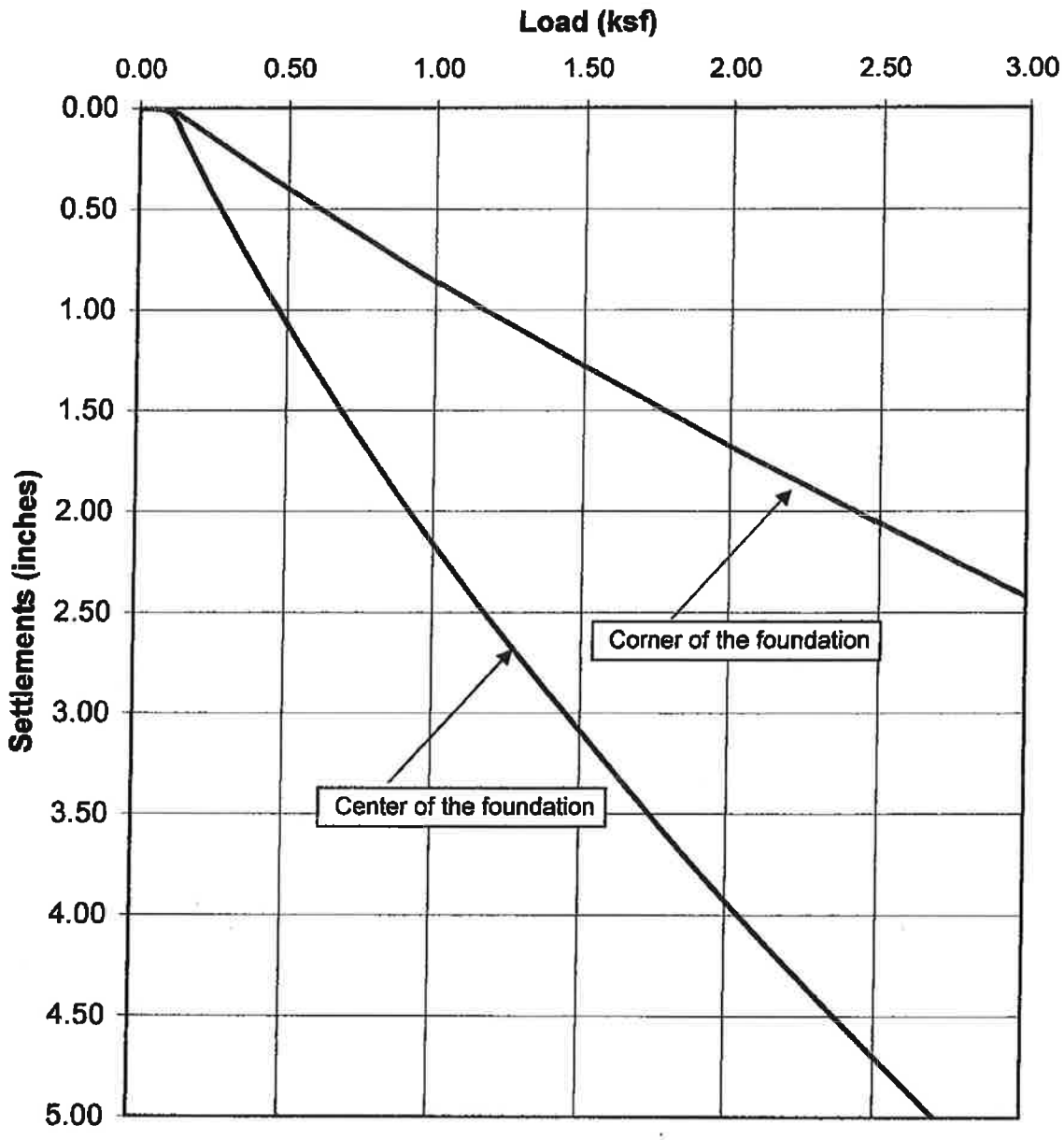

Notes:

1. A 30' x 60' foundation was used for settlement analysis

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Total Settlements for a Turbine Generator Foundation at Heber 2 Geothermal Plant

Figure 3

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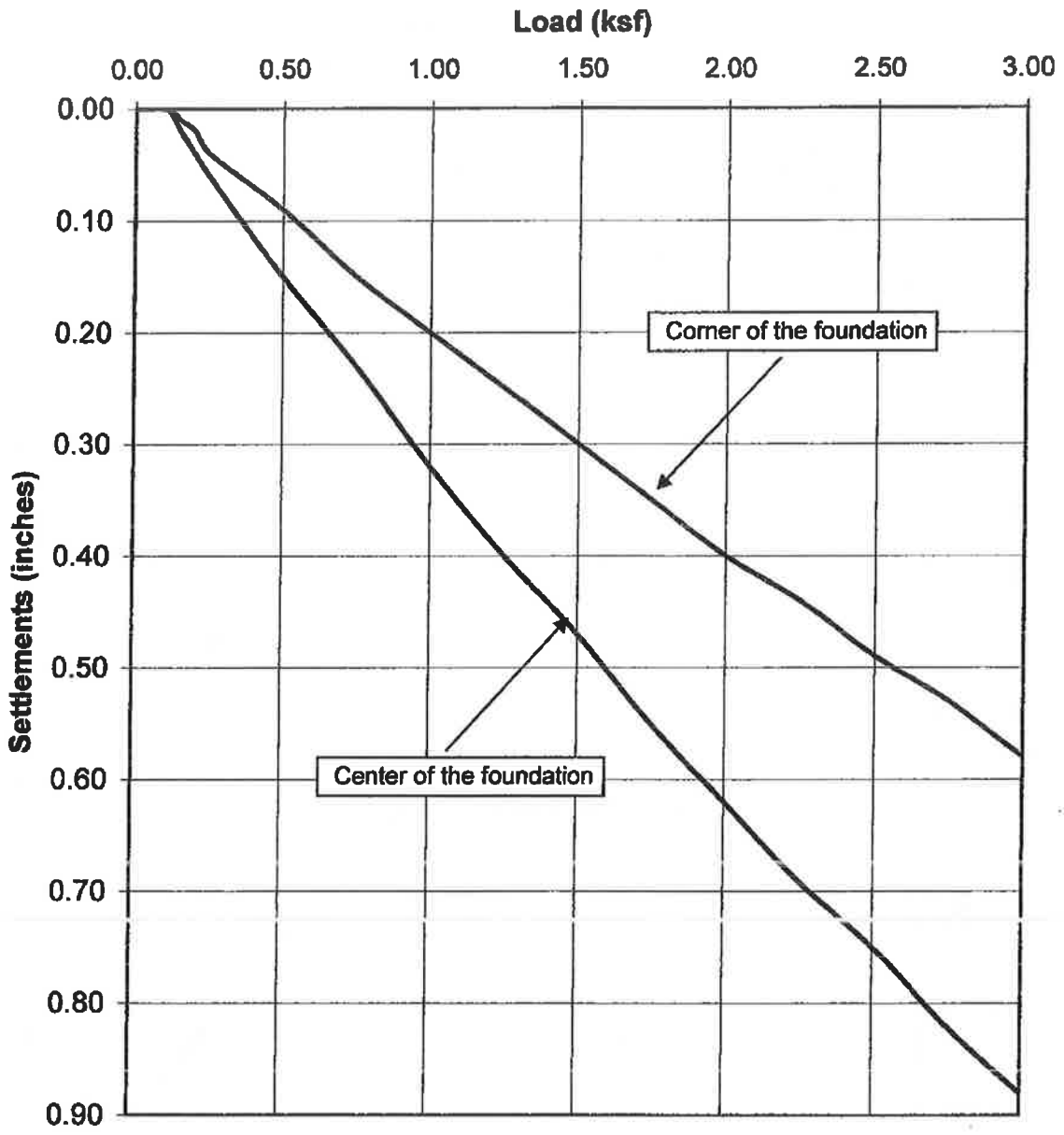

Notes:

1. A 5' x 5' foundation was used for settlement analysis

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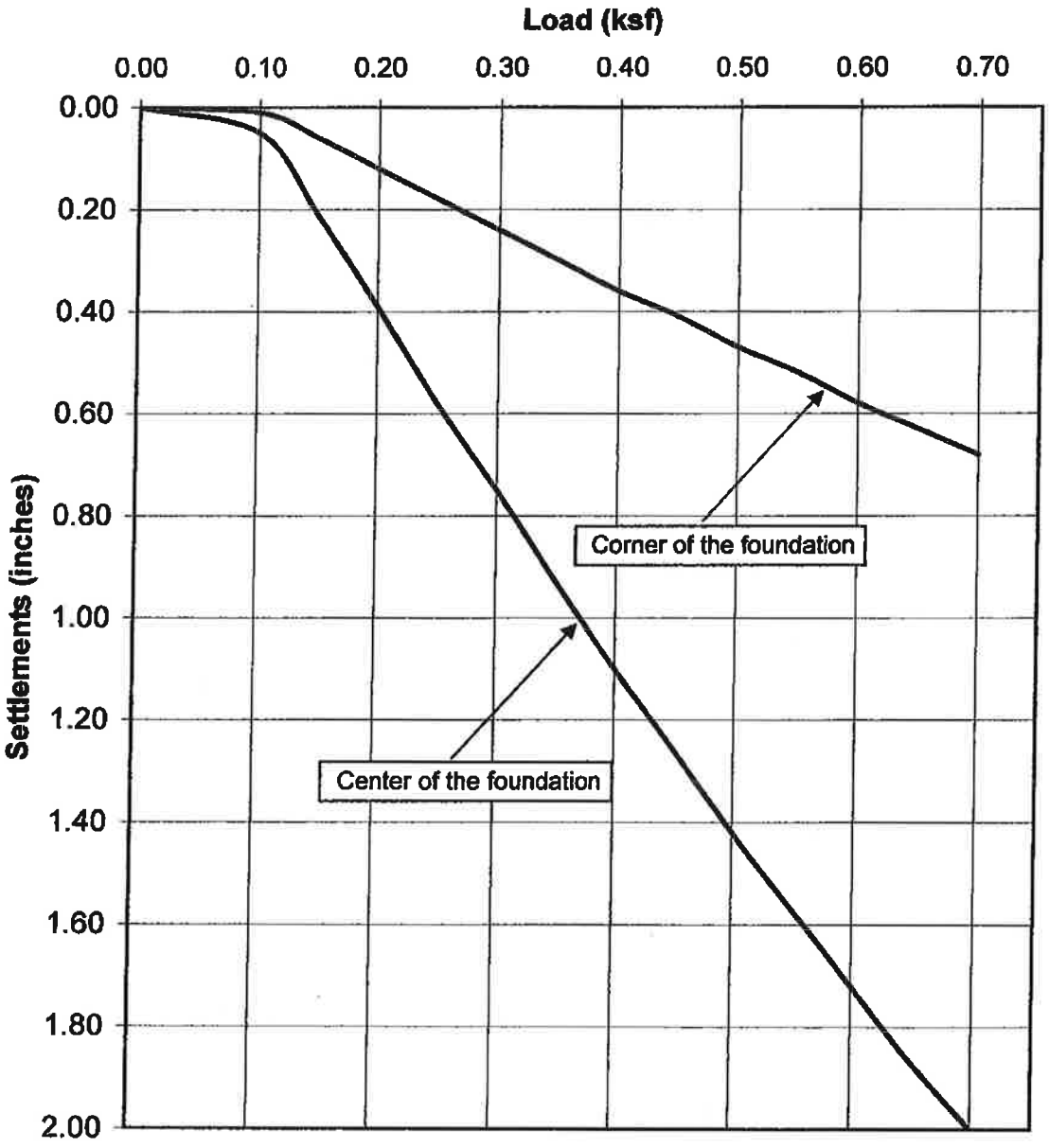
Total Settlements for a Cooling Tower Foundation at Heber 2 Geothermal Plant

Figure 4

EEC ORIGINAL PKG



Notes:

1. A 60' x 180' foundation was used for settlement analysis

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Total Settlements for a Cooling Tower Foundation at Heber 2 Geothermal Plant

Figure 5

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Control joints should be provided in all concrete slabs-on-grade at a maximum spacing (in feet) of 2 to 3 times the slab thickness (in inches) as recommended by American Concrete Institute (ACI) guidelines. All joints should form approximately square patterns to reduce randomly oriented contraction cracks. Contraction joints in the slabs should be tooled at the time of the pour or sawcut (¼ of slab depth) within 6 to 8 hours of concrete placement. Construction (cold) joints in foundations and area flatwork should either be thickened butt-joints with dowels or a thickened keyed-joint designed to resist vertical deflection at the joint. All joints in flatwork should be sealed to prevent moisture, vermin, or foreign material intrusion. Precautions should be taken to prevent curling of slabs in this arid desert region (refer to ACI guidelines).

All independent flatwork (sidewalks, housekeeping slabs) should be placed on a minimum of 2 inches of concrete sand or aggregate base, dowelled to the perimeter foundations where adjacent to the structures and sloped 1% or more away from the structure. A minimum of 18 inches of moisture conditioned (3% minimum above optimum) and 8 inches of compacted subgrade (83 to 87%) and a 10-mil (minimum) polyethylene separation sheet should underlie the flatwork. All flatwork should be jointed in square patterns and at irregularities in shape at a maximum spacing of 10 feet or the least width of the sidewalk.

4.4 Concrete Mixes and Corrosivity

Selected chemical analyses for corrosivity were conducted on bulk samples of the near surface soil from the project site (Plates C-2 and C-3). The native soils were found to have moderate to severe levels of sulfate ion concentration (1,052 to 3,006 ppm). Sulfate ions in high concentrations can attack the cementitious material in concrete, causing weakening of the cement matrix and eventual deterioration by raveling. The California Building Code recommends that increased quantities of Type II Portland Cement be used at a low water/cement ratio when concrete is subjected to moderate sulfate concentrations. Type V Portland Cement and/or Type II/V cement with 25% flyash replacement is recommended when the concrete is subjected to soil with severe sulfate concentration.

A minimum of 6.25 sacks per cubic yard of concrete (4,500 psi) of Type V Portland Cement with a maximum water/cement ratio of 0.45 (by weight) should be used for concrete placed in contact with native soil on this project. Admixtures may be required to allow placement of this low water/cement ratio concrete.

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There are no special requirements for concrete mixes when foundations are placed on 2.5 feet of low sulfate content granular fill.

The native soil has moderate to very severe level of chloride ion concentration (210 to 3,040 ppm). Chloride ions can cause corrosion of reinforcing steel, anchor bolts and other buried metallic conduits. Resistivity determinations on the soil indicate very severe potential for metal loss because of electrochemical corrosion processes. Mitigation of the corrosion of steel can be achieved by using steel pipes coated with epoxy corrosion inhibitors, asphaltic and epoxy coatings, cathodic protection or by encapsulating the portion of the pipe lying above groundwater with a minimum of 4 inches of densely consolidated concrete. ***No metallic pipes or conduits should be placed below foundations.***

Foundation designs shall provide a minimum concrete cover of four (4 inches around steel reinforcing or embedded components (anchor bolts, hold-downs, etc.) exposed to native soil or landscape water (to 18 inches above grade). If the 4-inch concrete edge distance cannot be achieved, all embedded steel components (anchor bolts, hold-downs, etc.) shall be epoxy dipped for corrosion protection or a corrosion inhibitor and a permanent waterproofing membrane shall be placed along the exterior face of the exterior footings. Additionally, the concrete should be thoroughly vibrated at footings during placement to decrease the permeability of the concrete.

4.5 Excavations

All site excavations should conform to CalOSHA requirements for Type B soil. The contractor is solely responsible for the safety of workers entering trenches. Temporary excavations with depths of 4 feet or less may be cut nearly vertical for short duration. Excavations deeper than 4 feet will require shoring or slope inclinations in conformance to CAL/OSHA regulations for Type B soil. Surcharge loads of stockpiled soil or construction materials should be set back from the top of the slope a minimum distance equal to the height of the slope. All permanent slopes should not be steeper than 3:1 to reduce wind and rain erosion. Protected slopes with ground cover may be as steep as 2:1. However, maintenance with motorized equipment may not be possible at this inclination.

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4.6 Seismic Design

This site is located in the seismically active southern California area and the site structures are subject to strong ground shaking due to potential fault movements along the Brawley, Superstition Hills, and Imperial Faults. Engineered design and earthquake-resistant construction are the common solutions to increase safety and development of seismic areas. Designs should comply with the latest edition of the CBC for Seismic Zone 4 using the seismic coefficients given in Section 3.4 of this report. ***This site lies within 11.3 km of a Type A fault overlying S_D (stiff) soil.***

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Section 5
LIMITATIONS AND ADDITIONAL SERVICES

5.1 Limitations

The recommendations and conclusions within this report are based on current information regarding the proposed additions to the Ormat Heber 2 geothermal power plant located on Dogwood Road southwest of Heber, California. The conclusions and recommendations of this report are invalid if:

- Structural loads change from those stated or the structures are relocated.
- The Additional Services section of this report is not followed.
- This report is used for adjacent or other property.
- Changes of grade or groundwater occur between the issuance of this report and construction other than those anticipated in this report.
- Any other change that materially alters the project from that proposed at the time this report was prepared.

Findings and recommendations in this report are based on selected points of field exploration, geologic literature, laboratory testing, and our understanding of the proposed project. Our analysis of data and recommendations presented herein are based on the assumption that soil conditions do not vary significantly from those found at specific exploratory locations. Variations in soil conditions can exist between and beyond the exploration points or groundwater elevations may change. If detected, these conditions may require additional studies, consultation, and possible design revisions.

This report contains information that may be useful in the preparation of contract specifications. However, the report is not worded is such a manner that we recommend its use as a construction specification document without proper modification. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.

This report was prepared according to the generally accepted *geotechnical engineering standards of practice* that existed in Imperial County at the time the report was prepared. No express or implied warranties are made in connection with our services. This report should be considered invalid for periods after two years from the report date without a review of the validity of the findings and recommendations by our firm, because of potential changes in the Geotechnical Engineering Standards of Practice.

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The client has responsibility to see that all parties to the project including, designer, contractor, and subcontractor are made aware of this entire report. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.

5.2 Additional Services

We recommend that Landmark Consultants, Inc. be retained as the geotechnical consultant to provide the tests and observations services during construction. If Landmark Consultants does not provide such services then *the geotechnical engineering firm providing such tests and observations shall become the geotechnical engineer of record and assume responsibility for the project.*

The recommendations presented in this report are based on the assumption that:

- Consultation during development of design and construction documents to check that the geotechnical recommendations are appropriate for the proposed project and that the geotechnical recommendations are properly interpreted and incorporated into the documents.
- Landmark Consultants will have the opportunity to review and comment on the plans and specifications for the project prior to the issuance of such for bidding.
- Continuous observation, inspection, and testing by the geotechnical consultant of record during site clearing, grading, excavation, placement of fills, building pad and subgrade preparation, and backfilling of utility trenches.
- Observation of foundation excavations and reinforcing steel before concrete placement.
- Other consultation as necessary during design and construction.

We emphasize our review of the project plans and specifications to check for compatibility with our recommendations and conclusions. Additional information concerning the scope and cost of these services can be obtained from our office.

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APPENDIX A

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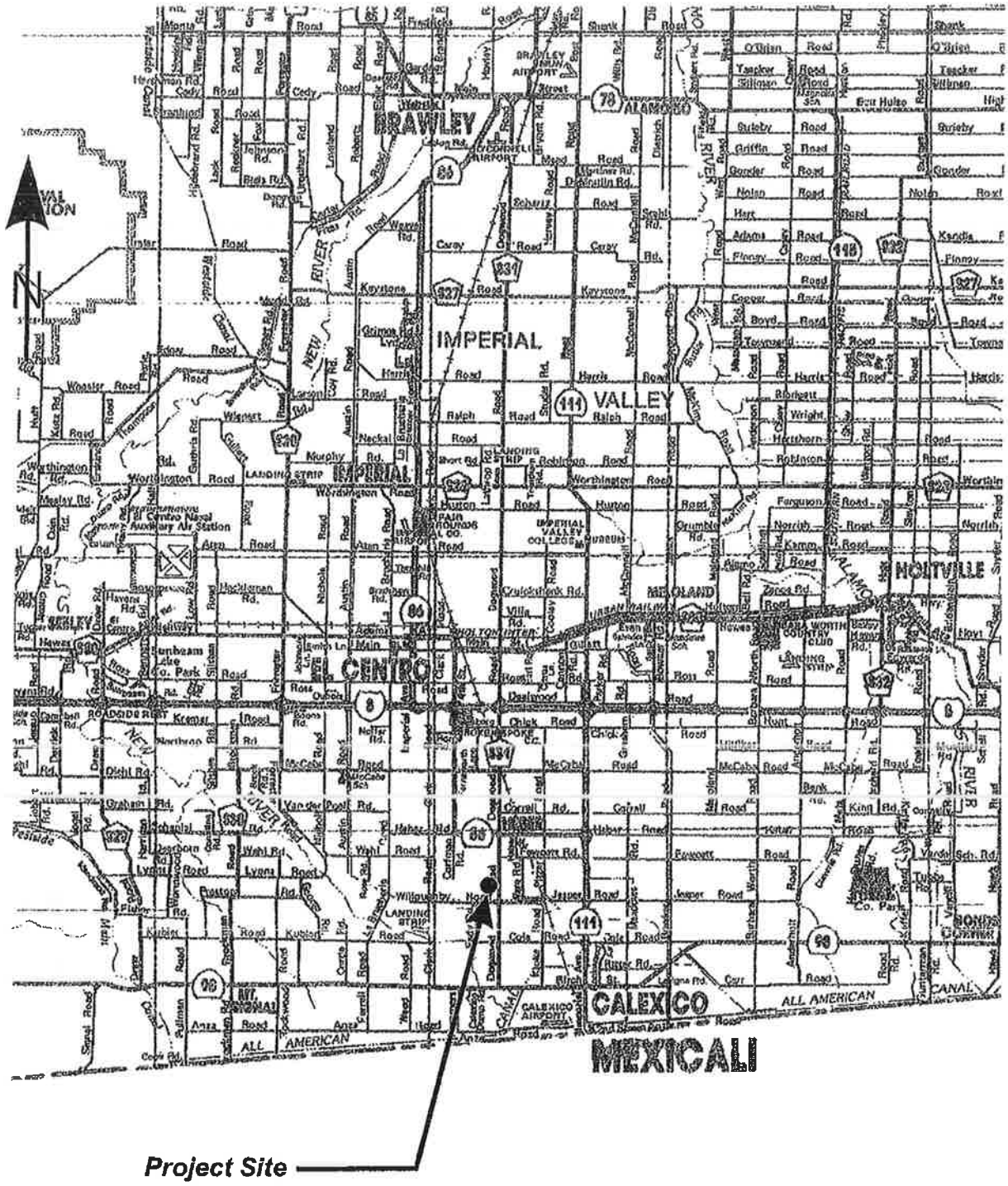

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Project No.: LE04354

Vicinity Map

Plate
A-1

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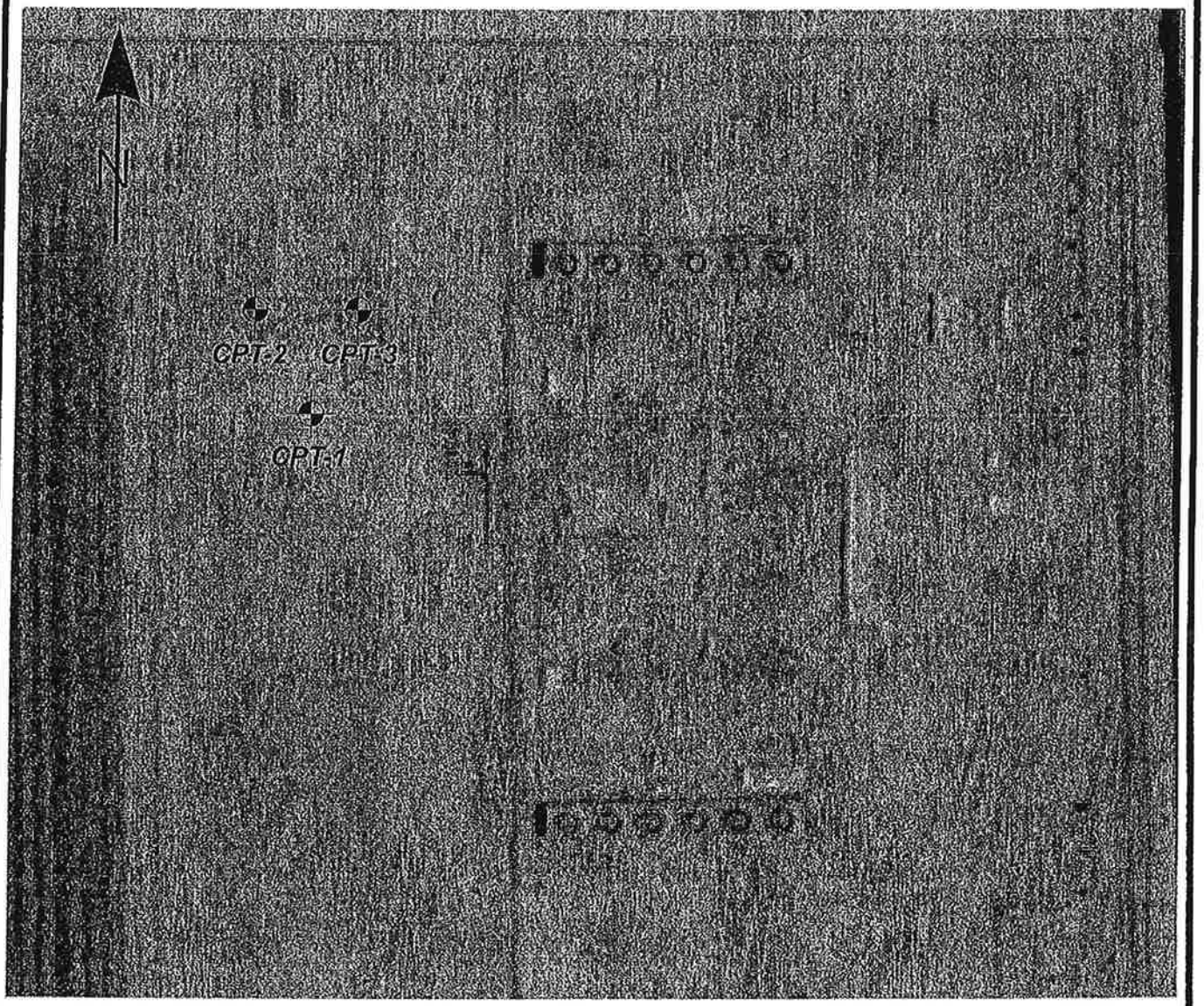

LANDMARK Geo-Engineers and Geologists a DBE/MBE/SBE Company Project No.: LE04354	Site and Exploration Map	Plate A-2

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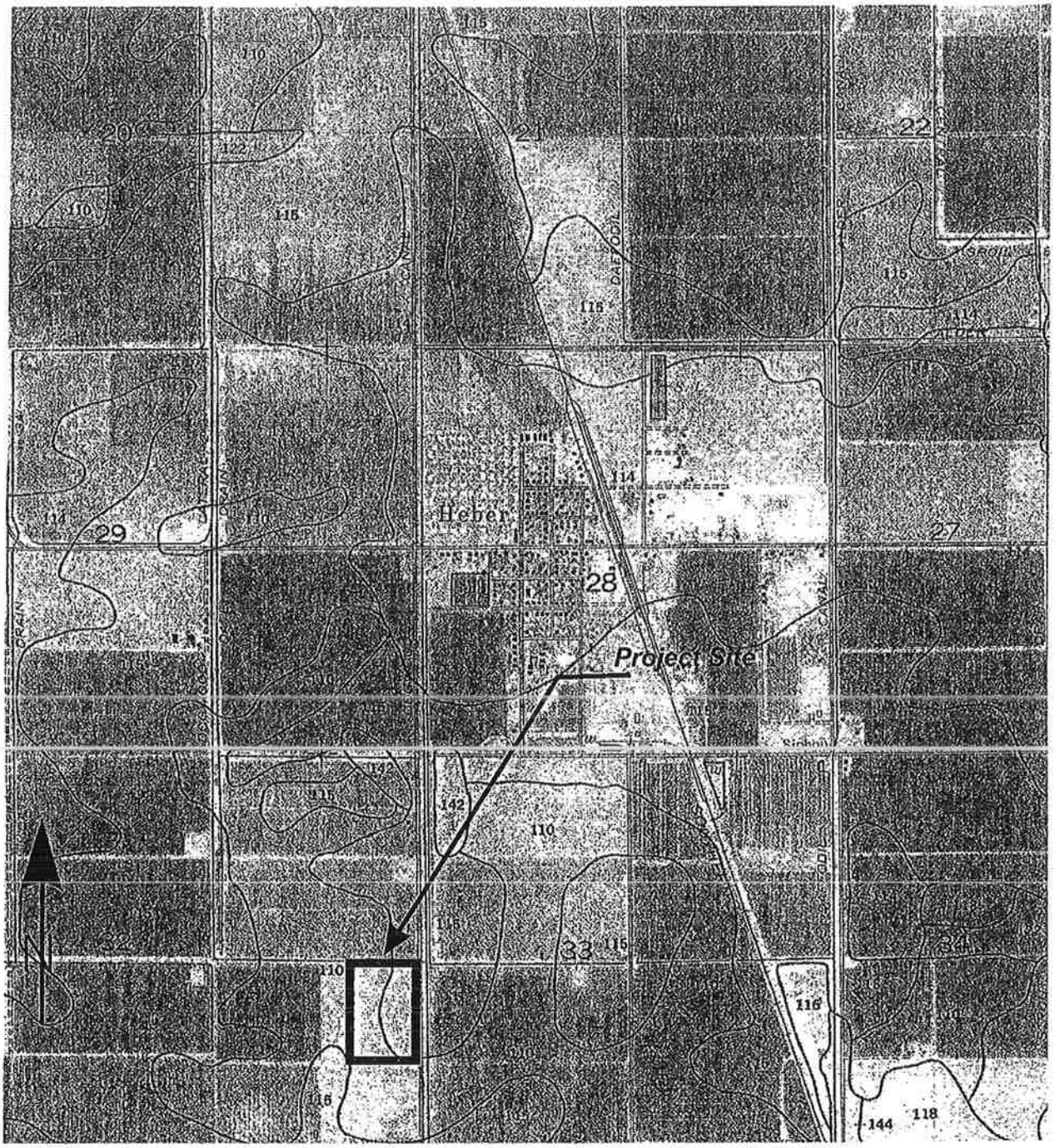

LANDMARK Geo-Engineers and Geologists a DBE/MBE/SBE Company Project No.: LE04354	Soil Survey Map	Plate A-3

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Soil Survey of

IMPERIAL COUNTY CALIFORNIA IMPERIAL VALLEY AREA



United States Department of Agriculture Soil Conservation Service
in cooperation with
University of California Agricultural Experiment Station
and
Imperial Irrigation District

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TABLE 11.--ENGINEERING INDEX PROPERTIES

[The symbol > means more than. Absence of an entry indicates that data were not estimated]

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
100----------	0-13	Loamy fine sand	SM	A-2	0	100	100	75-85	10-30	---	NP
Antho	13-60	Sandy loam, fine sandy loam.	SM	A-2, A-4	0	90-100	75-95	50-60	15-40	---	NP
101*:											
Antho----------	0-8	Loamy fine sand	SM	A-2	0	100	100	75-85	10-30	---	NP
	8-60	Sandy loam, fine sandy loam.	SM	A-2, A-4	0	90-100	75-95	50-60	15-40	---	NP
Superstition------	0-6	Fine sand-------	SM	A-2	0	100	95-100	70-85	15-25	---	NP
	6-60	Loamy fine sand, fine sand, sand.	SM	A-2	0	100	95-100	70-85	15-25	---	NP
102*. Badland											
103----------	0-10	Gravelly sand---	SP, SP-SM	A-1, A-2	0-5	60-90	50-85	30-55	0-10	---	NP
Carsitas	10-60	Gravelly sand, gravelly coarse sand, sand.	SP, SP-SM	A-1	0-5	60-90	50-85	25-50	0-10	---	NP
104* Fluvaquents											
105----------	0-13	Clay loam-------	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
106----------	0-13	Clay loam-------	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
107*----------	0-13	Loam----------	ML, CL-ML, CL	A-4	0	100	100	100	70-80	20-30	NP-10
Glenbar	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	95-100	75-95	35-45	15-30
108----------	0-14	Loam----------	ML	A-4	0	100	100	85-100	55-95	25-35	NP-10
Holtville	14-22	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	22-60	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
109----------	0-17	Silty clay------	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
Holtville	17-24	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	24-35	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
	35-60	Loamy very fine sand, loamy fine sand.	SM, ML	A-2, A-4	0	100	100	75-100	20-55	---	NP
110----------	0-17	Silty clay------	CH, CL	A-7	0	100	100	95-100	85-95	40-65	20-35
Holtville	17-24	Clay, silty clay	CH, CL	A-7	0	100	100	95-100	85-95	40-65	20-35
	24-35	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	55-85	25-35	NP-10
	35-60	Loamy very fine sand, loamy fine sand.	SM, ML	A-2, A-4	0	100	100	75-100	20-55	---	NP

See footnote at end of table.

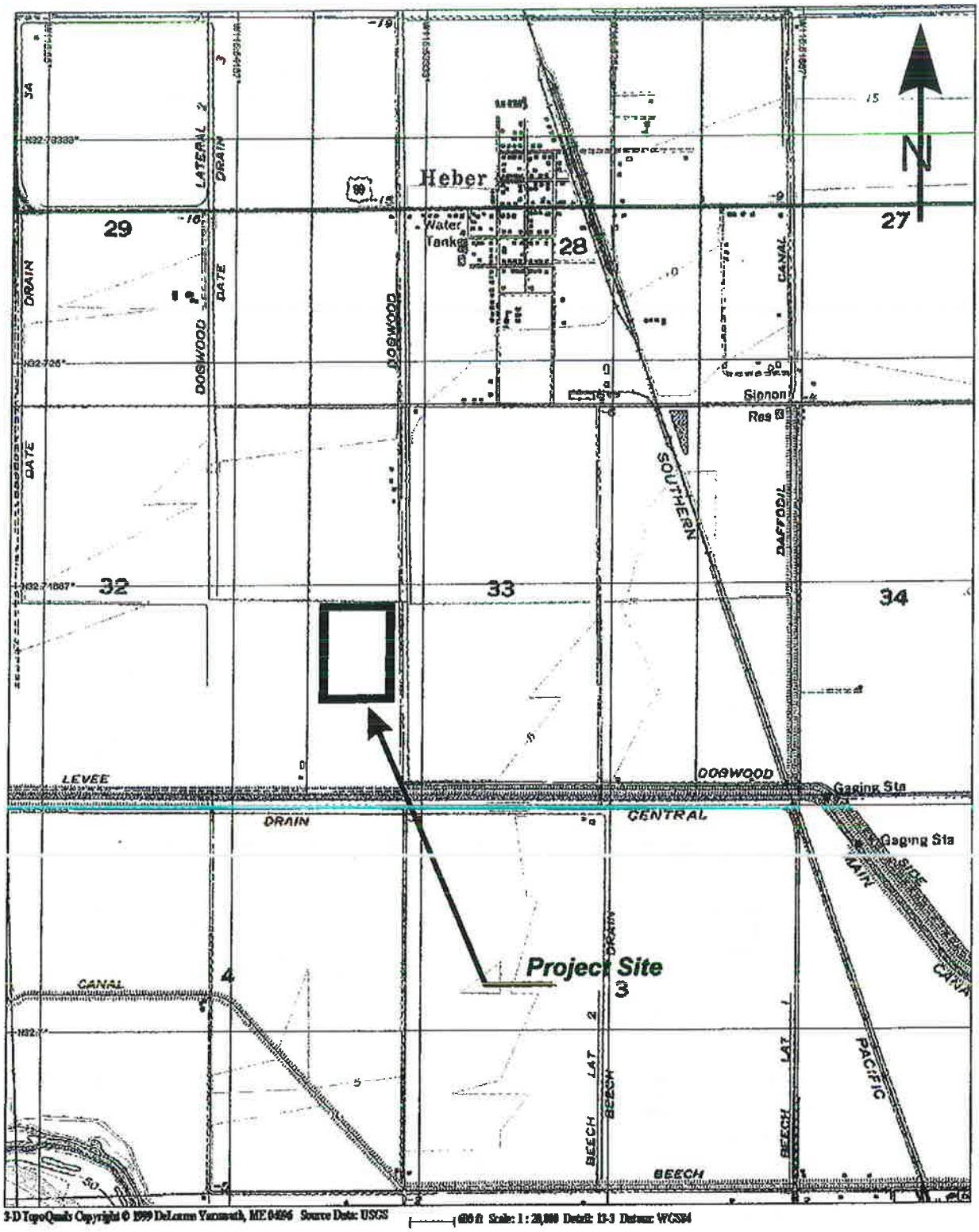
EEC ORIGINAL PKG

TABLE 11.--ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Frag-ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas-ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
111*:											
Holtville	0-10	Silty clay loam	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	10-22	Clay, silty clay	CL, CH	A-7	0	100	100	95-100	85-95	40-65	20-35
	22-60	Silt loam, very fine sandy loam.	ML	A-4	0	100	100	95-100	65-85	25-35	NP-10
Imperial	0-12	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
112	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
113	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay, clay, silty clay loam.	CH	A-7	0	100	100	100	85-95	50-70	25-45
114	0-12	Silty clay	CH	A-7	0	100	100	100	85-95	50-70	25-45
Imperial	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
115*:											
Imperial	0-12	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	12-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
Glenbar	0-13	Silty clay loam	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
	13-60	Clay loam, silty clay loam.	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
116*:											
Imperial	0-13	Silty clay loam	CL	A-7	0	100	100	100	85-95	40-50	10-20
	13-60	Silty clay loam, silty clay, clay.	CH	A-7	0	100	100	100	85-95	50-70	25-45
Glenbar	0-13	Silty clay loam	CL	A-6, A-7	0	100	100	90-100	70-95	35-45	15-25
	13-60	Clay loam, silty clay loam.	CL	A-6	0	100	100	90-100	70-95	35-45	15-30
117, 118	0-12	Loam	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
Indio	12-72	Stratified loamy very fine sand to silt loam.	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
119*:											
Indio	0-12	Loam	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
	12-72	Stratified loamy very fine sand to silt loam.	ML	A-4	0	95-100	95-100	85-100	75-90	20-30	NP-5
Vint	0-10	Loamy fine sand	SM	A-2	0	95-100	95-100	70-80	25-35	---	NP
	10-60	Loamy sand, loamy fine sand.	SM	A-2	0	95-100	95-100	70-80	20-30	---	NP
120*	0-12	Loam	ML, CL-ML	A-4	0	100	95-100	75-85	55-65	20-30	NP-10
Laveen	12-60	Loam, very fine sandy loam.	ML, CL-ML	A-4	0	95-100	85-95	70-80	55-65	15-25	NP-10

See footnote at end of table.

EEC ORIGINAL PKG



LANDMARK Geo-Engineers and Geologists a DBE/MBE/SBE Company **Project No.: LE04354**	**Topographic Map**	**Plate A-4**

EEC ORIGINAL PKG

APPENDIX B

EEC ORIGINAL PKG

CLIENT: ORMAT

PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

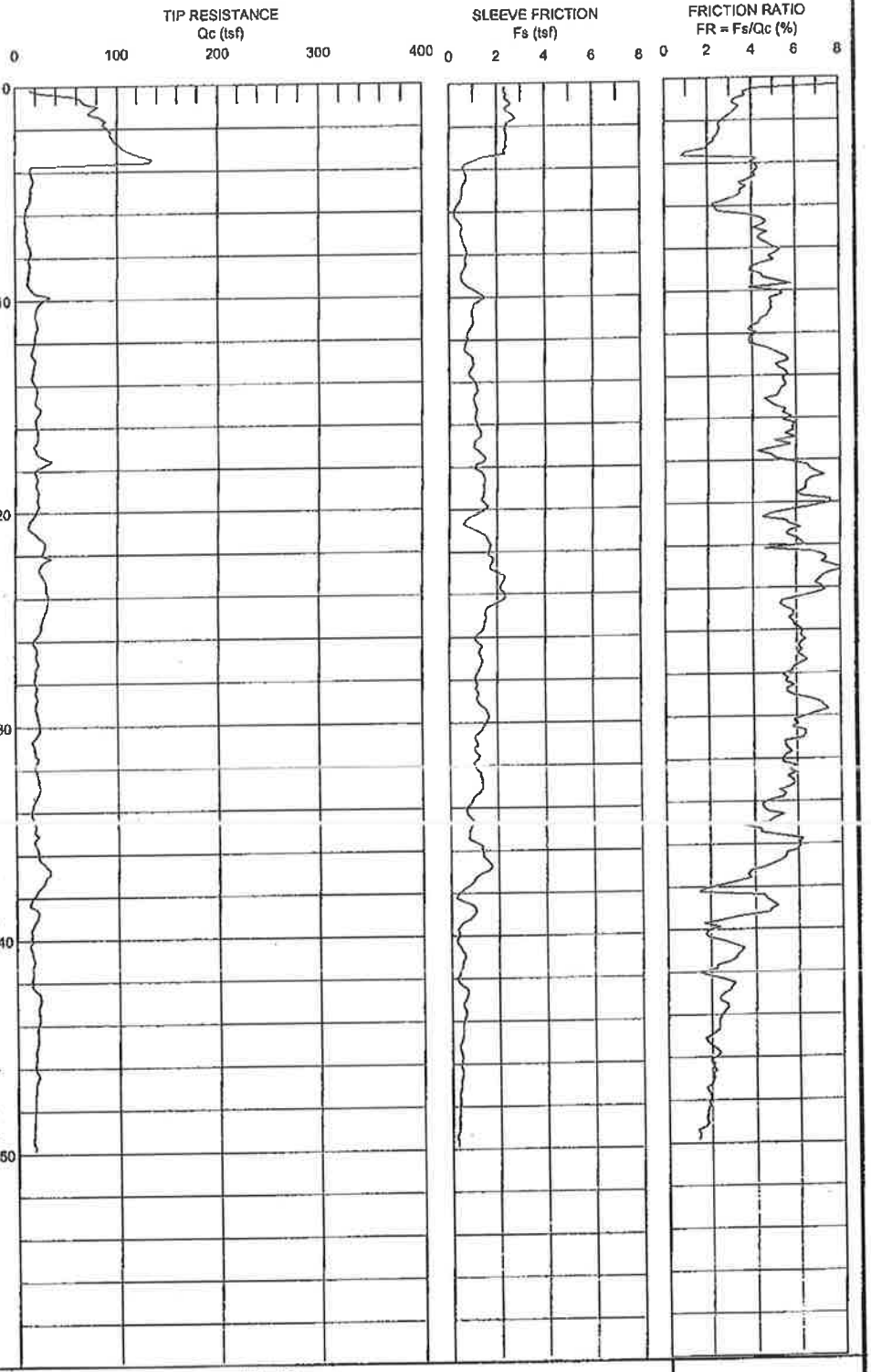
CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-1

DEPTH (FEET)	INTERPRETED SOIL PROFILE From Robertson & Campanella (1989)		
	GROUND EL. +/-		
	Clay	CL/CH	hard
	Sandy Silt to Clayey Silt	ML	very dense
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Silty Clay to Clay	CL	stiff
	Silty Clay to Clay	" "	stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	stiff
10	Clay	" "	very stiff
	Clay	" "	very stiff
	Silty Clay to Clay	CL	very stiff
	Clay	CL/CH	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Silty Clay to Clay	CL	stiff
40	Clayey Silt to Silty Clay	ML/CL	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	stiff
	Sandy Silt to Clayey Silt	ML	very loose
	Sandy Silt to Clayey Silt	" "	very loose
	Clayey Silt to Silty Clay	ML/CL	stiff
50			

End of Sounding @ 49.5 ft.



Project No: LE04354

LANDMARK
Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Plate B-1

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-1

Est. GWT (ft): 12.0

Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	31.82	10.13	3	Clay	CL/CH	very stiff	125	1.3	25	2.00		95			1.87	>10
0.30	1.0	71.19	3.50	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	20	2.00	134.6	45	107	43		
0.45	1.5	76.38	3.27	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	22	2.00	144.4	40	102	42		
0.60	2.0	88.21	2.88	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	25	2.00	166.8	35	101	42		
0.75	2.5	94.19	2.53	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	21	2.00	178.0	30	100	42		
0.93	3.0	101.94	2.35	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	23	2.00	192.7	30	99	42		
1.08	3.5	123.24	1.66	8	Sand to Silty Sand	SP/SM	very dense	115	5.5	22	2.00	233.0	20	102	42		
1.23	4.0	53.93	2.99	6	Sandy Silt to Clayey Silt	ML	dense	115	3.5	15	2.00	101.9	45	76	39		
1.38	4.5	16.43	4.19	3	Clay	CL/CH	stiff	125	1.3	13	2.00		85			0.95	>10
1.53	5.0	15.53	3.80	4	Silty Clay to Clay	CL	stiff	125	1.8	9	1.95		85			0.90	>10
1.68	5.5	13.99	3.48	4	Silty Clay to Clay	CL	stiff	125	1.8	8	1.85		85			0.80	>10
1.83	6.0	10.16	2.42	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	4	1.76		85			0.58	>10
1.98	6.5	10.41	3.55	4	Silty Clay to Clay	CL	stiff	125	1.8	6	1.69		95			0.59	>10
2.13	7.0	11.62	4.38	3	Clay	CL/CH	stiff	125	1.3	9	1.62		100			0.66	>10
2.28	7.5	13.29	4.44	3	Clay	CL/CH	stiff	125	1.3	11	1.56		95			0.76	>10
2.45	8.0	14.55	4.93	3	Clay	CL/CH	stiff	125	1.3	12	1.51		95			0.83	>10
2.60	8.5	13.90	4.96	3	Clay	CL/CH	stiff	125	1.3	11	1.46		100			0.79	>10
2.75	9.0	13.23	4.08	3	Clay	CL/CH	stiff	125	1.3	11	1.42		95			0.75	>10
2.90	9.5	13.66	4.68	3	Clay	CL/CH	stiff	125	1.3	11	1.38		100			0.77	>10
3.05	10.0	26.88	5.00	3	Clay	CL/CH	very stiff	125	1.3	22	1.34		80			1.55	>10
3.20	10.5	21.69	5.01	3	Clay	CL/CH	very stiff	125	1.3	17	1.32		90			1.24	>10
3.35	11.0	19.84	4.85	3	Clay	CL/CH	very stiff	125	1.3	16	1.30		95			1.13	>10
3.50	11.5	21.31	4.45	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	1.29		90			1.22	>10
3.65	12.0	18.97	4.00	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	1.27		90			1.08	>10
3.80	12.5	16.82	3.86	4	Silty Clay to Clay	CL	stiff	125	1.8	10	1.26		95			0.95	>10
3.95	13.0	18.18	4.91	3	Clay	CL/CH	very stiff	125	1.3	15	1.24		100			1.03	>10
4.13	13.5	17.33	5.43	3	Clay	CL/CH	stiff	125	1.3	14	1.23		100			0.98	>10
4.28	14.0	17.04	5.46	3	Clay	CL/CH	stiff	125	1.3	14	1.22		100			0.96	>10
4.43	14.5	21.21	5.45	3	Clay	CL/CH	very stiff	125	1.3	17	1.20		100			1.20	>10
4.58	15.0	19.96	5.21	3	Clay	CL/CH	very stiff	125	1.3	16	1.19		100			1.13	>10
4.73	15.5	23.41	4.80	3	Clay	CL/CH	very stiff	125	1.3	19	1.18		95			1.33	>10
4.88	16.0	20.50	5.51	3	Clay	CL/CH	very stiff	125	1.3	16	1.17		100			1.16	>10
5.03	16.5	21.94	5.88	3	Clay	CL/CH	very stiff	125	1.3	18	1.15		100			1.24	>10
5.18	17.0	19.22	5.48	3	Clay	CL/CH	very stiff	125	1.3	15	1.14		100			1.08	>10
5.33	17.5	27.57	5.03	3	Clay	CL/CH	very stiff	125	1.3	22	1.13		95			1.57	>10
5.48	18.0	23.29	5.22	3	Clay	CL/CH	very stiff	125	1.3	19	1.12		100			1.32	>10
5.65	18.5	20.85	6.67	3	Clay	CL/CH	very stiff	125	1.3	17	1.11		100			1.18	>10
5.80	19.0	21.33	6.77	3	Clay	CL/CH	very stiff	125	1.3	17	1.10		100			1.20	>10
5.95	19.5	21.97	6.29	3	Clay	CL/CH	very stiff	125	1.3	18	1.09		100			1.24	>10
6.10	20.0	21.34	7.09	3	Clay	CL/CH	very stiff	125	1.3	17	1.08		100			1.20	>10
6.25	20.5	15.48	5.72	3	Clay	CL/CH	stiff	125	1.3	12	1.07		100			0.86	5.53
6.40	21.0	15.87	5.20	3	Clay	CL/CH	stiff	125	1.3	13	1.06		100			0.88	5.65
6.55	21.5	26.53	5.79	3	Clay	CL/CH	very stiff	125	1.3	21	1.05		100			1.50	>10
6.70	22.0	27.19	6.21	3	Clay	CL/CH	very stiff	125	1.3	22	1.05		100			1.54	>10
6.85	22.5	29.12	6.18	3	Clay	CL/CH	very stiff	125	1.3	23	1.04		100			1.65	>10
7.00	23.0	24.40	7.41	3	Clay	CL/CH	very stiff	125	1.3	20	1.03		100			1.38	>10
7.18	23.5	29.74	7.65	3	Clay	CL/CH	very stiff	125	1.3	24	1.02		100			1.69	>10
7.33	24.0	31.24	7.01	3	Clay	CL/CH	very stiff	125	1.3	25	1.01		100			1.78	>10
7.48	24.5	31.71	6.74	3	Clay	CL/CH	very stiff	125	1.3	25	1.01		100			1.80	>10
7.63	25.0	28.38	5.36	3	Clay	CL/CH	very stiff	125	1.3	23	1.00		100			1.61	>10
7.78	25.5	25.50	5.79	3	Clay	CL/CH	very stiff	125	1.3	20	0.99		100			1.44	>10
7.93	26.0	21.23	6.01	3	Clay	CL/CH	very stiff	125	1.3	17	0.98		100			1.18	7.00
8.08	26.5	19.41	6.26	3	Clay	CL/CH	very stiff	125	1.3	16	0.98		100			1.08	6.00
8.23	27.0	21.10	6.12	3	Clay	CL/CH	very stiff	125	1.3	17	0.97		100			1.17	6.65
8.38	27.5	20.13	6.30	3	Clay	CL/CH	very stiff	125	1.3	16	0.96		100			1.12	6.00
8.53	28.0	19.23	5.66	3	Clay	CL/CH	very stiff	125	1.3	15	0.96		100			1.06	5.42
8.68	28.5	20.08	5.65	3	Clay	CL/CH	very stiff	125	1.3	16	0.95		100			1.11	5.76
8.85	29.0	20.55	5.67	3	Clay	CL/CH	very stiff	125	1.3	16	0.94		100			1.14	5.88
9.00	29.5	20.76	7.00	3	Clay	CL/CH	very stiff	125	1.3	17	0.94		100			1.15	5.88
9.15	30.0	22.80	6.88	3	Clay	CL/CH	very stiff	125	1.3	18	0.93		100			1.27	6.65

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-1

Est. GWT (ft): 12.0

Phi Correlation: 0 (0-Schm(78),1-R&C(83),2-PHT(74))

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	21.60	5.89	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.93		100			1.20	6.00
9.45	31.0	17.19	6.36	3 3	Clay	CL/CH	stiff	125	1.3	14	0.92		100			0.94	4.00
9.60	31.5	20.05	5.47	3 3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.10	5.10
9.75	32.0	19.47	5.50	3 3	Clay	CL/CH	very stiff	125	1.3	16	0.91		100			1.07	4.88
9.90	32.5	21.74	5.63	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.90		100			1.20	5.53
10.05	33.0	23.37	5.76	3 3	Clay	CL/CH	very stiff	125	1.3	19	0.90		100			1.30	6.10
10.20	33.5	20.39	5.56	3 3	Clay	CL/CH	very stiff	125	1.3	16	0.89		100			1.12	4.78
10.36	34.0	15.97	5.12	3 3	Clay	CL/CH	stiff	125	1.3	13	0.89		100			0.86	3.28
10.53	34.5	16.45	4.48	3 3	Clay	CL/CH	stiff	125	1.3	13	0.88		100			0.89	3.35
10.68	35.0	18.50	4.96	3 3	Clay	CL/CH	very stiff	125	1.3	15	0.88		100			1.01	3.91
10.83	35.5	19.11	4.05	4 4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.87		100			1.04	5.21
10.98	36.0	20.64	5.86	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.87		100			1.13	4.47
11.13	36.5	25.44	5.72	3 3	Clay	CL/CH	very stiff	125	1.3	20	0.86		100			1.41	6.21
11.28	37.0	31.72	4.84	4 4	Silty Clay to Clay	CL	very stiff	125	1.8	18	0.86		100			1.78	>10
11.43	37.5	25.49	3.77	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.85		100			1.41	>10
11.58	38.0	17.68	2.48	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.85		100			0.95	5.65
11.73	38.5	15.25	3.47	4 4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.85		100			0.81	3.35
11.88	39.0	20.64	4.84	3 3	Clay	CL/CH	very stiff	125	1.3	17	0.84		100			1.13	4.00
12.05	39.5	15.50	3.51	4 4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.84		100			0.82	3.28
12.20	40.0	14.77	2.00	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.83		100			0.78	3.91
12.35	40.5	13.50	2.07	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	5	0.83		100			0.70	3.43
12.50	41.0	15.96	3.29	4 4	Silty Clay to Clay	CL	stiff	125	1.8	9	0.82		100			0.85	3.28
12.65	41.5	15.32	3.05	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.82		100			0.81	4.00
12.80	42.0	14.74	2.01	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.82		100			0.77	3.66
12.95	42.5	17.48	2.54	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.81		100			0.93	4.78
13.10	43.0	22.47	2.80	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.23	7.13
13.25	43.5	20.78	2.49	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.13	6.21
13.40	44.0	21.29	2.62	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.16	6.43
13.56	44.5	19.71	2.35	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.06	5.53
13.73	45.0	19.60	2.17	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.05	5.42
13.88	45.5	18.05	1.84	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.79	13.5	100	13	30		
14.03	46.0	17.42	2.29	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.92	4.28
14.18	46.5	19.49	2.03	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.79	14.5	100	15	30		
14.33	47.0	17.99	2.10	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.96	4.37
14.48	47.5	16.62	1.85	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.88	3.83
14.63	48.0	16.66	1.91	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.78		100			0.88	3.83
14.78	48.5	15.96	1.83	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.77		100			0.83	3.58
14.93	49.0	15.56	1.78	5 5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.77		100			0.81	3.35
15.10	49.5	14.89	1.48	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	4	0.77	10.8	100	7	29		

EEC ORIGINAL PKG

CLIENT: ORMAT

PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

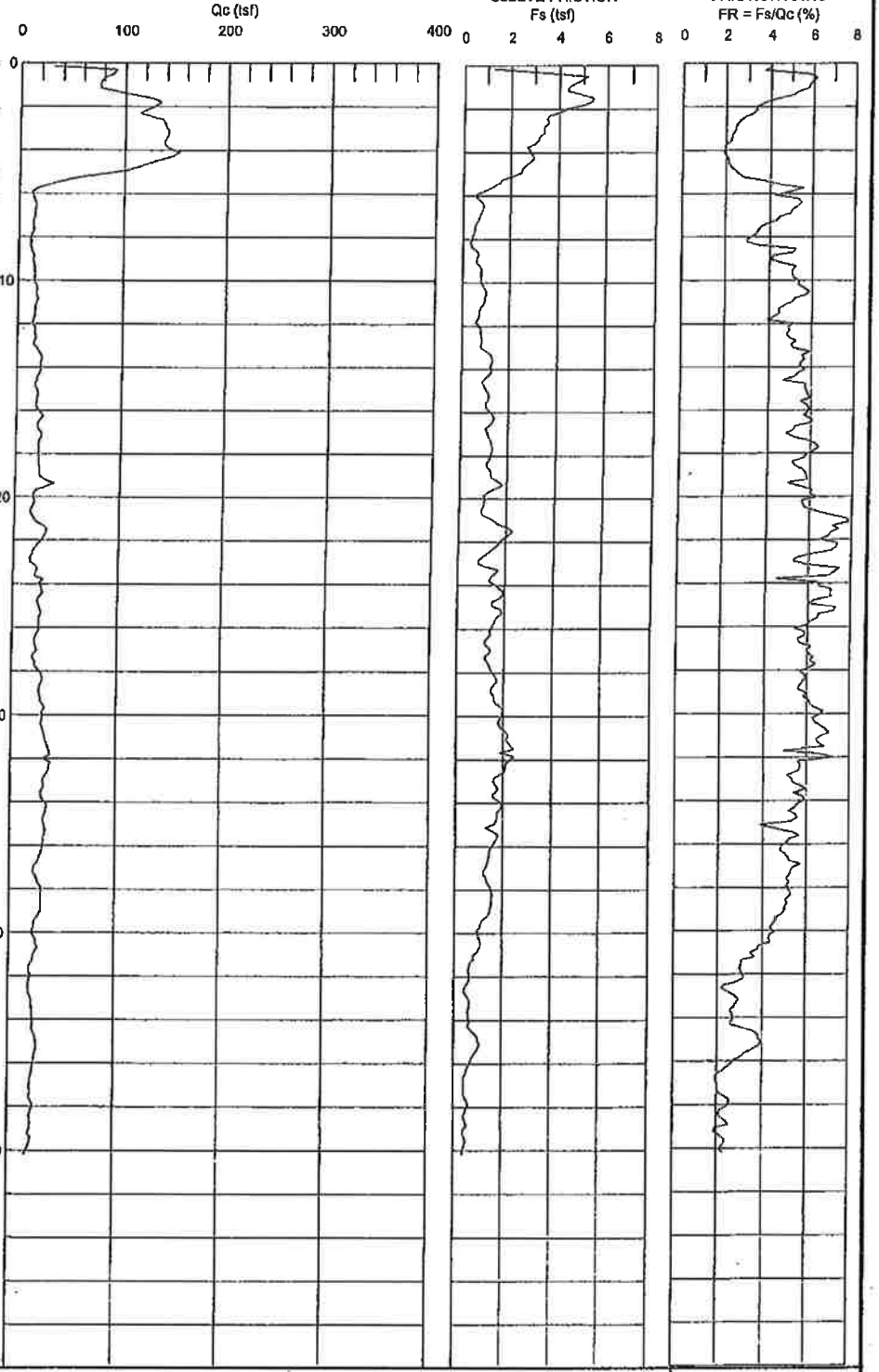
CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-2

DEPTH (FEET)	INTERPRETED SOIL PROFILE From Robertson & Campanella (1989)		
	GROUND EL. +/-		
	Overconsolidated Soil	??	very dense
	Overconsolidated Soil	" "	very dense
	Silty Sand to Sandy Silt	SM/ML	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Silty Sand to Sandy Silt	" "	very dense
	Clayey Silt to Silty Clay	ML/CL	hard
	Clay	CL/CH	stiff
	Silty Clay to Clay	CL	stiff
	Clay	CL/CH	stiff
10	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
20	Clay	" "	very stiff
	Clay	" "	stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
30	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
	Clay	" "	very stiff
40	Silty Clay to Clay	CL	very stiff
	Silty Clay to Clay	" "	very stiff
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Clayey Silt to Silty Clay	" "	very stiff
	Sandy Silt to Clayey Silt	ML	very loose
	Clayey Silt to Silty Clay	ML/CL	very stiff
	Sandy Silt to Clayey Silt	ML	very loose
50	Sandy Silt to Clayey Silt	" "	very loose

End of Sounding @ 50.0 ft.



Project No: LE04354

LANDMARK
Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Plate B-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-2

Est. GWT (ft): 12.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	70.28	4.52	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	28	2.00		50			4.13	>10
0.30	1.0	77.82	5.97	11	Overconsolidated Soil	??	very dense	120	1.0	78	2.00	147.1	55	110	43		
0.45	1.5	91.98	5.31	11	Overconsolidated Soil	??	very dense	120	1.0	92	2.00	173.9	50	107	43		
0.60	2.0	129.94	3.78	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	37	2.00	245.6	35	113	44		
0.76	2.5	119.62	3.11	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	34	2.00	226.1	30	107	43		
0.93	3.0	137.68	2.51	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	260.3	25	108	43		
1.08	3.5	140.87	2.30	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	266.3	25	106	43		
1.23	4.0	139.35	2.04	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	31	2.00	263.4	20	104	43		
1.38	4.5	144.85	2.01	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	32	2.00	273.8	20	103	42		
1.53	5.0	113.08	2.24	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	25	1.95	208.9	25	94	41		
1.68	5.5	52.70	3.38	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	1.86		50			3.08	>10
1.83	6.0	13.87	4.91	3	Clay	CL/CH	stiff	125	1.3	11	1.77		95			0.80	>10
1.98	6.5	15.08	5.36	3	Clay	CL/CH	stiff	125	1.3	12	1.70		95			0.87	>10
2.13	7.0	14.77	4.81	3	Clay	CL/CH	stiff	125	1.3	12	1.63		95			0.85	>10
2.28	7.5	13.38	3.90	3	Clay	CL/CH	stiff	125	1.3	11	1.57		90			0.76	>10
2.45	8.0	12.25	3.27	4	Silty Clay to Clay	CL	stiff	125	1.8	7	1.51		90			0.69	>10
2.60	8.5	11.34	3.86	3	Clay	CL/CH	stiff	125	1.3	9	1.46		100			0.64	9.79
2.75	9.0	13.62	4.43	3	Clay	CL/CH	stiff	125	1.3	11	1.42		95			0.77	>10
2.90	9.5	14.76	4.97	3	Clay	CL/CH	stiff	125	1.3	12	1.38		100			0.84	>10
3.05	10.0	15.04	5.19	3	Clay	CL/CH	stiff	125	1.3	12	1.34		100			0.85	>10
3.20	10.5	17.24	5.61	3	Clay	CL/CH	stiff	125	1.3	14	1.33		100			0.98	>10
3.35	11.0	17.82	5.31	3	Clay	CL/CH	very stiff	125	1.3	14	1.31		100			1.01	>10
3.50	11.5	16.22	4.53	3	Clay	CL/CH	stiff	125	1.3	13	1.29		100			0.92	>10
3.65	12.0	14.59	4.45	3	Clay	CL/CH	stiff	125	1.3	12	1.28		100			0.82	9.19
3.80	12.5	15.95	4.89	3	Clay	CL/CH	stiff	125	1.3	13	1.26		100			0.90	>10
3.95	13.0	16.10	5.07	3	Clay	CL/CH	stiff	125	1.3	13	1.25		100			0.91	>10
4.13	13.5	20.52	5.55	3	Clay	CL/CH	very stiff	125	1.3	16	1.23		100			1.17	>10
4.28	14.0	22.48	5.55	3	Clay	CL/CH	very stiff	125	1.3	18	1.22		100			1.28	>10
4.43	14.5	20.89	5.42	3	Clay	CL/CH	very stiff	125	1.3	17	1.21		100			1.19	>10
4.58	15.0	17.79	5.37	3	Clay	CL/CH	very stiff	125	1.3	14	1.19		100			1.00	>10
4.73	15.5	19.47	5.86	3	Clay	CL/CH	very stiff	125	1.3	16	1.18		100			1.10	>10
4.88	16.0	19.76	5.77	3	Clay	CL/CH	very stiff	125	1.3	16	1.17		100			1.12	>10
5.03	16.5	22.53	5.91	3	Clay	CL/CH	very stiff	125	1.3	18	1.16		100			1.28	>10
5.18	17.0	21.67	5.09	3	Clay	CL/CH	very stiff	125	1.3	17	1.15		100			1.23	>10
5.33	17.5	22.15	5.77	3	Clay	CL/CH	very stiff	125	1.3	18	1.13		100			1.25	>10
5.48	18.0	21.43	6.10	3	Clay	CL/CH	very stiff	125	1.3	17	1.12		100			1.21	>10
5.65	18.5	21.56	5.34	3	Clay	CL/CH	very stiff	125	1.3	17	1.11		100			1.22	>10
5.80	19.0	22.73	5.72	3	Clay	CL/CH	very stiff	125	1.3	18	1.10		100			1.29	>10
5.95	19.5	30.63	5.48	3	Clay	CL/CH	very stiff	125	1.3	25	1.09		95			1.75	>10
6.10	20.0	17.95	6.14	3	Clay	CL/CH	very stiff	125	1.3	14	1.08		100			1.00	7.41
6.25	20.5	17.30	5.70	3	Clay	CL/CH	stiff	125	1.3	14	1.07		100			0.96	6.65
6.40	21.0	16.60	6.99	3	Clay	CL/CH	stiff	125	1.3	13	1.07		100			0.92	6.10
6.55	21.5	26.75	7.44	3	Clay	CL/CH	very stiff	125	1.3	21	1.06		100			1.52	>10
6.70	22.0	28.17	6.81	3	Clay	CL/CH	very stiff	125	1.3	23	1.05		100			1.60	>10
6.85	22.5	20.17	7.24	3	Clay	CL/CH	very stiff	125	1.3	16	1.04		100			1.13	7.85
7.00	23.0	16.15	5.62	3	Clay	CL/CH	stiff	125	1.3	13	1.03		100			0.89	5.21
7.18	23.5	21.37	6.84	3	Clay	CL/CH	very stiff	125	1.3	17	1.02		100			1.20	8.27
7.33	24.0	24.23	5.98	3	Clay	CL/CH	very stiff	125	1.3	19	1.02		100			1.36	>10
7.48	24.5	27.09	6.88	3	Clay	CL/CH	very stiff	125	1.3	22	1.01		100			1.53	>10
7.63	25.0	23.97	6.46	3	Clay	CL/CH	very stiff	125	1.3	19	1.00		100			1.35	9.39
7.78	25.5	25.90	6.98	3	Clay	CL/CH	very stiff	125	1.3	21	0.99		100			1.46	>10
7.93	26.0	24.80	6.17	3	Clay	CL/CH	very stiff	125	1.3	20	0.99		100			1.39	9.59
8.08	26.5	22.94	5.66	3	Clay	CL/CH	very stiff	125	1.3	18	0.98		100			1.28	8.00
8.23	27.0	22.28	5.92	3	Clay	CL/CH	very stiff	125	1.3	18	0.97		100			1.24	7.27
8.38	27.5	20.15	6.14	3	Clay	CL/CH	very stiff	125	1.3	16	0.97		100			1.12	6.10
8.53	28.0	24.13	6.05	3	Clay	CL/CH	very stiff	125	1.3	19	0.96		100			1.35	8.14
8.68	28.5	28.28	5.86	3	Clay	CL/CH	very stiff	125	1.3	23	0.95		100			1.59	>10
8.85	29.0	26.02	5.73	3	Clay	CL/CH	very stiff	125	1.3	21	0.95		100			1.46	8.85
9.00	29.5	28.06	6.01	3	Clay	CL/CH	very stiff	125	1.3	22	0.94		100			1.56	>10
9.15	30.0	29.72	6.57	3	Clay	CL/CH	very stiff	125	1.3	24	0.93		100			1.68	>10

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-2

Est. GWT (ft): 12.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	28.55	6.41	3 3	Clay	CL/CH	very stiff	125	1.3	23	0.93		100			1.61	>10
9.45	31.0	31.07	6.84	3 3	Clay	CL/CH	very stiff	125	1.3	25	0.92		100			1.75	>10
9.60	31.5	34.71	6.59	3 3	Clay	CL/CH	very stiff	125	1.3	28	0.92		100			1.97	>10
9.75	32.0	35.27	6.25	3 3	Clay	CL/CH	very stiff	125	1.3	28	0.91		100			2.00	>10
9.90	32.5	37.01	5.65	3 3	Clay	CL/CH	hard	125	1.3	30	0.91		100			2.10	>10
10.05	33.0	32.37	5.31	3 3	Clay	CL/CH	very stiff	125	1.3	26	0.90		100			1.83	>10
10.20	33.5	30.28	5.70	3 3	Clay	CL/CH	very stiff	125	1.3	24	0.89		100			1.70	9.59
10.38	34.0	29.97	5.71	3 3	Clay	CL/CH	very stiff	125	1.3	24	0.89		100			1.68	9.19
10.53	34.5	34.16	5.42	3 3	Clay	CL/CH	very stiff	125	1.3	27	0.88		100			1.93	>10
10.68	35.0	31.53	5.44	3 3	Clay	CL/CH	very stiff	125	1.3	25	0.88		100			1.77	9.79
10.83	35.5	33.18	4.62	4 4	Silty Clay to Clay	CL	very stiff	125	1.8	19	0.87		100			1.87	>10
10.98	36.0	31.41	5.32	3 3	Clay	CL/CH	very stiff	125	1.3	25	0.87		100			1.77	9.19
11.13	36.5	28.95	4.94	3 3	Clay	CL/CH	very stiff	125	1.3	23	0.86		100			1.62	7.70
11.28	37.0	23.74	5.43	3 3	Clay	CL/CH	very stiff	125	1.3	19	0.86		100			1.31	5.42
11.43	37.5	24.03	5.19	3 3	Clay	CL/CH	very stiff	125	1.3	19	0.85		100			1.33	5.42
11.58	38.0	28.73	5.16	3 3	Clay	CL/CH	very stiff	125	1.3	23	0.85		100			1.60	7.13
11.73	38.5	29.89	5.19	3 3	Clay	CL/CH	very stiff	125	1.3	24	0.85		100			1.67	7.56
11.88	39.0	29.55	5.05	3 3	Clay	CL/CH	very stiff	125	1.3	24	0.84		100			1.65	7.27
12.05	39.5	25.32	4.72	3 3	Clay	CL/CH	very stiff	125	1.3	20	0.84		100			1.40	5.53
12.20	40.0	22.19	4.46	3 3	Clay	CL/CH	very stiff	125	1.3	18	0.83		100			1.22	4.37
12.35	40.5	24.43	4.30	4 4	Silty Clay to Clay	CL	very stiff	125	1.8	14	0.83		100			1.35	6.54
12.50	41.0	24.85	3.66	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.82		100			1.37	9.39
12.65	41.5	21.29	3.25	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.16	6.88
12.80	42.0	19.81	3.04	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.82		100			1.07	6.00
12.95	42.5	18.87	2.79	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.02	5.42
13.10	43.0	19.60	2.48	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.06	5.76
13.25	43.5	21.70	2.84	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.81		100			1.18	6.65
13.40	44.0	22.24	2.62	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.21	6.88
13.58	44.5	22.52	2.78	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.80		100			1.23	6.88
13.73	45.0	25.15	3.77	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.80		100			1.38	8.27
13.88	45.5	26.20	3.80	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.44	8.85
14.03	46.0	24.44	3.02	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.79		100			1.34	7.70
14.18	46.5	22.65	2.43	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.79		100			1.23	6.54
14.33	47.0	20.81	1.98	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.78	15.4	100	17	30		
14.48	47.5	20.51	2.12	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.78	15.1	100	17	30		
14.63	48.0	22.61	2.50	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.78		100			1.23	8.32
14.78	48.5	20.83	2.13	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.77	15.2	100	17	30		
14.93	49.0	20.93	2.27	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.77		100			1.13	5.42
15.10	49.5	20.67	2.11	6 6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	6	0.77	15.0	100	16	30		
15.25	50.0	19.06	2.25	5 5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.76		100			1.01	4.47

EEC ORIGINAL PKG

CLIENT: ORMAT

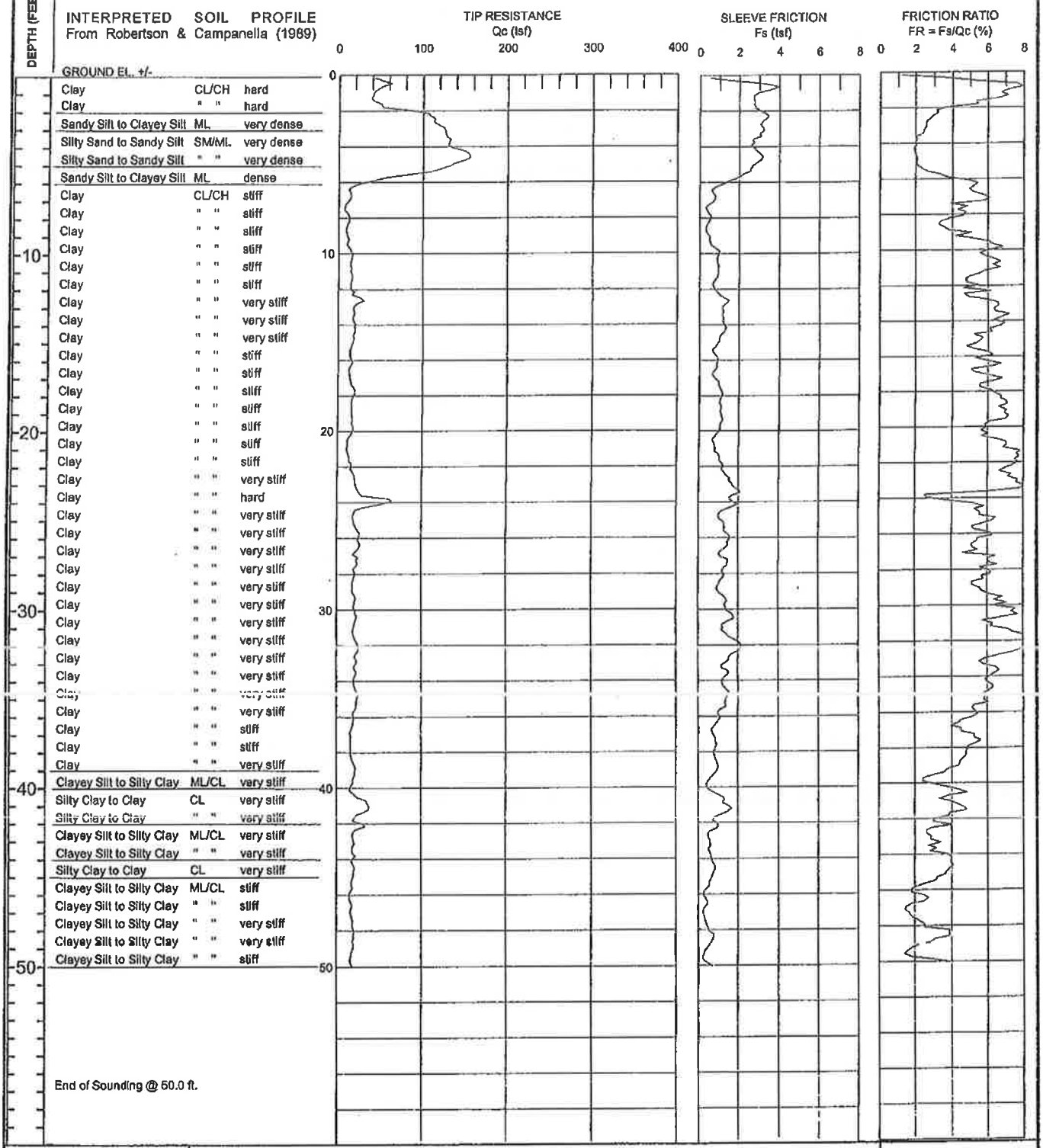
PROJECT: ORMAT Heber 2 Facilities, Heber, CA

LOCATION: See Site and Boring Location Plan

CONE PENETROMETER: HOLGUIN, FAHAN & ASSC. Truck Mounted Electric Cone with 23 ton reaction weight

DATE: 12/20/04

LOG OF CONE SOUNDING DATA CPT-3



Project No: LE04354

LANDMARK Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Plate B-3

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-3

Est. GWT (ft): 12.0 Phi Correlation: 0 (0-Schm(78),1-R&C(83),2-PHT(74))

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %		1 Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
0.15	0.5	51.76	3.36	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	2.00		50			3.04	>10
0.30	1.0	46.42	7.56	3	3	Clay	CL/CH	hard	125	1.3	37	2.00		75			2.73	>10
0.45	1.5	40.35	6.79	3	3	Clay	CL/CH	hard	125	1.3	32	2.00		75			2.37	>10
0.60	2.0	61.72	4.80	4	4	Silty Clay to Clay	CL	hard	125	1.8	35	2.00		55			3.62	>10
0.75	2.5	109.67	3.07	6	6	Sandy Silt to Clayey Silt	ML	very dense	115	3.5	31	2.00	207.3	35	104	43		
0.93	3.0	116.60	2.64	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	26	2.00	224.2	30	103	42		
1.08	3.5	127.70	2.43	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	28	2.00	241.4	25	103	42		
1.23	4.0	131.15	2.02	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	29	2.00	247.9	25	102	42		
1.38	4.5	147.55	1.96	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	33	2.00	278.9	20	103	42		
1.53	5.0	148.38	2.05	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	33	1.94	271.7	20	102	42		
1.68	5.5	111.44	2.28	7	7	Silty Sand to Sandy Silt	SM/ML	very dense	115	4.5	25	1.85	194.4	25	92	41		
1.83	6.0	40.17	4.02	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	16	1.76		60			2.34	>10
1.98	6.5	13.36	5.18	3	3	Clay	CL/CH	stiff	125	1.3	11	1.69		100			0.76	>10
2.13	7.0	13.22	5.65	3	3	Clay	CL/CH	stiff	125	1.3	11	1.62		100			0.75	>10
2.28	7.5	7.68	4.85	3	3	Clay	CL/CH	firm	125	1.3	6	1.56		100			0.43	6.10
2.45	8.0	11.50	4.55	3	3	Clay	CL/CH	stiff	125	1.3	9	1.51		100			0.65	>10
2.60	8.5	10.61	3.49	4	4	Silty Clay to Clay	CL	stiff	125	1.8	6	1.46		95			0.60	>10
2.75	9.0	9.81	4.10	3	3	Clay	CL/CH	stiff	125	1.3	8	1.42		100			0.55	6.54
2.90	9.5	10.85	5.09	3	3	Clay	CL/CH	stiff	125	1.3	9	1.38		100			0.61	7.00
3.05	10.0	14.61	6.36	3	3	Clay	CL/CH	stiff	125	1.3	12	1.34		100			0.82	>10
3.20	10.5	14.97	5.91	3	3	Clay	CL/CH	stiff	125	1.3	12	1.32		100			0.85	>10
3.35	11.0	14.49	6.53	3	3	Clay	CL/CH	stiff	125	1.3	12	1.31		100			0.82	>10
3.50	11.5	15.94	5.42	3	3	Clay	CL/CH	stiff	125	1.3	13	1.29		100			0.90	>10
3.65	12.0	14.15	5.01	3	3	Clay	CL/CH	stiff	125	1.3	11	1.27		100			0.79	8.56
3.80	12.5	20.31	5.15	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.26		95			1.16	>10
3.95	13.0	23.81	5.79	3	3	Clay	CL/CH	very stiff	125	1.3	19	1.24		95			1.36	>10
4.13	13.5	18.35	6.42	3	3	Clay	CL/CH	very stiff	125	1.3	15	1.23		100			1.04	>10
4.28	14.0	18.13	6.73	3	3	Clay	CL/CH	very stiff	125	1.3	15	1.22		100			1.02	>10
4.43	14.5	19.70	6.56	3	3	Clay	CL/CH	very stiff	125	1.3	16	1.20		100			1.12	>10
4.58	15.0	18.07	5.71	3	3	Clay	CL/CH	very stiff	125	1.3	14	1.19		100			1.02	>10
4.73	15.5	14.86	5.24	3	3	Clay	CL/CH	stiff	125	1.3	12	1.18		100			0.83	7.00
4.88	16.0	14.60	5.69	3	3	Clay	CL/CH	stiff	125	1.3	12	1.17		100			0.81	6.85
5.03	16.5	13.49	6.25	3	3	Clay	CL/CH	stiff	125	1.3	11	1.16		100			0.75	5.65
5.18	17.0	13.31	5.44	3	3	Clay	CL/CH	stiff	125	1.3	11	1.14		100			0.74	5.31
5.33	17.5	16.20	6.21	3	3	Clay	CL/CH	stiff	125	1.3	13	1.13		100			0.90	7.13
5.48	18.0	19.16	5.98	3	3	Clay	CL/CH	very stiff	125	1.3	15	1.12		100			1.08	9.59
5.65	18.5	15.49	6.80	3	3	Clay	CL/CH	stiff	125	1.3	12	1.11		100			0.86	6.32
5.80	19.0	15.81	6.89	3	3	Clay	CL/CH	stiff	125	1.3	13	1.10		100			0.88	6.32
5.95	19.5	16.32	7.00	3	3	Clay	CL/CH	stiff	125	1.3	13	1.09		100			0.91	6.43
6.10	20.0	17.26	5.95	3	3	Clay	CL/CH	stiff	125	1.3	14	1.08		100			0.96	6.88
6.25	20.5	13.28	5.76	3	3	Clay	CL/CH	stiff	125	1.3	11	1.07		100			0.73	4.37
6.40	21.0	11.14	6.84	3	3	Clay	CL/CH	stiff	125	1.3	9	1.06		100			0.60	3.28
6.55	21.5	12.48	7.40	3	3	Clay	CL/CH	stiff	125	1.3	10	1.06		100			0.68	3.74
6.70	22.0	14.92	7.62	3	3	Clay	CL/CH	stiff	125	1.3	12	1.05		100			0.82	4.89
6.85	22.5	17.77	6.98	3	3	Clay	CL/CH	stiff	125	1.3	14	1.04		100			0.99	6.32
7.00	23.0	21.45	7.34	3	3	Clay	CL/CH	very stiff	125	1.3	17	1.03		100			1.20	8.41
7.18	23.5	24.58	7.84	3	3	Clay	CL/CH	very stiff	125	1.3	20	1.02		100			1.39	>10
7.33	24.0	51.65	3.68	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	21	1.02		70			2.98	>10
7.48	24.5	34.37	4.91	3	3	Clay	CL/CH	very stiff	125	1.3	27	1.01		95			1.98	>10
7.63	25.0	18.84	5.44	3	3	Clay	CL/CH	very stiff	125	1.3	15	1.00		100			1.05	6.10
7.78	25.5	21.09	6.11	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.99		100			1.18	7.13
7.93	26.0	26.12	5.49	3	3	Clay	CL/CH	very stiff	125	1.3	21	0.99		100			1.47	>10
8.08	26.5	26.28	5.55	3	3	Clay	CL/CH	very stiff	125	1.3	21	0.98		100			1.48	>10
8.23	27.0	21.92	5.06	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.97		100			1.22	7.13
8.38	27.5	23.63	6.15	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.97		100			1.32	8.00
8.53	28.0	20.49	6.07	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.96		100			1.14	6.10
8.68	28.5	19.11	5.87	3	3	Clay	CL/CH	very stiff	125	1.3	15	0.95		100			1.06	5.31
8.85	29.0	18.15	5.24	3	3	Clay	CL/CH	stiff	125	1.3	15	0.95		100			1.00	4.78
9.00	29.5	21.72	6.18	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.94		100			1.21	6.32
9.15	30.0	20.63	6.55	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.93		100			1.14	5.65

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CONE PENETROMETER INTERPRETATION (based on Robertson & Campanella, 1989, refer to Key to CPT logs)

Project: ORMAT Heber 2 Facilities, Heber, CA Project No: LE04354 Date: 12/20/04

CONE SOUNDING: CPT-3

Est. GWT (ft): 12.0 Phi Correlation: 0 0-Schm(78),1-R&C(83),2-PHT(74)

Base Depth meters	Base Depth feet	Avg Tip Qc, tsf	Avg Friction Ratio, %	1 Soil Type	Soil Type	Soil Classification	USC	Density or Consistency	Est. Density (pcf)	Qc to N	SPT N(60)	Cn or Cq	Norm. Qc1n	Est. % Fines	Rel.. Dens. Dr (%)	Nk: Phi (deg.)	17.0 Su (tsf)	OCR
9.30	30.5	22.90	7.51	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.93		100			1.27	6.54
9.45	31.0	20.57	6.23	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.14	5.42
9.60	31.5	19.55	6.90	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.92		100			1.08	4.89
9.75	32.0	23.76	8.37	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.91		100			1.32	6.54
9.90	32.5	24.30	8.05	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.90		100			1.35	6.65
10.05	33.0	22.78	6.54	3	3	Clay	CL/CH	very stiff	125	1.3	18	0.90		100			1.26	5.88
10.20	33.5	21.56	5.91	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.89		100			1.19	5.31
10.38	34.0	20.82	6.40	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.89		100			1.15	4.89
10.53	34.5	21.17	6.04	3	3	Clay	CL/CH	very stiff	125	1.3	17	0.88		100			1.17	4.89
10.68	35.0	24.71	6.05	3	3	Clay	CL/CH	very stiff	125	1.3	20	0.88		100			1.37	6.21
10.83	35.5	23.14	5.91	3	3	Clay	CL/CH	very stiff	125	1.3	19	0.87		100			1.28	5.53
10.98	36.0	19.96	5.21	3	3	Clay	CL/CH	very stiff	125	1.3	16	0.87		100			1.09	4.28
11.13	36.5	19.03	4.88	3	3	Clay	CL/CH	very stiff	125	1.3	15	0.86		100			1.04	3.91
11.28	37.0	16.19	4.33	3	3	Clay	CL/CH	stiff	125	1.3	13	0.86		100			0.87	3.07
11.43	37.5	16.02	5.36	3	3	Clay	CL/CH	stiff	125	1.3	13	0.85		100			0.86	3.00
11.58	38.0	16.15	5.06	3	3	Clay	CL/CH	stiff	125	1.3	13	0.85		100			0.86	3.00
11.73	38.5	17.81	4.75	3	3	Clay	CL/CH	stiff	125	1.3	14	0.85		100			0.96	3.35
11.88	39.0	21.66	4.41	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	0.84		100			1.19	5.65
12.05	39.5	20.18	3.42	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.84		100			1.10	6.65
12.20	40.0	17.00	2.62	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.83		100			0.91	5.00
12.35	40.5	20.64	4.32	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	12	0.83		100			1.12	5.00
12.50	41.0	36.57	3.70	5	5	Clayey Silt to Silty Clay	ML/CL	hard	120	2.5	15	0.82		95			2.06	>10
12.65	41.5	31.64	4.64	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	18	0.82		100			1.77	>10
12.80	42.0	23.58	3.56	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	9	0.82		100			1.29	8.14
12.95	42.5	24.97	3.28	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	10	0.81		100			1.37	8.85
13.10	43.0	19.07	2.71	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.03	5.42
13.25	43.5	18.86	2.98	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.81		100			1.01	5.31
13.40	44.0	19.54	3.20	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.80		100			1.05	5.53
13.58	44.5	19.29	3.97	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.80		100			1.04	3.91
13.73	45.0	19.79	3.86	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.80		100			1.07	4.00
13.88	45.5	17.66	3.31	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.79		100			0.94	4.47
14.03	46.0	16.42	2.18	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.79		100			0.87	3.91
14.18	46.5	15.61	2.35	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	6	0.78		100			0.82	3.58
14.33	47.0	16.68	1.80	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.78	12.3	100	11	29		
14.48	47.5	18.25	1.80	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.78	13.4	100	13	30		
14.63	48.0	19.39	2.43	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.78		100			1.04	4.89
14.78	48.5	19.39	3.87	4	4	Silty Clay to Clay	CL	very stiff	125	1.8	11	0.77		100			1.04	3.58
14.93	49.0	19.13	2.69	5	5	Clayey Silt to Silty Clay	ML/CL	very stiff	120	2.5	8	0.77		100			1.02	4.57
15.10	49.5	16.46	1.59	6	6	Sandy Silt to Clayey Silt	ML	very loose	115	3.5	5	0.77	11.9	100	10	29		
15.25	50.0	16.91	2.83	5	5	Clayey Silt to Silty Clay	ML/CL	stiff	120	2.5	7	0.76		100			0.89	3.74

EEC ORIGINAL PKG

APPENDIX C

EEC ORIGINAL PKG

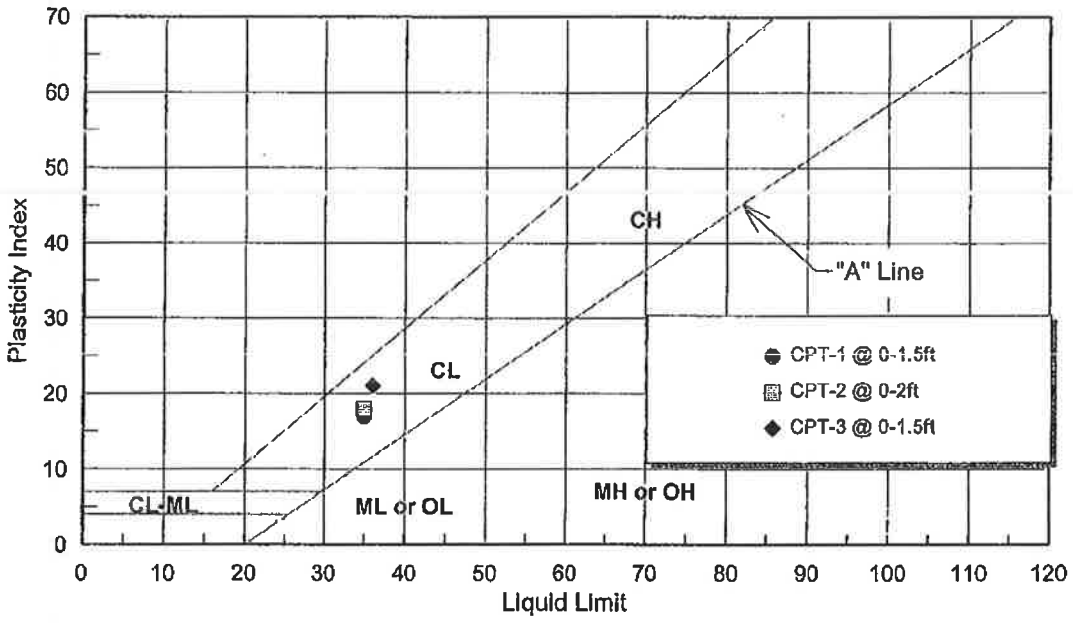
LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

ATTERBERG LIMITS (ASTM D4318)

Sample Location	Sample Depth (ft)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	USCS Classif-ation
CPT-1	0-1.5	35	18	17	CL
CPT-2	0-2	35	17	18	CL
CPT-3	0-1.5	36	15	21	CL

PLASTICITY CHART



LANDMARK
Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Project No: LE04354

Atterberg Limits Test Results

Plate C-1

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

CHEMICAL ANALYSES

Boring:	CPT-1	CPT-1	CPT-2	CPT-2	CalTrans
Sample Depth, ft:	0-1.5	1.5-3	0-2	2-3	Method
pH:	7.9	7.9	7.8	7.9	643
Electrical Conductivity (mmhos):	2.5	1.7	1.8	0.9	424
Resistivity (ohm-cm):	260	1000	300	1000	643
Chloride (Cl), ppm:	3,040	230	1,490	220	422
Sulfate (SO4), ppm:	2,812	3,006	1,500	1,106	417

General Guidelines for Soil Corrosivity

Material Affected	Chemical Agent	Amount in Soil (ppm)	Degree of Corrosivity
Concrete	Soluble Sulfates	0 -1000	Low
		1000 - 2000	Moderate
		2000 - 20,000	Severe
		> 20,000	Very Severe
Normal Grade Steel	Soluble Chlorides	0 - 200	Low
		200 - 700	Moderate
		700 - 1500	Severe
		> 1500	Very Severe
Normal Grade Steel	Resistivity	1-1000	Very Severe
		1000-2000	Severe
		2000-10,000	Moderate
		10,000+	Low

LANDMARK
Géo-Engineers and Geologists
a DBE/MBE/SBE Company

Project No: LE04354

Selected Chemical Analyses Results

Plate C-2

EEC ORIGINAL PKG

LANDMARK CONSULTANTS, INC.

CLIENT: ORMAT
PROJECT: ORMAT Heber 2 Facilities, Heber, CA
JOB NO: LE04354
DATE: 12/28/04

CHEMICAL ANALYSES

Boring:	CPT-3	CPT-3	CalTrans Method
Sample Depth, ft:	0-1.5	1.5-3	
pH:	7.9	7.8	643
Electrical Conductivity (mmhos):	1.5	1.3	424
Resistivity (ohm-cm):	450	1000	643
Chloride (Cl), ppm:	570	210	422
Sulfate (SO4), ppm:	1,785	1,052	417

General Guidelines for Soil Corrosivity

Material Affected	Chemical Agent	Amount in Soil (ppm)	Degree of Corrosivity
Concrete	Soluble Sulfates	0 -1000	Low
		1000 - 2000	Moderate
		2000 - 20,000	Severe
		> 20,000	Very Severe
Normal Grade Steel	Soluble Chlorides	0 - 200	Low
		200 - 700	Moderate
		700 - 1500	Severe
		> 1500	Very Severe
Normal Grade Steel	Resistivity	1-1000	Very Severe
		1000-2000	Severe
		2000-10,000	Moderate
		10,000+	Low

LANDMARK Geo-Engineers and Geologists
a DBE/MBE/SBE Company

Project No: LE04354

Selected Chemical Analyses Results

Plate C-3

EEC ORIGINAL PKG

APPENDIX D

EEC ORIGINAL PKG

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AIR QUALITY ANALYSIS SUMMARY FOR THE ORMAT HEBER 2 GEOTHERMAL REPOWER PROJECT

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PROJECT NO.:	246-2-1
COPIES:	Melissa Wendt, ORMAT Nevada Inc.
DATE:	August 12, 2019

The Second Imperial Geothermal Company (SIGC), a wholly owned subsidiary of ORMAT Nevada Inc. (ORMAT), proposes to replace six existing water-cooled ORMAT Energy Converters (OECs) with two new water-cooled OECs at the Heber 2 Geothermal Energy Complex in Imperial County, CA. The project also entails installing three new 10,000 gallon above ground storage tanks to accommodate additional isopentane. The project will affect volatile organic compound (VOC) air emissions at the facility. The proposed changes are not expected to affect emission rates of other regulated pollutant emissions.

1.0 Project Description

The Heber 2 Complex is a geothermal power generation facility located on private lands owned by SIGC/ORMAT in southern Imperial County. The facility operates under Imperial County Air Pollution Control District (ICAPCD) Permit to Operate (PTO) #2217A-4. Heber 2 currently consists of six Integrated Two-Level Units (ITLU) which have a gross combined power output rating of 36 megawatts. PTO #2217A-4 also covers two adjacent, connected facilities to Heber 2: Goulds 2 and Heber South. These two facilities each consist of one ORMAT Energy Converter (OEC) with gross outputs of 10 and 12 megawatts, respectively. Ancillary equipment for the combined facilities includes cooling towers, an evacuation skid/vapor recovery maintenance unit (VRMU), motive fluid (MF) storage tanks, and diesel engines for emergency use.

The proposed development would occur entirely on Assessor's Parcel Number (APN) 054-250-031, which is a 39.99-acre property. The address for Heber 2 is 855 Dogwood Road, Heber, CA 92249.

1.1 Proposed Development

Development of the proposed project includes the installation of two new OEC units, manufactured by ORMAT, to replace the six existing ITLUs which were also manufactured by ORMAT in 1992. The total disturbance would be approximately 4 acres, entirely within the

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existing Heber 2 site. The existing ITLUs will either be demolished or abandoned in place. The development site is completely devoid of any vegetation and is actively disturbed as part of ongoing energy generation operations at the Heber 2 Complex. Considering its current condition, site preparation for the installation of the proposed facilities would be limited to light excavation and soil compaction.

ORMAT Energy Converter-1 (OEC-1)

The proposed OEC-1 unit is a two-turbine combined cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, vaporizer, water cooled condensers, preheaters and recuperators, with the OEC served by the existing evacuation skid/vapor recovery maintenance unit for purging and maintenance events. The design capacity for the unit is 25.43 MW gross.

ORMAT Energy Converter-2 (OEC-2)

The proposed OEC-2 unit is a two-cycle binary unit, operating on a subcritical Rankine cycle, with isopentane as the motive fluid for the system. This system also consists of a generator, turbines, vaporizers, water cooled condensers and preheaters, with the OEC served by the existing evacuation skid/vapor recovery maintenance unit (VRMU) for purging and maintenance events. The design capacity for the unit is 14.01 MW gross.

Three Additional Isopentane Above Ground Storage Tanks

To support the new OEC units, three new storage tanks for additional isopentane supply would be installed. There are two existing storage tanks at Heber 2 and one at Goulds 2. The new tanks would be sited adjacent to the existing Heber 2 tanks. Each of the new and existing tanks has a capacity of 10,000 gallons.

2.0 Existing Air Emissions

The Heber 2 facility is a minor source of air pollution and operates in compliance with all applicable air quality requirements and its permit to operate (PTO #2217A-4). Air emission sources currently at the facility include the geothermal power generating units, cooling towers, VRMU, and emergency diesel equipment.

The existing power generating units (6 ITLUs and 2 OECs) have a combined gross power generating capacity of 58 megawatts. These units generate power by taking geothermal energy (e.g. heat) to vaporize liquid isopentane, which is the motive fluid that powers the turbines to create electricity.

The primary air pollutant from the facility is isopentane, which is a VOC. Isopentane emissions occur due to maintenance, purging, and fugitive leaks. During maintenance, the unit is shut

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down and the isopentane is evacuated before the system is opened for the necessary work to be performed. To evacuate the system, the liquid isopentane is transferred to storage tanks, and the remaining vapors are passed through the VRMU. The overall recovery rate of isopentane during evacuation is greater than 99.9%. However, trace quantities of vapors as well as liquid collected at low points in the system where the liquid cannot be completely drained result in VOC emissions when the unit is opened to the atmosphere.

Purging is the process by which impurities are removed from the isopentane closed circuit. Contamination of the isopentane causes operating efficiency losses, so purging is performed on a regular basis. Vapors are passed through the VRMU and the isopentane is collected and returned to the system while other gases are removed.

Fugitive losses of isopentane can occur due to failing seals, valves, flanges, etc.

Current permitted emission limits for the facility are provided in Table 1. In addition to isopentane emissions, there are particulate emissions from the cooling towers as well as particulates, NO_X, CO, SO_2, and VOC emissions from the emergency diesel engines. Potential emissions of PM_{10}, $PM_{2.5}$, NO_X, CO, SO_2 and VOCs from the cooling towers and diesel engines, combined, are less than 2 tons per year for each pollutant.

Table 1. Facility-wide Isopentane Emission Limits

Emission Source	Isopentane Emission Limit
1st Quarter (Jan – Mar)	185 lbs/day
2nd Quarter (Apr – Jun)	137 lbs/day
3rd Quarter (Jul – Sep)	137 lbs/day
4th Quarter (Oct – Dec)	218 lbs/day

Emissions are calculated on a quarterly average basis.

3.0 Method for Predicting Emissions for Proposed Development

The proposed changes to the facility do not include changes to the cooling towers or emergency diesel equipment. The only expected change to emissions from the proposed development is the isopentane emissions from the geothermal power generating units (OECs and ITLUs).

Future potential isopentane emissions were estimated based on actual emissions from the facility for the previous two years. Isopentane emissions are related to the size of the system, so emissions were estimated by scaling the previous actual emissions according to the change in MF volume at the facility. The existing six ITLUs and two OECs have a combined volume of 120,000 gallons, and the three MF storage tanks have a total capacity of 30,000 gallons. After the

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proposed development, the combined volume of the existing and new OECs will be 111,000 gallons, and the MF tanks will have 60,000 gallons total capacity.

Maintenance and fugitive emissions were also adjusted for the decreased complexity of the new units. By replacing six smaller units with two larger units, the number of seals, flanges, pumps valves, etc. is reduced significantly. A 50% emission reduction factor was applied to account for the approximately 50% fewer potential sites for leaks and equipment failure.

Isopentane emissions were estimated as follows:

- Maintenance and purging emissions were estimated based on the worst-case quarterly emissions for maintenance and purging from the previous two years. These emission rates were scaled based on the ratio of the future OEC volume (111,000 gallons) to the existing ITLU plus OEC volume (120,000 gallons). Maintenance emissions were then scaled using the 50% reduction factor described above.

- Fugitive emissions were estimated based on the worst-case quarterly emission rate over the last two years, scaled based on the total system capacity of the system including MF tanks (171,000 gallons proposed versus 150,000 existing). Emissions were then scaled with the 50% reduction factor described above.

This emission estimation method is a reasonably conservative estimate (e.g. an overestimation) of future emissions. The new units benefit from improvements in the design and technology that have occurred during the decades since the existing units were constructed. These improvements reduce fugitive leaks as well as emissions during MF evacuation for maintenance but are not accounted for in the emission estimate. Additionally, these new units are expected to have lower emissions because the units they are replacing have higher maintenance requirements due to their age.

4.0 Potential Emissions Summary for Proposed Development

Previous actual isopentane emissions, estimated potential emissions, as well as emission limits in PTO #2217A-4 for the Heber 2 Complex are given below in Table 2. Note that the estimated emissions for the facility after the proposed development remain below the current permitted emission limits. The estimated emissions are reasonably conservative for the reasons described above.

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Table 2. Actual and Potential Emissions for Heber 2 Facility

	Facility Total Emissions	
Isopentane Emissions	**lbs / day**	**tons / year**
Actual Emissions (2017 – 2018)	117.5	14.9
Estimated Potential Emissions	64.5	11.8
Emissions Increase	-52.9	-3.1
Current Permit Limit (varies)	137 - 218	
Proposed Permit Limit (varies)	137 - 202	

The currently permitted isopentane emission limits vary by calendar quarter. In quarters two and three, the limit is 137 pounds per day. In quarters one and four, additional facility maintenance is typically performed, which potentially increase emissions. The current limit for the first quarter is 185 pounds per day and the fourth quarter limit is 218 pounds per day. The proposed reduction in OEC total size from 130,000 to 121,000 will reduce the volume of isopentane that needs to be evacuated for maintenance operations. SIGC is requesting to reduce the isopentane emission limits by an amount equivalent to the reduction in OEC volume (7.5%) for the two quarter with higher maintenance emissions. The proposed limits are 171 and 202 pounds per day for the first and fourth quarters, respectively.

The proposed changes are not expected to affect emissions of other regulated pollutants.

5.0 Air Quality Protection Measures

ORMAT has implemented measures to limit air emissions at Heber 2. These measures include but are not limited to the following:

- A water truck is used on site to control fugitive dust emissions.
- A five mile per hour speed limit at the site further reduces fugitive dust emissions.
- During windy conditions, additional watering is conducted to minimize wind-blown fugitive dust.
- Equipment is operated according to best practices and maintained according to design specifications.
- The OECs and ITLUs are inspected for leaks using specialized leak detection equipment during every shift, and leaks are repaired quickly.

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- Any breakdown resulting in air emissions is reported to ICAPCD and corrected promptly (within 24 hours when possible).
- The VRMU is tested annually to confirm proper function and high isopentane recovery rates.

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ORMAT, HEBER 2
GEOTHERMAL POWER GENERATION FACILITY
HEBER, CALIFORNIA

Hazard Assessment for Heber 2 Expansion Project

Revision	Date	Description
0.0	July 10, 2019	Initial Issue

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1.0 FACILITY OVERVIEW

This technical assessment was conducted to fulfill the Hazard Assessments Offsite Consequence Analysis (OCA) requirements of the following regulations:

- 40 CFR §68.65 – Environmental Protection Agency (EPA) "Risk Management Plan (RMP)"[1]
- 19 CCR 2750.1 to 2750.9 – California Code of Regulation "California Accidental Release Prevention (CalARP) Program"[2]

This assessment is completed for the **Ormat – Heber 2 Geothermal Complex** Facility located in Heber, California. The facilitie's location at 885 Dogwood Road, Heber, CA 92249 is illustrated in Figure 1 below. The yellow marker depicts the location of the three 10,000 gallon isopentane vessels.



Figure 1: Aerial View of the Facility Location

COVERED PROCESS	FORMAT	LATITUDE	LONGITUDE
Isopentane Vessel 1	Degrees/Minutes/Seconds	32°42'51.20"N	115°32'10.47"W
Isopentane Vessel 2	Degrees/Minutes/Seconds	32°42'51.38"N	115°32'10.44"W

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Isopentane Vessel 3	Degrees/Minutes/Seconds	32°42'51.56"N	115°32'10.43"W

2.0 COVERED PROCESS

The ***Ormat – Heber 2 Geothermal Complex*** has three geothermal electrical generating plants in Heber, CA operated by Ormat Nevada, Inc. Heber 2 consists of the H2, Gould-2 (G-2), and Heber South binary processes. The projects use the renewable geothermal resources of the Heber Known Geothermal Resource Area (KGRA) to generate electrical power.

The Heber 2 Geothermal Project produces electricity by using a vaporized motive fluid to spin a turbine connected to a generator. In the H2 binary processes, isopentane is the motive fluid.

The covered processes at the facility are listed below.

Table 1: Ormat—Heber 2 Geothermal Complex Facility Covered Process

PLANT	REGULATED SUBSTANCE	INVENTORY IN SINGLE VESSEL (LBS.)	TANK TYPE	LARGEST STORAGE INVENTORY
Heber 2	Isopentane	51,400	Storage	10,000 gallon tank

This hazard assessment will focus on the regulated substance, isopentane, in Heber 2. The facility is classified as Prevention Program 3 and is regulated by the Environmental Protection Agency's Risk Management Program (EPA RMP) for Chemical Accidental Release Prevention in accordance with the Code of Federal Regulations, Title 40, Chapter I, Subchapter C, Part 68, Subpart B Sections 68.20 to 68.42 (40 CFR §68.20 - 68.42)[1] for isopentane, because it is held on site in excess of 10,000 lbs. The unit is a geothermal power plant and utilizes isopentane as the motive fluid in the generation of electricity.

3.0 LEVEL OF CONCERN

To address potential health effects for the worst-case release scenario, the following are the key endpoints of concern for the EPA RMP as defined in Title 40 CFR Section 68.22(2):

(i) Explosion. An overpressure of 1 psi.

(ii) Radiant heat/exposure time. A radiant heat of 5 kW/m^2 for 40 seconds.

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(iii) Lower flammability limit. A lower flammability limit as provided in NFPA documents or other generally recognized sources.

The distance from the point of release to the endpoint identified above defines a radius circle of concern for which consequences are reported in the Risk Management Plan.

4.0 WORST-CASE SCENARIO

The US EPA RMP determines the worst-case release quantity in Title 40 CFR Part 68.25(b) as follows:

> *The worst-case release quantity shall be the greater of the following:*
>
> *(1) For substances in a vessel, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity;*
>
> *(2) For substances in pipes, the greatest amount in a pipe, taking into account administrative controls that limit the maximum quantity.*

Given the substance released is a flammable, the US EPA RMP gives further guidelines in 68.25 (f):

> *Worst-Case scenario-flammable liquids. The owner or operator shall assume that the quantity of the substance, as determined under paragraph (b) of this section and the provisions below, vaporizes resulting in a vapor cloud explosion. A yield factor of 10 percent of the available energy released in the explosion shall be used to determine the distance to the explosion endpoint if the model used is based on TNT equivalent methods.*
>
> *(1) For regulated flammable substances that are normally liquids at ambient temperature, the owner or operator shall assume that the entire quantity in the vessel or pipe as determined under paragraph (b) of this section, is spilled instantaneously to form a liquid pool. For liquids at temperatures below their atmospheric boiling point, the volatilization rate shall be calculated at the condition specified in paragraph (d) of this section.*
>
> *(2) The owner or operator shall assume that the quantity which becomes vapor in the first 10 minutes is involved in the vapor cloud explosion.*

Normally, to develop the worst-case scenario, the covered process is reviewed and a suitable worst-case release analysis is identified through a review of vessels and storage tanks to

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determine the single vessel with the largest quantity of the regulated substance. However, in this particular Hazard Assessment, the worst-case scenario instead analyzes a release from one of the three new 10,000 gallon isopentane storage vessels. This updated Hazard Assessment was performed to account for the modifications made to Heber 2 as part of the facility's expansion project, and thus, an exclusive examination of the three new 10,000 gallon storage vessels was performed rather than a review of the entire facility.

The 10,000 gallon isopentane storage vessel located closest to the residential neighborhood northeast of the plant was examined as a representative sample for the worst-case release scenario since this vessel has the largest potential to impact the community. EPA's RMP*Comp[3] modeling software was used to determine the distance to the endpoint for the worst-case release scenario analysis. The vulnerability zone resulting from this analysis was then reviewed. A vulnerability zone is defined as a circle whose center is the point of release and its radius is the length of the endpoint, which is predicted by the dispersion model (e.g., RMP*Comp).

4.1 Worst-Case Scenario Selection Process

The process of worst-case release scenario identification is summarized as follows. Figure 2 on the following page depicts the steps in this process.

- **Inventory Calculation**: The first step was to perform the inventory calculations for the 10,000 gallon storage vessels in the covered units and systems.
- **Screening Analysis**: The 10,000 gallon isopentane storage vessels' location was screened, and the single vessel that had the greatest potential to impact the community was selected for analysis. Once this vessel was identified, RMP*Comp was used to model the scenarios and determine the dispersion endpoints for the worst-case release scenarios. This was performed to determine the vulnerability zone associated with the worst-case release scenarios.
- **Review of the Vulnerability Zone**: The vulnerability zone resulting from the previous step was reviewed and is representative for the plant's worst-case scenario.
- **Worst-Case Analysis**: To document the worst-case scenario, the potential public receptors within the vulnerability zone were identified. All modeling inputs, calculations and assumptions are documented.

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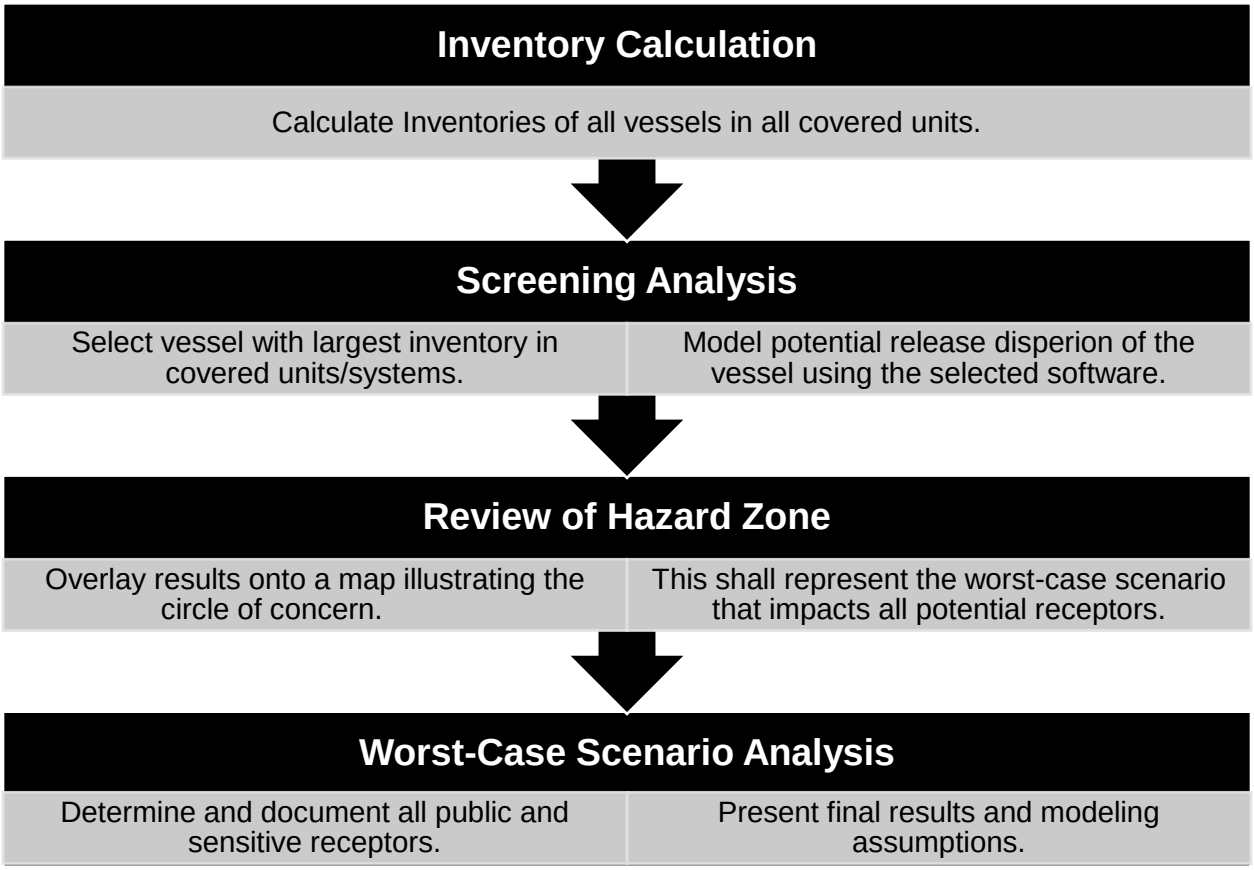

Figure 2: Worst-Case Scenario Selection Process

4.2 Flammable Release Potential Consequences

Several possible consequences of releases of flammable substances are discussed below. It should be noted that the following possible consequences apply to not only worst-case release analysis.

- **Flash Fire**. This event may result from dispersion of a flammable vapor cloud and ignition of the cloud following dispersion. Such a fire could flash back and could represent a severe heat radiation hazard to anyone in the area of the cloud. The lower flammability limit (LFL) endpoint, specified in the rule, would be appropriate for flash fires (vapor cloud fires).
- **Pool Fire**. Spill of a liquid whose boiling point is above ambient temperature may form a liquid pool, which could ignite and form a pool fire. The applicable endpoint specified in the rule is the heat radiation level of 5 kW/m^2.

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- **BLEVE.** A BLEVE (Boiling Liquid Expanding Vapor Explosion) is a potential release scenario associated with a large quantity of flammable materials kept at below their boiling points. A BLEVE that may lead to a fireball could produce intense heat. This event may occur if a vessel containing flammable material ruptures as a result of exposure to fire. Heat radiation from the fireball is the primary hazard and vessel fragments and overpressure from the explosion are generally considered unlikely. To estimate the distance to a radiant heat level that can cause second degree burns (a heat "dose" equivalent to the specified radiant heat endpoint of 5 kW/m^2 for 40 seconds). Consistent with the EPA's "Risk Management Program Guidance for Offsite Consequence Analysis" published guidance, BLEVEs are generally considered unlikely events and were therefore not considered a probable event for the Offsite Consequence Analysis.
- **Vapor Cloud Explosion.** For a vapor cloud explosion to occur, rapid release of a large quantity, turbulent conditions (caused by a turbulent release or congested conditions in the area of the release, or both), and other factors are generally necessary. The endpoint for vapor cloud explosions is 1 psi.
- **Jet Fire.** This may result from the puncture or rupture of a tank or pipeline containing a compressed or liquefied gas under pressure. The gas discharging from the hole can form a jet that "blows" into the air in the direction away from the hole; the jet then may ignite. Jet fires could contribute to BLEVEs and fireballs if they impinge on tanks of flammable substances. A large horizontal jet fire may have the potential to pose an offsite hazard.

For the flammable worst-case release scenario, a vapor cloud explosion was the most appropriate consequence.

4.3 Endpoints

As mentioned previously, for flammable materials, the endpoints specified by the EPA RMP are:

- Overpressure of 1 pound per square inch (psi) for vapor cloud explosions
- Radiant heat of 5 kilowatts per square meter (kW/m^2) for jet fires
- Lower flammability limit (LFL) for flash fires

The rule specifies endpoints for fires based on the heat radiation level that may cause second degree burns from a 40-second exposure and the LFL, which is the lowest concentration in air at which a substance will burn. For a vapor cloud explosion, the endpoint is 1 psi, which is the force

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to cause partial demolition of houses with potential serious injuries to people, or shattering glass windows with potential skin laceration from flying glass.

4.4 Modeling Assumptions

The EPA RMP regulation imposes several assumptions that were adhered to when performing the offsite consequence analysis of the worst-case release scenario[4]. These are conservative assumptions for weather and release conditions. The distance to the endpoint estimated under worst-case conditions provides an estimate for the maximum possible area that might be affected by these unlikely conditions. It should be noted that EPA's intention for the vulnerability zone representing a worst-case release scenario is to provide a basis for discussion among the regulated industry, emergency responders, and the public, rather than a basis for any specific actions.

- **Meteorological Parameters:** For the worst-case release analysis, RMP*Comp uses the following assumptions. It should be noted that meteorological conditions could have little effect on some scenarios for flammable substances (e.g., vapor cloud explosions).
    - *Atmospheric stability*: F stability (very stable conditions)
    - *Wind speed:* 1.5 meters/second
    - *Ambient Temperature:* 77 ^{o}F
    - *Relative Humidity*: The typical relative humidity at the stationary source, which is 50%
- **Dispersion & Impact Modeling Parameters:**
    - *Height of Release:* Ground level, per EPA Rule requirement
    - *Vapor Cloud Explosion Impact:* A TNT-equivalent model has been used assuming that 10 percent of the energy in the cloud would contribute to the explosion
- **Mitigation Systems:** Once a release has occurred, mitigation systems are means (structures, equipment, or activities) that help minimize the transport of material to the atmosphere. Mitigation systems can be characterized as passive or active systems.
    - *Passive mitigation systems do not require activation, an energy source, or movement of components to perform their intended function*

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- *Active mitigation systems do require activation, an energy source, and/or movement of components to perform their intended function*

It should be emphasized that the effectiveness of mitigation systems was taken into account when these systems were considered in the offsite consequence analysis. The effectiveness is determined based on how well the systems are designed and their abilities to respond reliably upon demand. The rule permits consideration of only passive mitigation systems for the worst-case release analysis provided that the systems are capable of withstanding the event triggering the release scenario and would still function as intended. For the worst-case release scenario, no passive mitigation measures were considered in the offsite consequence analysis.

4.5 Worst-Case Release Scenario

One worst-case scenario (WCS) was developed for the facility. For the worst-case release scenario, one of the new 10,000 gallon storage vessels containing isopentane at the Ormat – Heber 2 Geothermal Complex Facility was considered. The storage vessel is capable of storing a maximum of 10,000 gallons of isopentane. According to the Chevron Philips Chemical Company safety data sheet, the density of isopentane is 5.14 lbs/gal, which yields a total mass of 51,400 pounds of isopentane held in the storage vessel. The worst case scenario considers the catastrophic failure of one of the 10,000 gallon isopentane storage vessels, which would result in a release of the entire contents of the vessel. All dispersion modeling parameters utilized in the worst-case release scenario modeling is listed in Table 2 below. A summary of the scenario is presented in Table 3. Appendix A of this report provides a detailed description of the worst-case release scenario, RMP*Comp modeling output, MARPLOT 5.1.1[5] output with 2010 population estimates, and a map with the vulnerability zone denoted by a circle superimposed on the map.

Table 2: Worst Case Release Scenario Dispersion Modeling Parameters

PARAMETER	INPUT VALUE	NOTES
Isopentane Input Parameters		
Mass Released	51,400 lbs	Calculations shown in Appendix A.
Meteorological Parameters		

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PARAMETER	INPUT VALUE	NOTES
Atmospheric Stability	F stability	As per 40 CFR §68.22 (b), "For the worst-case release analysis, the owner or operator shall use a wind speed of 1.5 meters per second and F atmospheric stability class"
Wind Speed	1.5 m/s	
Ambient Temperature	77ºF	As per 40 CFR §68.22 (c), "An owner or operator using the RMP Offsite Consequence Analysis Guidance may use 25 °C and 50 percent humidity as values for these variables"
Relative Humidity	50%	
Dispersion and Impact Modeling Parameters		
Height of Release	Ground level	
Topography	N/A	Topography is not applicable to releases of flammable substances as it does not affect the radius impacted by a vapor cloud explosion.
Isopentane Mitigation System		
Passive Mitigation	None	
Active Mitigation	None	

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Table 3: Worst-Case Scenario Results Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
WCS: 10,000 gallon Isopentane Storage Vessel Rupture/Release	Isopentane	Overpressure of 1 psi	0.3 miles

4.6 Worst-Case Analysis Considerations

The worst-case distances to the flammable endpoints are based on a number of very conservative assumptions. The following summarizes the assumptions:

- The likelihood of a vessel rupture is extremely low. As a result, the release of entire inventory of a vessel is an unrealistic assumption.
- An overpressure of 1 psi is unlikely to have serious direct effects on people. This overpressure may cause property damage such as partial demolition of houses, which can result in injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

5.0 ALTERNATIVE RELEASE SCENARIO

Alternative scenarios are potential releases that may result in consequences whose footprints represented by the endpoints could extend beyond the plant boundary. For a release case to be considered an alternative scenario, two conditions must be met:

1. The likelihood of the alternative release scenarios should be higher than that of the worst-case release scenarios.
2. The distance to endpoint from an alternative release scenario must go beyond the plant fence line.

As put forth in Title 40 CFR Section 68.28(a):

> *The owner or operator shall identify and analyze…at least one alternative release scenario to represent all flammable substances held in a covered process*

Title 40 CFR Section 68.28 (b)(2) defines the scenarios typically considered, but not limited to, the following:

> *(i) Transfer hose releases due to splits or sudden hose uncoupling;*

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(ii) Process piping releases from failures at flanges, joints, welds, valves and valve seals, and drains or bleeds

(iii) Process vessel or pump release due to cracks, seal failure, or drain, bleed, or plug failure; and

(iv) Vessel overfilling and spill, or over pressurization and venting through relief valves or rupture disks.

(v) Shipping container mishandling and breakage or puncturing leading to a spill.

For alternative release scenarios, active mitigation systems, such as interlocks, shutdown systems, pressure relieving devices, flares, emergency isolation systems, and fire water and deluge systems, as well as passive mitigation systems are considered, if they were applicable. In order to be credited, the mitigation systems considered must be capable of withstanding the event that triggers the release while remaining functional.

5.1 Alternative Release Scenario Selection Process

The process of alternative release scenario identification is summarized as follows and depicted in Figure 3.

- **Selection of Candidate Alternative Release Scenario:** The process of alternative release scenario identification was initiated with the review of the worst-case release case. Additional vessels, containing various quantities of regulated substances, which considered having a higher likelihood of release, were then reviewed. In this process, all covered processes were reviewed and the candidate case for the alternative release scenario analysis was subsequently selected. The following criteria was utilized to identify the potential scenario:
    - Corrosion history and corrosive services
    - Past incidents and near misses
    - Potential equipment failure
    - Operating conditions
    - Potential for human error
    - Consequences considered in the unit Process Hazard Analysis
- **Analysis of the Selected Alternative Release Scenario:** Once the candidate scenario was selected, RMP*Comp was utilized to model the selected scenario. The vulnerability zone resulting from the analysis of the alternative release scenario was then reviewed. The size of release, which was estimated from a hole in the shaft seal on a vertical pump,

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was calculated for this scenario. The release duration was primarily based on the length of time needed for operators to stop the release. In general, 10 minutes is a reasonable response time to stop the release based on the presence of monitoring equipment in the vicinity which notify operators of any substantial releases

- **Alternative Release Scenario**: The alternative release scenario for the flammable substance was selected and modeled to evaluate potential offsite impacts. Documentation of this scenario included modeling calculations, parameters and assumptions.

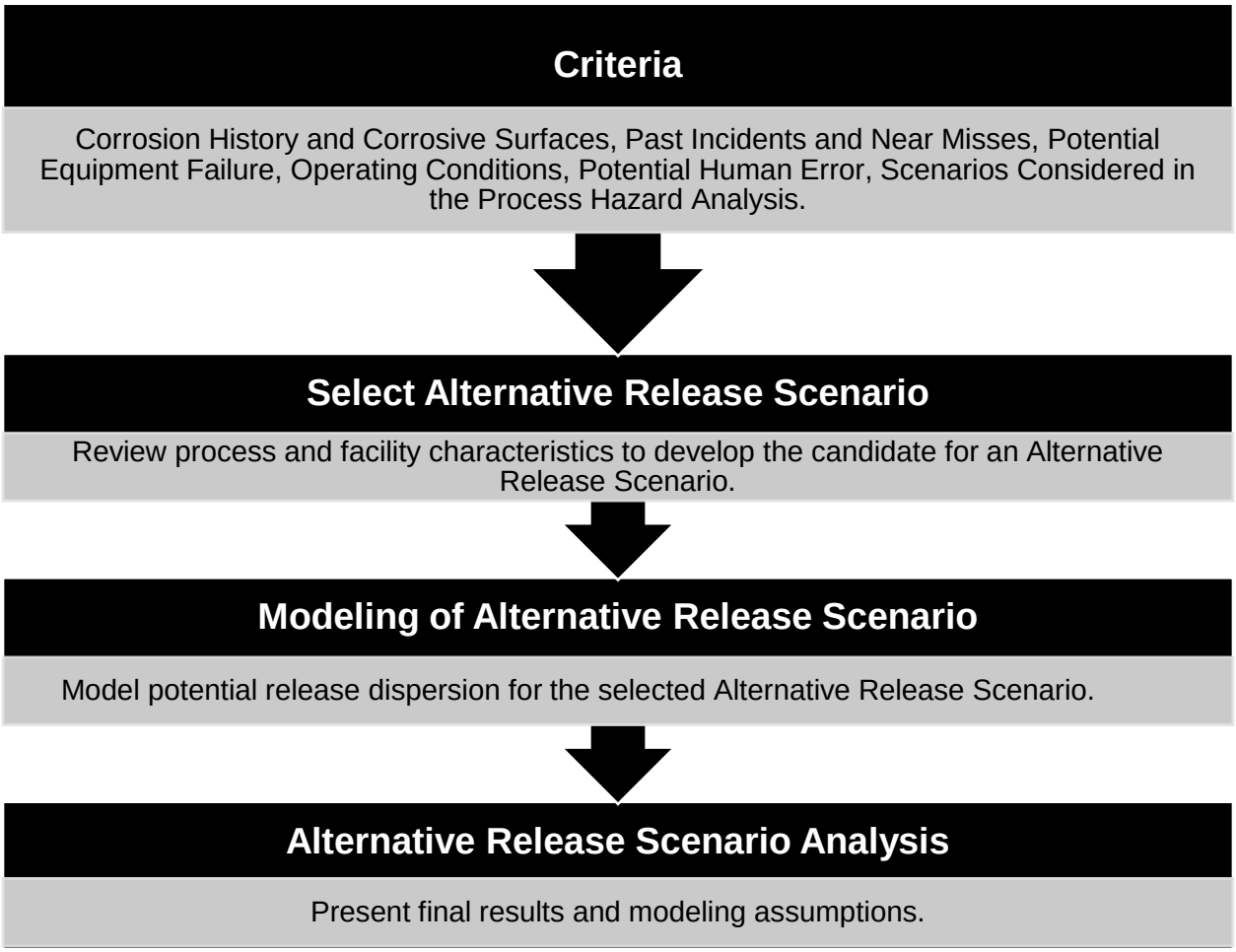

Figure 3: Alternative Release Scenario Selection Process

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5.2 Modeling Assumptions

The EPA RMP regulation does not impose any mandatory assumptions for the OCA of the alternative release scenario. All dispersion modeling parameters utilized in the alternative release scenario modeling are listed in Table 4. For the alternative release scenario, a release due to a break in the product transfer hose connection during truck loading has been considered. Appendix B of this report provides a detailed description of the worst-case release scenario, RMP*Comp modeling output, MARPLOT 5.1.1 output with 2010 population estimates, and a map with the vulnerability zone denoted by a circle superimposed on the map.

Table 4: Alternative Release Scenario Dispersion Modeling Parameters

Parameter	Input Value	Notes
Isopentane Input Parameters		
Quantity Released	38,733 lbs	The most likely alternative release scenario involves the uncoupling of a transfer hose during truck loading operations. Calculations shown in Appendix B.
Release Rate	3,873.3 lbs/min	Calculations shown in Appendix B.
Release Duration	10 mins	The reasonable, assumed response time operators require to stop and isolate the leak.
Meteorological Parameters		
Atmospheric Stability	D stability	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, “this guidance assumes wind speed of 3 meters per second and D stability”
Wind Speed	3.0 m/s	
Ambient Temperature	77ºF	

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Parameter	Input Value	Notes
Relative Humidity	50%	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, "this guidance assumes 25ºC and 50 percent humidity"
Dispersion and Impact Modeling Parameters		
Height of Release	Ground Level	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, "this guidance assumes a ground-level release"
Topography	N/A	Topography is not applicable to releases of flammable substances as it does not affect the radius impacted by a vapor cloud explosion.
Isopentane Mitigation System		
Passive Mitigation	None	
Active Mitigation	None	

5.3 Alternative Release Scenario

A summary of the alternative release scenario is presented in Table 5. Appendix B of this report provides a detailed description of the alternative release scenarios, RMP*Comp modeling outputs, MARPLOT 5.1.1 outputs with 2010 population estimates, and a map with circles representing the vulnerability zones.

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Table 5: Alternative Release Scenario Result Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
ARS: Transfer Hose uncoupling from 10,000 gallon Isopentane Storage Vessel during Truck Loading Operations	Isopentane	Overpressure of 1 psi	0.1 miles

5.4 Alternative Release Analysis Considerations

Typically, the same conservative assumptions apply for the alternative release analysis as for the worst-case release analysis. Although the alternative release scenario is intended to be more likely than the worst-case release scenario, the analysis of the alternative release scenario should not be expected to provide a realistic estimate of an area in which off-site impact may occur. The same conservative endpoints have been used for both the worst-case and the alternative release analysis. These endpoints are intended to represent exposure levels below which most members of the public will not experience serious long-term health effects.

6.0 OFFSITE IMPACTS

A summary of the off-site impacts from an accidental release, including population and sensitive receptors, is discussed in the following sub-sections.

6.1 Impacted Population

In order to determine the impacted population around the facility, the potential for exposure within the endpoint was determined. The furthest endpoint distances reached by the worst-case scenario and alternative release scenario along with the estimated impacted population are summarized in Table 8:

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Table 6: Impacted Population for OCA Scenarios

SCENARIO	ENDPOINT DISTANCE (MILES)	ESTIMATED IMPACTED POPULATION
WCS: 10,000 gallon Isopentane Storage Vessel Rupture/Release	0.3	0
ARS: Transfer Hose uncoupling from 10,000 gallon Isopentane Storage Vessel during Truck Loading Operations	0.1	0

The population was estimated using 2010 census tract data with the MARPLOT 5.1.1 software. When calculating population densities for large areas that encompass many tracts, the accuracy is rated as good; however, for small areas that encompass only two or three partial tracts, the population data may be skewed due to the unequal distribution within the tract. The use of MARPLOT 5.1.1 is pursuant to guidance endorsed by the US EPA. MARPLOT 5.1.1 requires the latitude and longitude of the facility in order to calculate the population. The latitude and longitude were estimated using Google Earth GPS[6] software and an aerial photo.

6.2 Offsite Sensitive Receptor Data Sources

Table 9 includes a list of websites and software used to locate offsite sensitive receptors. A few sites will perform a distance search in order to determine the eligibility of a possible receptor. For all other sites, a map interpolation determines whether the receptor falls within the circle of concern.

Table 7: Websites and Software Used

SOURCE	RECEPTORS THIS SOURCE IS USED TO IDENTIFY	METHOD OF DETERMINING ELIGIBILITY
maps.google.com[7]	Used to identify all receptors	Distance search in conjunction with a map interpolation
Google Earth	This mapping software is used to locate all receptors. It also	Software will map the location of the receptor.

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	incorporates an internet search with the map to locate businesses.	

6.3 Offsite Sensitive Receptors

RMP requirements state that sensitive populations such as schools, hospitals, day-care centers, long-term health care facilities, prisons, residential areas, public use parks/recreational areas, and major commercial facilities, located within the "at risk" area must be identified. These sensitive populations include individuals who could not remove themselves from the exposure area without assistance. The sensitive populations also include industrial installations which may have a hazardous process that cannot be immediately left unattended. Table 8 shows a summary of offsite population receptors and offsite environmental receptors for isopentane, within the circle of concern as determined by the worst-case and alternative release scenarios.

Table 8: Summary of Sensitive and Environmental Receptors

RECEPTOR	WCS (0.3 MI)	ARS (0.1 MI)
Population Receptors		
Schools	No	No
Residences	No	No
Hospitals	No	No
Prisons/Correction Facilities	No	No
Recreation Areas	No	No
Major Commercial, Office, or Industrial Areas	No	No
Child Daycare	No	No
Long-term Health Care (e.g., convalescent homes)	No	No

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RECEPTOR	WCS (0.3 MI)	ARS (0.1 MI)
Other (Government Buildings)	No	No
Environmental Receptors		
National or State Parks, Forests, or Monuments	No	No
Officially Designated Wildlife Sanctuaries, Preserves, or Refuges	No	No
Federal Wilderness Areas	No	No
Other (Landmark & Indian Reservations)	No	No

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7.0 WORST-CASE RELEASE AND ALTERNATIVE RELEASE SCENARIOS

The following sections outlines a summary of the parameters used for the one worst case release scenario and the one alternative release scenario analyzed for the Heber 2 expansion project.

7.1 Worst-Case Scenario

The worst-case scenario evaluated the release of the entire contents of one of the new 10,000 gallon isopentane storage vessels, containing 51,400 pounds of isopentane. The following table provides a summary of the parameters used for the worst-case scenario and the corresponding inputs.

Table 9: Worst-Case Scenario Parameter/Input Summary

Worst-Case Scenario	
Chemical	Isopentane
Model Used	EPA's RMP*Comp™
Scenario	Vapor Cloud Explosion
Quantity Released (lbs)	51,400 lbs
Endpoint Used	Overpressure of 1 psi
Distance to Endpoint (miles)	0.3
Estimated Residential Population within Distance to Endpoint (numbers)	0
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No

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Worst-Case Scenario	
Other	Local Roads/Highways and Agricultural Land
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Blast Walls	No
Other	No

7.2 Alternative Release Scenario

It was determined that a release due to a break in the isopentane transfer hose connection during truck loading, was the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. The following table provides a summary of the parameters that were used for alternative release scenario and the corresponding inputs.

Table 10: Worst-Case Scenario Parameter/Input Summary

Alternative Release Scenario	
Chemical	Isopentane
Model Used	EPA's RMP*Comp™
Scenario	Vapor Cloud Explosion
Quantity Released (lbs)	38,733
Endpoint Used	1 psi
Distance to Endpoint (miles)	0.1

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Alternative Release Scenario	
Estimated Residential Population within Distance to Endpoint (numbers)	0
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No
Other	Local Roads/Highways and Agricultural Land
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Blast Walls	No
Other	No
Active Mitigation Considered	
Sprinkler Systems	No
Deluge Systems	No
Water Curtain	No
Excess Flow Valve	No
Other	No

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Alternative Release Scenario

8.0 FIVE YEAR ACCIDENT HISTORY

There have been no applicable CalARP/RMP/PSM releases of isopentane at the facility within the last five years, therefore, this section is not applicable.

9.0 REFERENCES

1. Code of Federal Regulations (CFR), Title 40, Chapter I, Subchapter C, Part 68, Subpart B, Sections 68.20 to 68.42, “Hazard Assessment”; 2015, January 1.
2. California Code of Regulations (CCR), Title 19, Division 2, Chapter 4.5, Article 4, Sections 2750.1 to 2750.9, “Hazard Assessment”; 2015, January 1.
3. RMP*Comp™ Version 2.01, U.S. Environmental Protection Agency, February 2012. https://cdxnodengn.epa.gov/cdx-rmp-maintain/action/rmp-comp.
4. Risk Management Program Guidance for Offsite Consequence Analysis, U.S. Environmental Protection Agency, March 2009.
5. MARPLOT® 5.1.1 Mapping Software (internet download), National Oceanic and Atmospheric Administration and U.S. Environmental Protection Agency. http://www.epa.gov/osweroe1/content/cameo/marplot.htm. October 2015
6. Google ™ Earth, version 7.3.2.5776, Google, Inc. (2019)
7. Google ™ Maps, Google, Inc. (2019)

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APPENDIX A
WORST-CASE SCENARIO CALCULATIONS

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WORST-CASE SCENARIO (WCS)

The selected worst-case release scenario analyzes the hypothetical rupture of the 10,000 gallon isopentane vessel 3 introduced as part of the Heber 2 facility's expansion project. The vessel being analyzed can store up to 51,400 pounds of isopentane. Additionally, this vessel is located closest to the residential neighborhood northeast of the plant, and therefore the vessel with the largest potential to impact the community. Per requirement of the EPA rule for flammable substances, it was assumed that the whole quantity is instantaneously released.

The scenario also assumes that the cloud is ignited with a delay, under which the impact is higher than an immediate ignition. The delayed ignition would allow the air to get entrained in the cloud and form a larger and well-mixed explosive vapor cloud. If this vapor cloud ignited, the resultant blast could generate overpressure damage. A TNT-equivalent model has been used assuming that 10 percent of the energy in the cloud would contribute to the explosion, as required by the EPA Rule.

The RMP*Comp Model calculation predicts that the area impacted by the endpoint, which is an overpressure of 1 psi, is a circle with approximately 0.3 mile radius. According to MARPLOT 5.1.1 using 2010 census data, there are 0 residents in 0 housing units within this vulnerability zone for all three vessels and thus only one is shown below for representation. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the RMP*Comp modeling output, as well as the MARPLOT results.

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Table 11: WCS Modeling Parameters

WCS Modeling Parameters	
Regulated Substance	Isopentane
Vessel	Isopentane Storage Vessel
Latitude / Longitude	32°42'51.56"N / 115°32'10.43"W
Physical State	Liquefied Gas Under Pressure
Basis Of Results	RMP*Comp Version 1.07
Scenario	Vapor Cloud Explosion
Quantity Released	51,400 Pounds
Release Rate	Instantaneous
Release Duration	Instantaneous
Wind Speed & Stability Class	1.5 m/s & F Stability
Topography	N/A
Distance to Endpoint	0.3 Miles to 1 psi Overpressure
Public & Environmental Receptors	0 Residents, 0 Housing Units
Passive Mitigation Considered	None

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Figure 4: WCS EPA RMP*Comp Modeling Results

Estimated Distance Calculation

Estimated distance to 1 psi overpressure: 0.3 miles (0.5 kilometers)

This is the distance to the overpressure endpoint of 1 pound per square inch specified for this regulated substance under the RMP Rule.

Scenario Summary

Chemical:	Isopentane [Butane, 2-methyl-]
CAS number:	78-78-4
Threat type:	Flammable Liquid
Scenario type:	Worst-case
Quantity released:	51400 pounds
Release type:	Vapor Cloud Explosion
Liquid temperature:	77 F
Mitigation measures:	NONE
Release rate to outside air:	7960 pounds per minute
Quantity evaporated in 10 minutes:	51400.0 pounds

Assumptions about this scenario

Wind speed:	1.5 meters/second (3.4 miles/hour)
Stability class:	F
Air temperature:	77 degrees F (25 degrees C)

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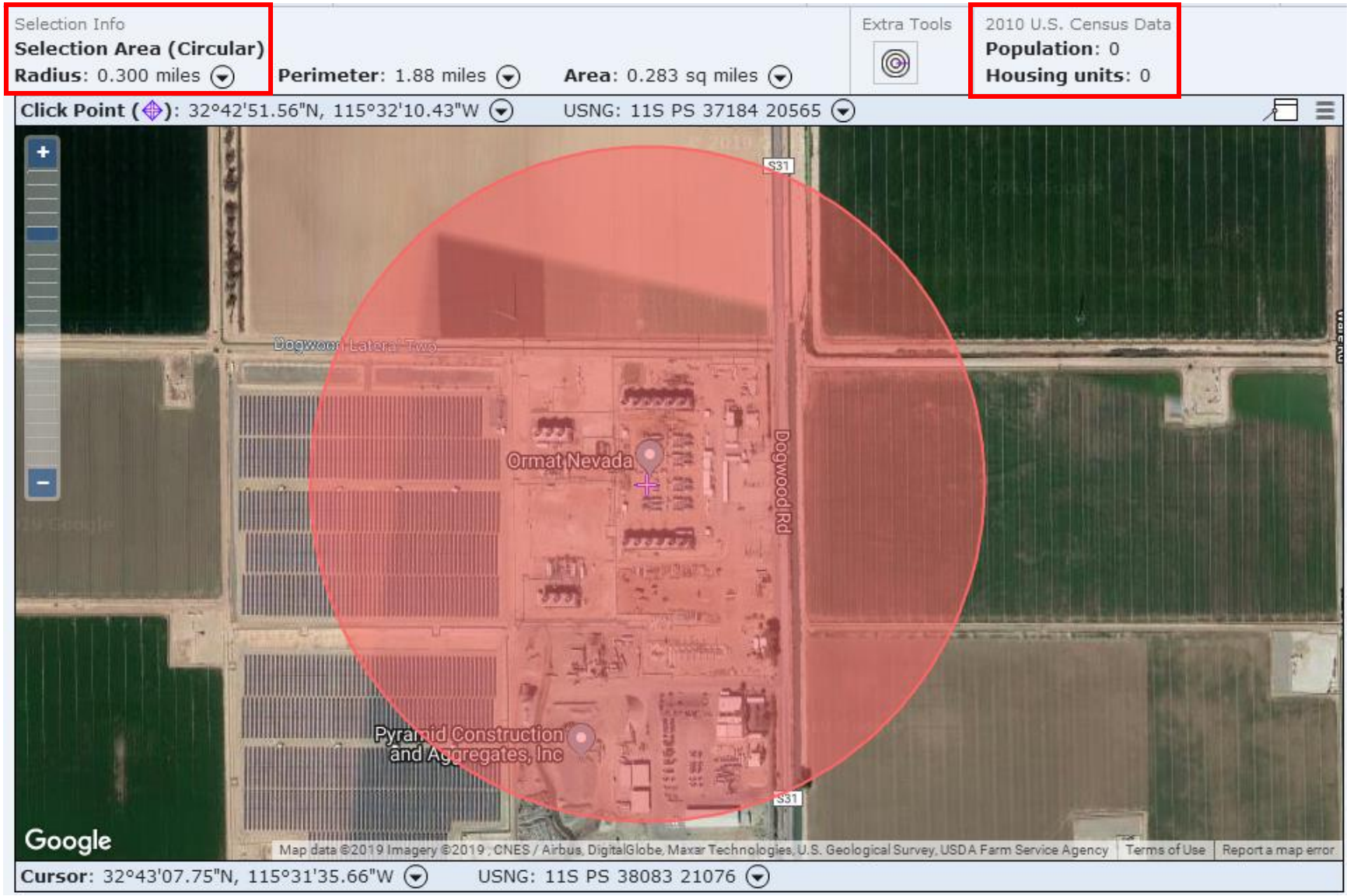
Figure 5: WCS MARPLOT 5.1.1 Population Estimates



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APPENDIX B
ALTERNATIVE SCENARIO CALCULATIONS

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ALTERNATIVE RELEASE SCENARIO (ARS)

The selected alternative release scenario is a release due to a break in the product (isopentane) transfer hose connection during truck loading. This was considered the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. It is assumed that the transfer hose uncouples during isopentane transfer operations and that it is released through an area of 12.6 square inches. The release duration is assumed to be 10 minutes, which is a conservative assumption considering both the facility operator and truck drivers are in attendance during transfer operations. In the evaluations of this alternative release scenario, no mitigation measures were considered.

In order to calculate the release quantity for a transfer hose rupture, the release rate through the transfer hose must be calculated. The following equation, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis, illustrates the calculation of the release rate for flammables liquefied under pressure through a transfer hose:

$$\mathrm{QR} = \mathrm{HA} \times 6.82 \sqrt{\left(\frac{11.7}{DF^2} \times LH + \frac{669}{DF} + P_g \right)}$$

Where:

- QR = Release rate (lb/min)
- HA = Hole or puncture area (square inches)
- DF = Density Factor, dimensionless, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis
- LH = Height of liquid level above hole (inches)
- P_g = Gauge pressure of the tank (psig)

To calculate the release rate utilizing the above equation, the values for each of the variables were calculated for isopentane:

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Hole Area

The transfer hose used in isopentane filling operations at both plants is 4 inches in diameter. Thus, the hole area is based upon the transfer hose rupturing and calculated using the following:

$$HA = \pi r^2 = 12.6 \text{ in}^2$$

Density Factor

The Density Factors are obtained from Appendix C of the EPA Risk Management Plan Guidance for Offsite Consequence Analysis. The Density Factor value for isopentane is 0.79.

Liquid Height

The height of the liquid level above the hole is determined by the nominal liquid level in the vessel. The isopentane transfer point is taken to be at the bottom of the tank. Assuming that the isopentane storage vessel is full of liquid, the liquid height is 60 inches.

Pressure

The normal operating pressure of the isopentane motive fluid storage tank was identified to be 60 psig.

Modeling

Using these values, the release rate of 3873.3 lbs/min of isopentane is determined. Over the assumed 10 minute release period, this result in a total of 38,733 lbs of isopentane releasing that could potentially form a vapor cloud with the possibility of detonation.

The RMP*Comp Model calculation predicts that the area impacted by the endpoint, which is overpressure of 1 psi, is a circle with approximately a 0.10 mile radius. According to MARPLOT 5.1.1 using 2010 census data, there are 0 residents in 0 housing units within this vulnerability zone. This analysis was performed on the isopentane vessel 3 which is located closest to the residential neighborhood northeast of the plant, and therefore the vessel with the largest potential to impact the community. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the RMP*Comp modeling output, as well as the MARPLOT results.

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Table 12: ARS Modeling Parameters

ARS Modeling Parameters	
Regulated Substance	Isopentane
Vessel	Isopentane Storage Vessel
Unit & Location	Isopentane Tank
Latitude / Longitude	32°42'51.56"N / 115°32'10.43"W
Physical State	Liquefied Gas Under Pressure
Basis Of Results	RMP*Comp Version 1.07
Scenario	Vapor Cloud Explosion
Quantity Released	38,733 pounds
Release Rate	3873.3 lbs/min
Release Duration	10 minutes
Wind Speed & Stability Class	3 m/s & D Stabiltiy
Topography	N/A
Distance To Endpoint	0.1 Miles to 1 psi Overpressure
Public & Environmental Receptors	0 Residents, 0 Housing Units
Passive Mitigation Considered	None

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Figure 6: ARS EPA RMP*Comp Modeling Results

Estimated Distance Calculation

Estimated distance to lower flammability limit: <0.1 miles (<0.16 kilometers)

This is the distance to the lower flammability limit specified for this regulated substance under the RMP Rule.

Scenario Summary

Chemical:	Isopentane [Butane, 2-methyl-]
CAS number:	78-78-4
Threat type:	Flammable Liquid
Scenario type:	Alternative
Release duration:	10 minutes
Release type:	Vapor Cloud Fire
Release rate:	3873 pounds per min
Liquid temperature:	77 F
Mitigation measures:	NONE
Release rate to outside air:	3870 pounds per minute
Surrounding terrain type:	Urban surroundings (many obstacles in the immediate area)
Lower flammability limit:	41 mg/L

Assumptions about this scenario

Wind speed:	3 meters/second (6.7 miles/hour)
Stability class:	D
Air temperature:	77 degrees F (25 degrees C)

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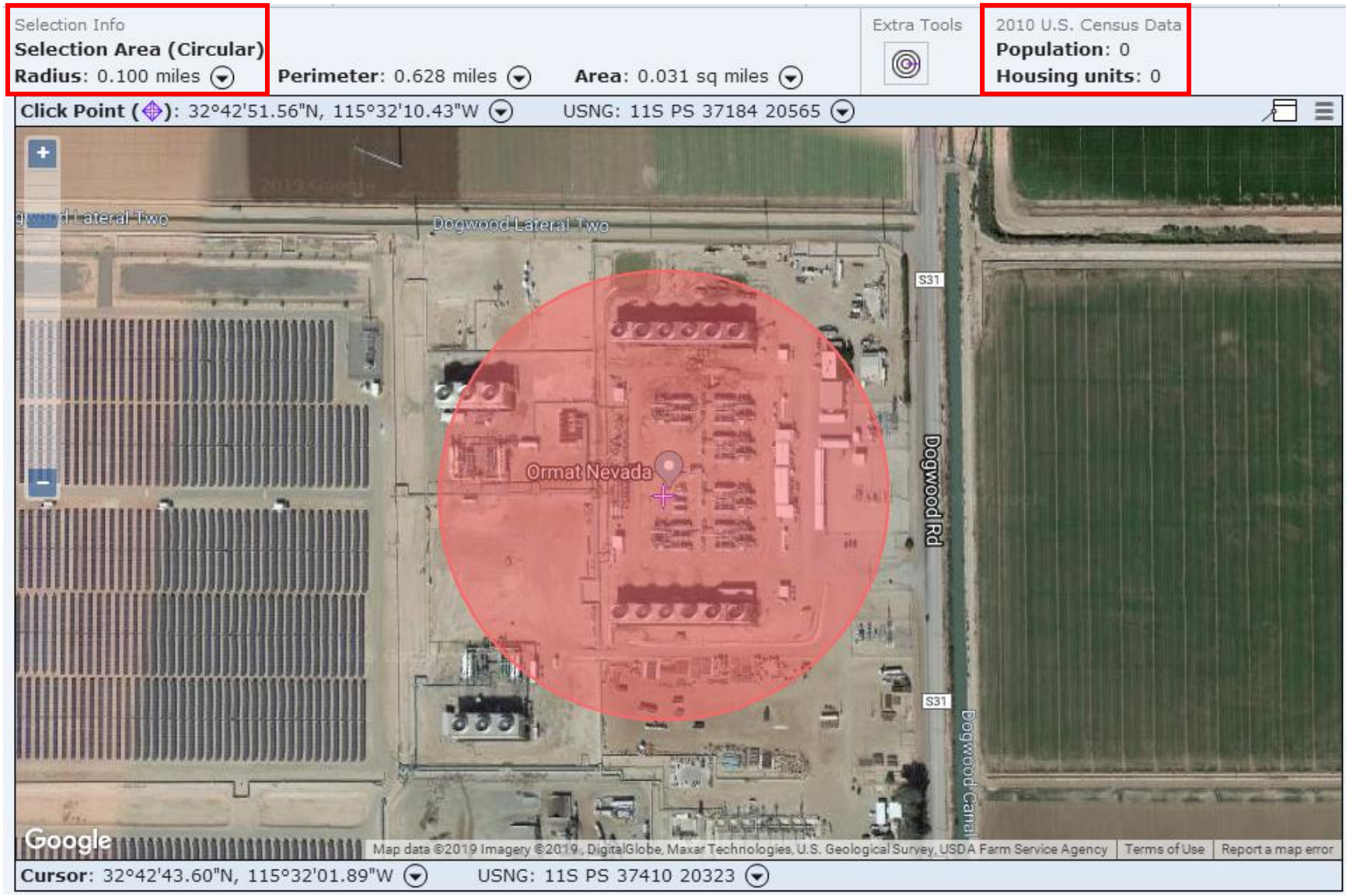
Figure 7: ARS MARPLOT 5.1. Population Estimates



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IMPERIAL COUNTY

PLANNING & DEVELOPMENT SERVICES DEPARTMENT

Reclamation Plan Application

OWNER, OPERATOR AND AGENT:

1. Applicant (Name, Mailing Address and Telephone Number):
   Second Imperial Geothermal Company
   a wholly owned subsidiary of ORMAT Nevada, Inc.
   6140 Plumas Street
   Reno, Nevada 89519
   (775) 356-9029

2. Property Owner (s), or owner of Surface Rights (Name, Mailing Address and Telephone Number): [if different from applicant]
   See 1.

3. Owner of Mineral Rights (Name, Mailing Address and Telephone Number): [if different than applicant]
   See 1.

5. Lessee (Name, Mailing Address and Telephone Number):
   See 1.

6. Operator (Name, Mailing Address and Telephone Number): [if different than applicant]
   See 1.

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7. Agent of Process (Name, Mailing Address and Telephone Number):
Melissa Wendt
Director, Project Development
6140 Plumas Street
Reno, Nevada 89519
(775) 356-9029

LOCATION:

8. Legal Description: (must be full legal)
855 Dogwood Road, Heber, CA (APN 054-250-031)
Tract 44, Township 16 South, Range 14 East, SBB&M

Assessor Parcel No.: 054-250-031
Longitude: 115°32'15.1W
Latitude: 32°42'52.2N
Elevation: near zero

9. Size of the land(s) that will be affected by mining operation. Total acreage:
Heber 2 site is approximately 40 acres.

10. Describe existing and proposed access to the mine site: (please be specific)
Via existing ingress/egress. Primary highway access is provided via Interstate-8. Dogwood Road stems off of I-8 and provides immediate access to the site.

GEOLOGICAL BACKGROUND:

11. Mineral commodity to be minded:
Geothermal fluids. However, no new wells are proposed.

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12. General Geological description of the area:
The site is located within the Piliocene to Holocene, Q Geologic Unit. The Colorado Desert geomorphic province spans central Imperial County, where the site is located, often referred to as the Salton Trough. Low-lying barren desert located between alluvium-covered, active branches of the San Andreas Fault

13. Detailed description of the geology of the actual site in which surface mining is to be conducted:
Site is underlain by Cenozoic sedimentary rocks and alluvial, lacustrine, and eolian deposits. Surface sediments are about 275 feet below sea level. The site contains Holtville silty clays (wet) and Imperial-Glenbar silty clay loams (wet).

14. Brief description of the environmental setting of the site and the surrounding areas. Existing land uses, soil, vegetation, ground water elevation and surface water characteristics.
The site is completly devoid of any vegetation or water resources. Dry lean silty clays dominate the site, extending 4-5 ft. below the surface. The site is comprised of a graded, developed area that consists of exposed soils and gravel. Site within the active geothermal power plant area.

MINING OPERATION AND PRODUCTION:

15. Proposed starting date of operation: Plant in production since 1992

Estimated life of operation: 30 years, 2019-2049

Termination Date: 2049

Duration of first phase: _____

Second phase: _____

Third phase: _____

Fourth phase: _____

16. Operation will be (include days and hours of operation):

Continuous: Plant operates 24 hour per day, 7 days per week

Intermittent: _____

Seasonal: _____

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17. Maximum anticipated annual production (Tons or Cubic Yards):
N/A

18. Total anticipated production:

Minerals:	N/A	cubic yards/tons	0
Tailings retained on site:		cubic yards/tons	0
Tailings disposed off site:		cubic yards/tons	0

Maximum anticipated depth (indicate on map location of benchmarks to verify mine depth):
N/A - Project does not propose drilling or extraction.

19. Describe mining method:
N/A - no mining is proposed as part of the Project.

20. Describe nature of processing and explain disposal of tailings or waste.
N/A - no tailings will be processed as part of the Project.

21. Do you plan to use cyanide or other toxic materials in your operations?
Three additional above ground storage tanks will be used for isopentane storage. Site will include two 10,000 gallon tanks and three 10,000 gallon tanks.

Do you plan to use or store petroleum products or other hazardous materials on the site?
Yes.

Describe refueling and maintenance of vehicles.
Construction equipment will be fueled on-site, as necessary. Fuel will be limited to diesel and gasoline, to fuel heavy and light equipment. Repairs to construction equipment will be performed on-site by certified mechanics. Spill prevention BMPs and safe handling techniques will be employed throughout the construction phase.

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22. Indicate the quantity of water to be used, source of water, method of conveyance to the mine site, the quantity, quality and method of disposal of used and/or surplus water. Indicate if water well to be used for mine operation (drilling, reactivation, changing use or increasing volume of water well may require Conditional Use Permit approval).

No additional water will be required to support the proposed facilities. Water will be used for dust suppression during ground disturbing activities. A 5,000 gallon water truck is expected to be used. Approximately 20,000 gallons of water are expected to be used. The existing Heber 2 facility will provide the water via existing permits.

23. Describe phases of mining if applicable and concurrent reclamation including time schedule for concurrent activities.

No mining is proposed as part of the Project. Site reclamation would be performed at the end of the facilities' lifecycle (30 years).

24. Describe the types of equipment that will be used in the operation, including the estimated average daily trips (ADT) that will be generated by the operation.

Backhoes, excavators, heavy trucks, light vehicles, compactors, hand tools, welding equipment, water truck, crane.

25. Include the following maps: (NOTE: Without these the application is automatically incomplete.)

(1) Topographic Map with overlay showing proposed area to be mined.

(2) Site Plan showing mine layout and dimensions.

(3) General Vicinity Map showing the location of the mine site in Imperial County.

(4) Cross Section Map. (N/A - no subsurface activities proposed.)

RECLAMATION:

26. Indicate by overlay of map of Item No. 24, or by color or symbol on map those areas to be covered by the reclamation plan:

Total acreage: 39.99 acres
APN 054-250-031

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27. Describe the ultimate physical condition of the site and specify the proposed use (s) or potential uses of the land after reclamation. Explain if utilities, haul or access roads will be removed or reclaimed.

The site is within a developed area used for geothermal energy generation. The site is completely devoid of any vegetation or water resources. The site consists of exposed soils and gravel. The site would likely be returned to a natural state or agricultural production after geothermal energy production has concluded. No roads would be developed for the Project and access will be provided via existing roads.

28. Describe relationship of the interim uses than mining and the ultimate physical condition to:

(a) Imperial County Zoning Ordinance

(b) Imperial County General Plan

The site is zoned as A-2-G-SPA and is within the Geothermal Overlay Zone, which allows for major geothermal energy projects. The proposed facilities and uses are consistent with the Imperial County Zoning Ordinance and General Plan.

29. Notarized statement that all owners of the possessory interest in the land have been notified of the proposed uses or potential uses identified in Item No. 25 (see Attachment "A").

N/A - The site owner is the applicant (ORMAT) and no other parties have an interest on the subject property.

30. Describe soil conditions and proposed topsoil salvage plan.

The site's soils are comprised of silty clays and loams. The site is arid and presently devoid of any vegetation or water resources. The site's topsoil is low quality. Approximately 18 inches of topsoil will be excavated from the 2.5 acre development site and piled. After gravel is deposited and compacted, the piled topsoil will be used as backfill material.

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31. Describe the methods, their sequence and timing, to be used in bringing the reclamation of the land to its end state. Indicate on map (Items Nos. 24 and 25) or on diagrams as necessary. Include discussion of the pertinent items listed below.

(a) Backfilling and grading

(b) Stabilization of slopes

(c) Stabilization of permanent waste dumps, tailings, etc.

(d) Rehabilitation of pre-mining drainage

(e) Removal, disposal or utilization of residual equipment, structure, refuse, etc.

(f) Control and disposal of contaminants, especially with regard to surface runoff and ground water

(g) Treatment of streambeds and streambanks to control erosion and sedimentation

(h) Removal or minimization of residual hazards

(i) Resoiling, revegetation with evidence that selected plants can survive given the site's topography, soil and climate:

See Attachment D (Revegetation Plan)

32. If applicant has selected a short term phasing of his reclamation, describe in detail the specific reclamation to be accomplished during the first phase:

All reclamation activities would occur at the conclusion of the facilities' lifecycle (2049).

33. Describe how reclamation of this site in this manner may affect future mining at this site and in the surrounding area:

Reclamation of the site would remove all facilities from the entire Heber 2 site. Reclamation activities would likely return the land to a natural state or agricultural production. These activities would not affect any future mining or geothermal operations on the site or in the vicinity.

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34. Notarized statement that the person submitting the plan accepts responsibility for reclaiming the mined lands in accordance with the Reclamation Plan (Attachment “B”):
Attached.

35. Include Reclamation Cost Calculations as Attachment “C”:
Attached.

36. Describe proposed Revegetation Plan (attach as “Attachment D” if necessary):
The entire Heber 2 site would be dismantled and removed. All wells would abandoned per DOGGR requirements. Once free of facilities, the site would be disced and seeded with a native mix, per Imperial County's recommendation. See Attachment D.

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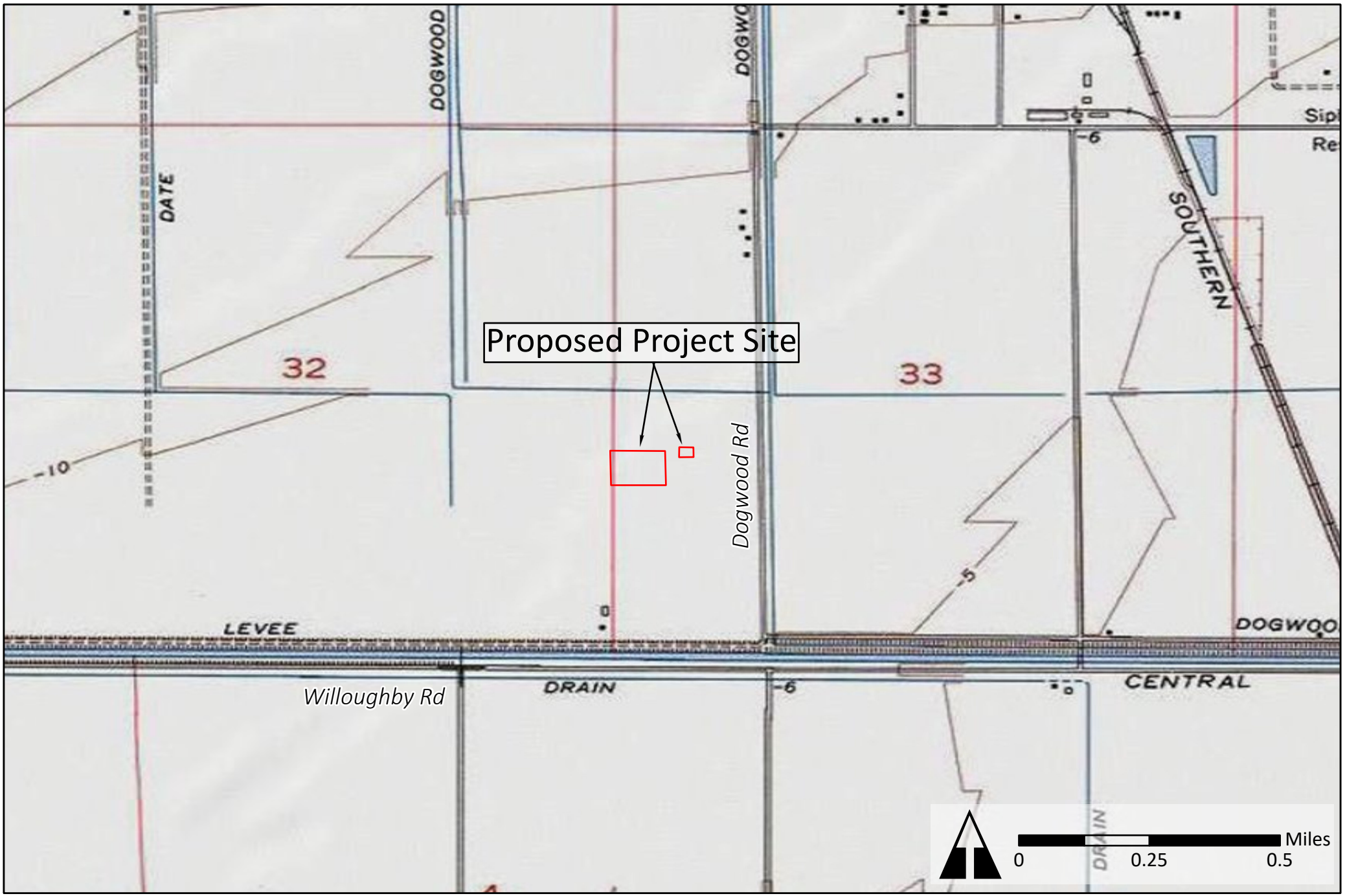

TOPOGRAPHIC MAP OF PROJECT SITE

Figure 1

ORMAT

Date: July 2019

Catalyst ENVIRONMENTAL SOLUTIONS

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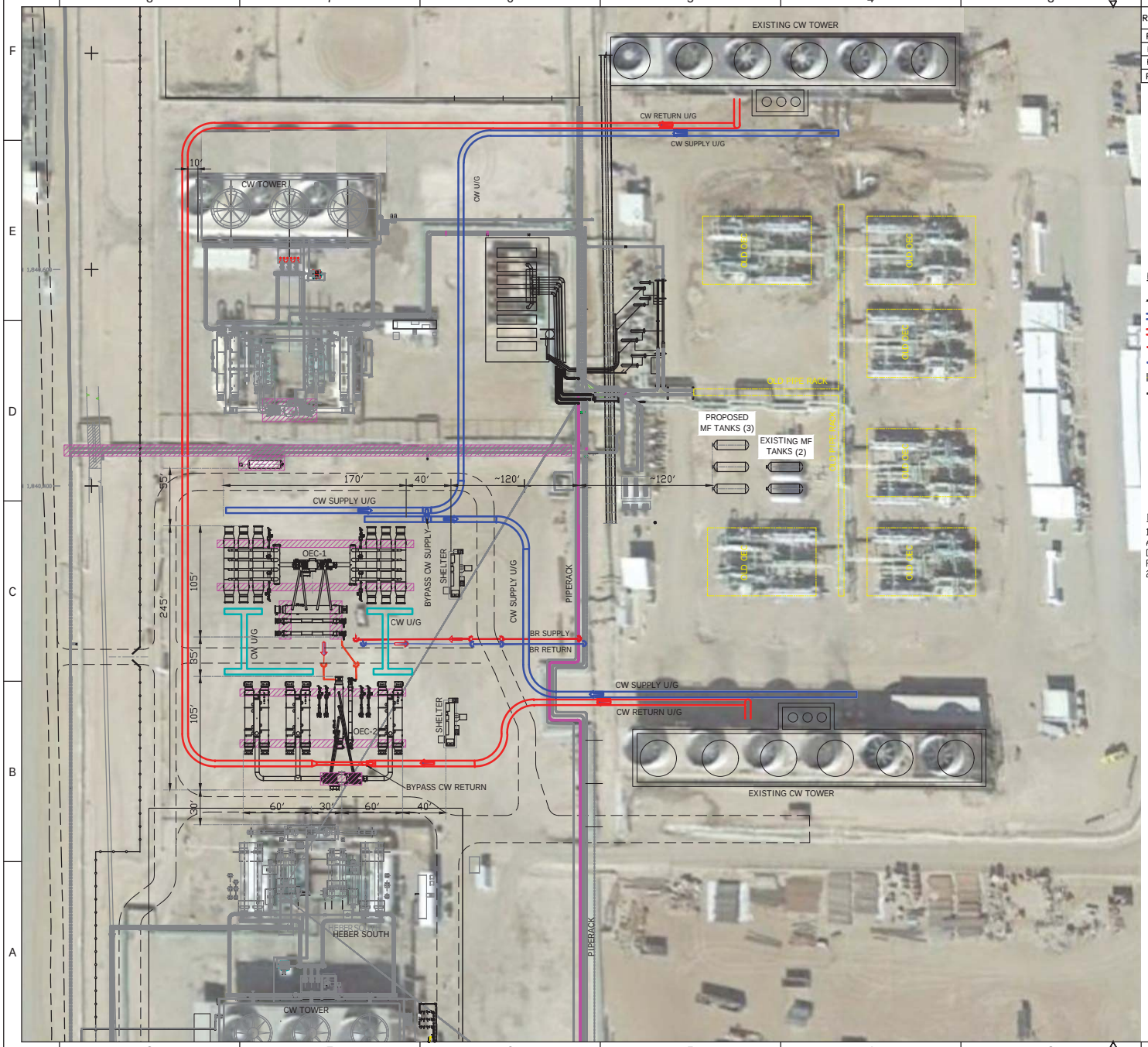

REV	DESCRIPTION	DATE	BY	CHK	ENG	PRJ
P6	UPDATE MODELS OES-1 & OEC-2	5.APR.2019	A.S.	A.N.		S.H.
P7	UPDATE MODELS OES-1	17.APR.2019	A.S.	A.N.		S.H.
P8	UPDATE OEC-1 & OEC-2	27.MAY.2019	A.S.	A.N.		S.H.
P9	UPDATE LOCATION OEC-1	18.JULY.2019	A.S.	A.N.		S.H.

N

KEY:

- EXISTING FENCE LINE
- PROPOSED UNDERGROUND CW SUPPLY LINE
- PROPOSED UNDERGROUND CW RETURN LINE
- PROPOSED BR SUPPLY LINE
- PROPOSED BR RETURN LINE
- EQUIPMENT TO BE DECOMMISSIONED
- EXISTING EQUIPMENT TO REMAIN
- CW — COOLING WATER
- U/G — UNDERGROUND
- BR — GEOTHERMAL BRINE
- OEC — ORMAT ENERGY CONVERTOR
- MF — MOTIVE FLUID

NOTE:

1. THE ARRANGEMENT AND SIZES PRESENTED ARE PRELIMINARY AND INDICATIVE ONLY AND SUBJECT TO CHANGED ON DESIGN OPTIMIZATION , DETAILED DESIGN AND ACTUAL EQUIPMENT PURCHASED (MANUFACTURED).
2. DIMENSIONS ARE IN MM [FEET], ELEVATIONS ARE IN MM FEET]

0 20' 100' 200'

GRAPHIC SCALE (FEET)

PREPARED BY:

Stantec

PHONE: FAX:

FOR:

Second Imperial Geothermal Company
855 B Dogwood Road
Heber CA 92249

TITLE:

HEBER2 REPOWER
GENERAL ARRANGEMENT
POWER PLANT ON MAP

DRAWN BY: KAM	DESIGNED BY:
CHECKED BY:	APPROVED BY:
PROJECT NUMBER: 01OT.01234.01.0123	SCALE: AS SHOWN
DATE: 04/01/04	FILE PATH: K:/(CLIENT) OR JOB #

SHEET:

1 OF 1

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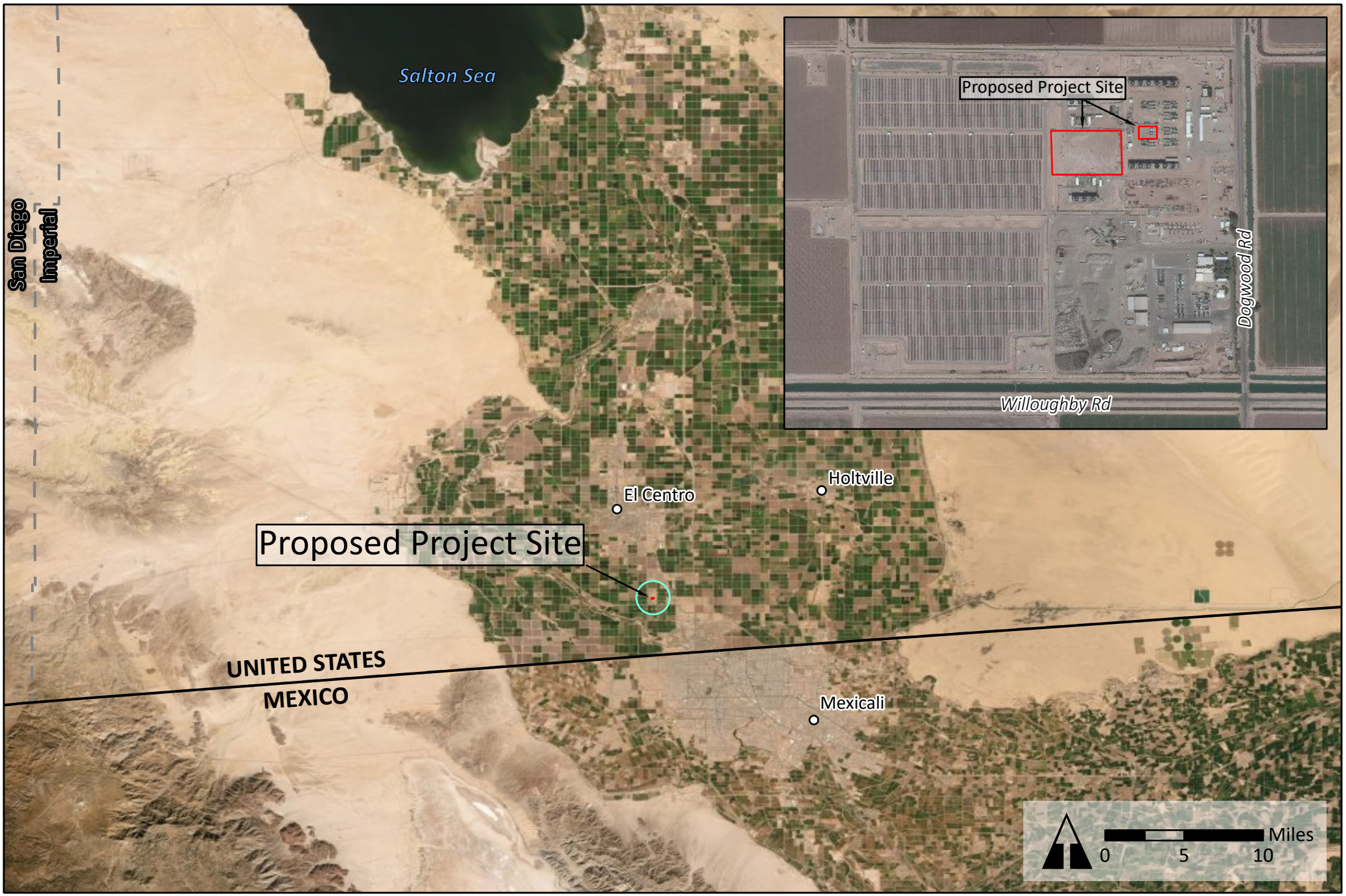

Legend

- United States/Mexico Border
- County Line
- Project Site
- 1-Mile Radius

PROPOSED PROJECT SITE - HEBER 2

Figure 1

ORMAT

Date: July 2019

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ATTACHMENT "A"

STATEMENT OF NOFICATION

I, the undersigned, have notified all owners of the possessory interest in the land of the proposed use (s) or potential uses identified in Item No. 26 of the Reclamation Plan.

Signed this _____ day

of _____, 2005.

_____

Operator or Operator's Agent

MAIN OFFICE: 801 Main Street El Centro, CA 92243 (760) 482-4236 FAX: (760) 353-8338 E-MAIL: planning@imperialcounty.net
ECON. DEV. OFFICE: 836 Main Street El Centro, CA 92243 (760) 482-4900 FAX: (760) 337-8907

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ATTACHMENT "B"

STATEMENT OF RESPONSIBILITY

I, the undersigned, hereby agree to accept full responsibility for reclaiming all mined lands as described and submitted herein with any modifications requested by the County of Imperial as conditions of approval.

Signed this 12th day

of August, 2019.

Connie Stechman

Operator or Operator's Agent

Connie Stechman, VP Finance
Ormat Nevada, Inc.

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ATTACHMENT "C"

RECLAMATION COST ANALYSIS

MAIN OFFICE: 801 Main Street El Centro, CA 92243 (760) 482-4236 FAX: (760) 353-8338 E-MAIL: planning@imperialcounty.net
ECON. DEV. OFFICE: 836 Main Street El Centro, CA 92243 (760) 482-4900 FAX: (760) 337-8907

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Reclamation Cost Estimate for Heber 2 Geothermal Energy Complex

Date: July 31, 2019

RE: **Reclamation Cost Estimate for the Heber 2 Geothermal Energy Complex**

This cost estimate has been prepared for the Heber 2 Geothermal Repower Project and provides a general estimate to perform well abandonment and site reclamation/revegetation for the entire 40-acre Heber 2 Complex site.

Well Hole Abandonment

- Cost of Abandoning Two Injection Wells

  2 wells x 200 feet[1] x $16.10/foot[2] = **$6,440**

Site Reclamation and Revegetation

- Cost of Reclaiming 40 acres

  $10,235[2] (first acre) + 219,765 ($5,635/acre[2] for 39 acres) = **$230,000**

TOTAL COST ESTIMATE: $236,440

References

[1] California Department of Conservation Oil, Gas, and Geothermal Resources. April 2019. California Code of Regulations, Section 1723. Available online at: https://www.conservation.ca.gov/index/Documents/DOGGR-SR-1%20Web%20Copy.pdf

[2] New Mexico Energy, Minerals, and Natural Resources Department. 2013. Guidance for Estimating Reclamation Costs. Available online at: http://www.emnrd.state.nm.us/MMD/MARP/documents/MMD_Part3FAGuidelines_Sept2013.pdf

Reclamation estimates provided in this document were increased by 15% to account for six years of inflation and potential contingency costs.

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ATTACHMENT “D”

REVEGATION PLAN

(REVISED MARCH 25, 2005)
JH/lh/S:/forms_lists/reclamation plan aplication

MAIN OFFICE: 801 Main Street El Centro, CA 92243 (760) 482-4236 FAX: (760) 353-8338 E-MAIL: planning@imperialcounty.net
ECON. DEV. OFFICE: 836 Main Street El Centro, CA 92243 (760) 482-4900 FAX: (760) 337-8907

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Revegetation Plan for Heber 2 Geothermal Energy Complex

Date: July 31, 2019

From: Catalyst Environmental Solutions

RE: **Revegetation Plan for the Heber 2 Geothermal Repower Project**

INTRODUCTION

The Second Imperial Geothermal Company (SIGC), a wholly owned subsidiary of ORMAT Nevada, Inc (ORMAT), owns and operates the Heber 2 Geothermal Energy Complex (Heber 2). ORMAT proposes to amend CUP No. 06-0006 to allow for the installation of two new air cooled ORMAT Energy Converters (OECs); three additional above ground storage tanks (ABSTs); and, additional pipes to connect the proposed facilities with the existing Heber 2 Geothermal Energy Complex (hereinafter, "Project"). All proposed facilities would be developed within the existing Heber 2 Complex and fence line. This application also proposes to renew the permitted life of the entire Heber 2 facility (including the Goulds 2 and Heber South geothermal energy facilities) to 30 years (2019-2049).

This Revegetation Plan has been prepared in support of the Reclamation Plan Application as part of the CUP amendment application for the Heber 2 Geothermal Repower Project.

Project Location

The Heber 2 Complex is located on private lands owned by ORMAT in southern Imperial County (**Figure 1)**. The proposed development would occur entirely on Assessor's Parcel Number (APN) 054-250-031, which is a 39.99-acre property. The address for Heber 2 is 855 Dogwood Road, Heber, CA 92249.

Reclamation, Abandonment, and Revegetation Schedule

Reclamation, abandonment, and revegetation activities would commence at the closure of the Heber 2 Geothermal Energy Complex in 2049, if the CUP amendment application is approved by Imperial County. Activities would commence after two injection wells have been plugged and the dismantlement and removal/disposal of the energy facilities. If necessary, reseeding would be held off until the appropriate season (e.g. fall, spring). Activities would take approximately 6 months to complete.

Site Preparation

After all wells have been plugged and facilities are removed from the site, any soil piles or grades will be evened out by an excavator. The site is near zero elevation and is very flat and absent of topography. Reclamation activities will mimic the existing grade of the site and not introduce a new gradient/slope to the area. The site will then be rolled with a soil aerator/loosener. After site reclamation, topsoil will be transported to the site and deposited evenly across the site.

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Selection of Plant Materials

The Heber 2 Complex site is completely devoid of vegetation, as the site is used for geothermal energy generation and contains industrial equipment that should not have vegetation under/around the facilities. See **Appendix A** of the CUP application for Site Photographs. The surrounding area is dominated by agricultural production and no natural areas are in the immediate vicinity of the Project Site. SIGC/ORMAT will reseed the entire 40-acre site with a seed mix approved by Imperial County.

Irrigation and Maintenance

Revegetation of the site will be maintained by a contractor every two weeks to conduct weeding, watering, and removing trash/debris. The site will be irrigated by water truck as necessary to establish the new vegetation.

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ORMAT, HEBER 2
GEOTHERMAL POWER GENERATION FACILITIES
HEBER, CALIFORNIA

Hazard Assessment

Revision	Date	Description
0.0	October 16, 2020	Initial Issue – Concrete Secondary Containment Area and Relocating New Storage Vessels

Risk Management Professionals, Inc.
Two Venture Plaza, Suite 500, Irvine, California 92618
Phone: 949-282-0123 – E-mail: Client.Services@RMPCorp.com

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Appendix A: Worst-Case Scenario Calculations

Appendix B: Alternative Case Scenario Calculations

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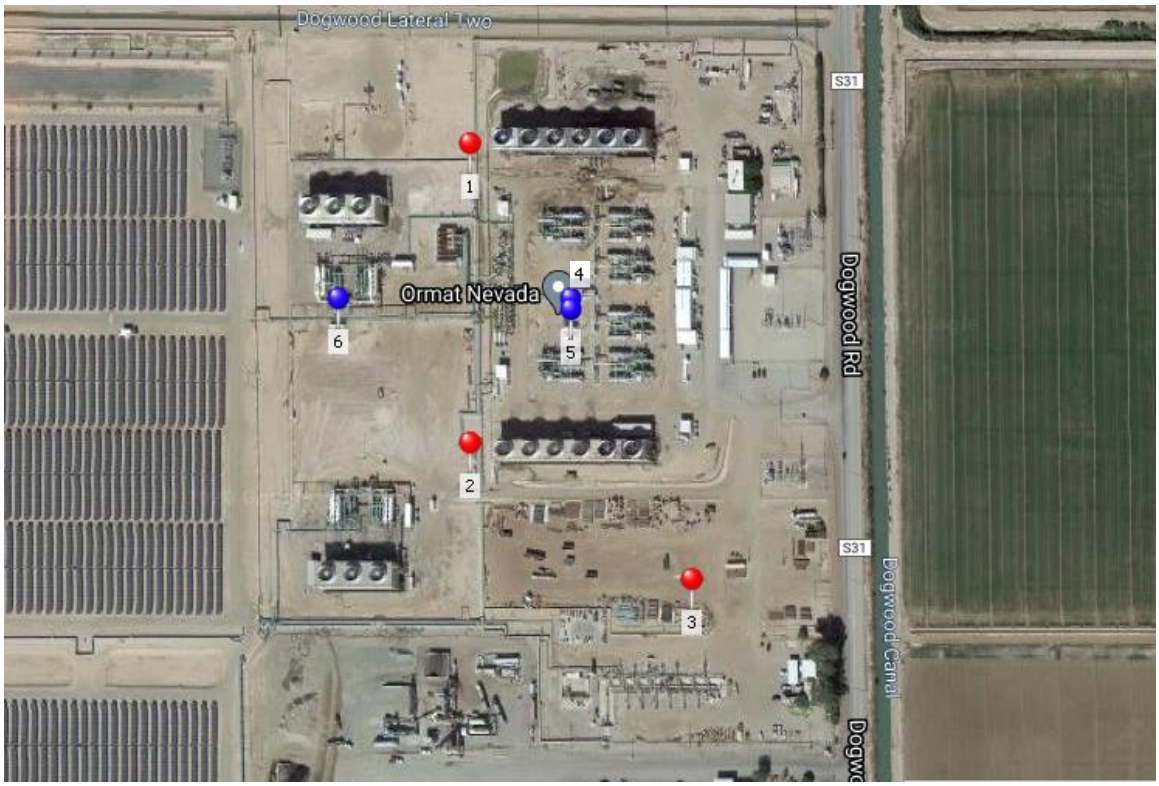
1.0 FACILITY OVERVIEW

This technical assessment was conducted to fulfill the Hazard Assessment Offsite Consequence Analysis (OCA) requirements of the following regulations:

- 40 CFR §68.65 – Environmental Protection Agency (EPA) "Risk Management Plan (RMP)"[1]
- 19 CCR 2750.1 to 2750.9 – California Code of Regulation "California Accidental Release Prevention (CalARP) Program"[2]

This assessment is completed for the **Ormat– Heber 2 Geothermal Complex** Facility located in Heber, California. The facility's location at 855 Dogwood Road, Heber, CA 92249 is illustrated in Figure 1 below. The blue markers depict the locations of the three existing 10,000-gallon vessels and red markers for three new 10,000-gallon isopentane vessels that are being added to the facility as part of the Repower project. The coordinates for each vessel's location are presented in Table 1 and Table 2 on the following page.

Figure 1: Aerial View of the Facility Location



The following page presents a closer view of the facility's storage vessel locations, as well as tables displaying the approximate locations of the three new and three existing storage vessels.

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Figure 2: Aerial View of the Storage Vessel Locations



Table 1: Ormat—Heber 2 New Storage Vessel Coordinates

NEW VESSELS	FORMAT	LATITUDE	LONGITUDE
Isopentane Vessel 1	Degrees/Minutes/Seconds	32°42'54.66"N	115°32'12.54"W
Isopentane Vessel 2	Degrees/Minutes/Seconds	32°42'48.40"N	115°32'12.55"W
Isopentane Vessel 3	Degrees/Minutes/Seconds	32°42'45.55"N	115°32'07.03"W

Table 2: Ormat—Heber 2 Existing Storage Vessel Coordinates

EXISTING VESSELS	FORMAT	LATITUDE	LONGITUDE
Isopentane Vessel 4	Degrees/Minutes/Seconds	32°42'51.42"N	115°32'10.02"W
Isopentane Vessel 5	Degrees/Minutes/Seconds	32°42'51.21"N	115°32'10.02"W
Isopentane Vessel 6	Degrees/Minutes/Seconds	32°42'51.42"N	115°32'15.82"W

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2.0 COVERED PROCESS

The ***Ormat – Heber 2 Geothermal Complex*** has three geothermal electrical generating plants in Heber, CA. Heber 2 consists of the H2, Gould-2 (G-2), and Heber South binary processes. The projects use the renewable geothermal resources of the Heber Known Geothermal Resource Area (KGRA) to generate electrical power.

The Heber 2 Geothermal Project produces electricity by using a vaporized motive fluid to spin a turbine connected to a generator. In the H2 binary processes, isopentane is the motive fluid.

The covered processes at the facility are listed below.

Table 3: Ormat—Heber 2 Geothermal Complex Facility Covered Process

PLANT	REGULATED SUBSTANCE	MAXIMUM INVENTORY IN SINGLE VESSEL (GAL)[A]	TANK TYPE	VESSEL STORAGE INVENTORY
Heber 2	Isopentane	9,000	Storage	10,000-gallon tank

[A] This value represents the maximum amount stored in a single vessel, taking into account administrative controls, which are in place to limit the quantity stored.

This hazard assessment will focus on the regulated substance, isopentane, in Heber 2. The facility is classified as Prevention Program 3 and is regulated by the Environmental Protection Agency's Risk Management Program (EPA RMP) for Chemical Accidental Release Prevention in accordance with the Code of Federal Regulations, Title 40, Chapter I, Subchapter C, Part 68, Subpart B Sections 68.20 to 68.42 (40 CFR §68.20 - 68.42)[1] for isopentane, because it is held on site in excess of 10,000 lbs. The geothermal power plant utilizes isopentane as the motive fluid in the generation of electricity.

3.0 LEVEL OF CONCERN

To address potential health effects for the worst-case release scenario, the following are the key endpoints of concern for the EPA RMP as defined in Title 40 CFR Section 68.22(2):

(i) Explosion. An overpressure of 1 psi.

(ii) Radiant heat/exposure time. A radiant heat of 5 kW/m^2 for 40 seconds.

(iii) Lower flammability limit. A lower flammability limit as provided in NFPA documents or other generally recognized sources.

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The distance from the point of release to the endpoint identified above defines a radius circle of concern for which consequences are reported in the Risk Management Plan.

4.0 WORST-CASE SCENARIO

The US EPA RMP determines the worst-case release quantity in Title 40 CFR Part 68.25(b) as follows:

> *The worst-case release quantity shall be the greater of the following:*
>
> *(1) For substances in a vessel, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity;*
>
> *(2) For substances in pipes, the greatest amount in a pipe, taking into account administrative controls that limit the maximum quantity.*

Given the substance released is a flammable, the US EPA RMP gives further guidelines in 68.25 (f):

> *Worst-Case scenario-flammable liquids. The owner or operator shall assume that the quantity of the substance, as determined under paragraph (b) of this section and the provisions below, vaporizes resulting in a vapor cloud explosion. A yield factor of 10 percent of the available energy released in the explosion shall be used to determine the distance to the explosion endpoint if the model used is based on TNT equivalent methods.*
>
> *(1) For regulated flammable substances that are normally liquids at ambient temperature, the owner or operator shall assume that the entire quantity in the vessel or pipe as determined under paragraph (b) of this section, is spilled instantaneously to form a liquid pool. For liquids at temperatures below their atmospheric boiling point, the volatilization rate shall be calculated at the condition specified in paragraph (d) of this section.*
>
> *(2) The owner or operator shall assume that the quantity which becomes vapor in the first 10 minutes is involved in the vapor cloud explosion.*

Furthermore, vapor cloud explosions are considered a conservative analysis as Chapter 4: OCA of the General Risk Management Program Guidance states:

> *As in the case of the worst-case release analysis for toxic substances, the worst-case distance to the endpoint for flammable substances is based on a number of very*

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conservative assumptions. Release of the total quantity of a flammable substance in a vessel or pipe into a vapor cloud generally would be highly unlikely. Vapor cloud explosions are also unlikely events; in an actual release, the flammable gas or vapor released to air might disperse without ignition, or it might burn instead of exploding, with more limited consequences. The endpoint of 1 psi is intended to be conservative and protective; it does not define a level at which severe injuries or death would be commonly expected. An overpressure of 1 psi is unlikely to have serious direct effects on people; this overpressure may cause property damage such as partial demolition of houses, which can result in injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

To develop the worst-case scenario, the largest storage vessel was selected. As stated in 19°CCR §2750.3, the worst-case release quantity is the greatest amount held in a single vessel, taking into account inventory procedures and limits.

The Areal Locations of Hazardous Atmospheres (ALOHA)[3] modeling software was used to determine the distance to the endpoint for the worst-case release scenario analysis. The vulnerability zone resulting from this analysis was then reviewed. A vulnerability zone is defined as a circle whose center is the point of release and its radius is the length of the endpoint, which is predicted by the dispersion model (e.g., ALOHA).

4.1 Worst-Case Scenario Selection Process

The process of worst-case release scenario identification is summarized as follows. Figure 3 on the following page depicts the steps in this process.

- **Inventory Calculation**: The first step was to perform the inventory calculations for the 10,000-gallon storage vessels in the covered units and systems.
- **Screening Analysis**: The 10,000-gallon isopentane storage vessels' location was screened. ALOHA modeling software was used to model the scenario and determine the dispersion endpoints for the worst-case release scenario. This was performed to determine the vulnerability zone associated with the worst-case release scenario.
- **Review of the Vulnerability Zone**: The vulnerability zone resulting from the previous step was reviewed and is representative for the plant's worst-case scenario.
- **Worst-Case Analysis**: To document the worst-case scenario, the potential public receptors within the vulnerability zone were identified. All modeling inputs, calculations and assumptions are documented.

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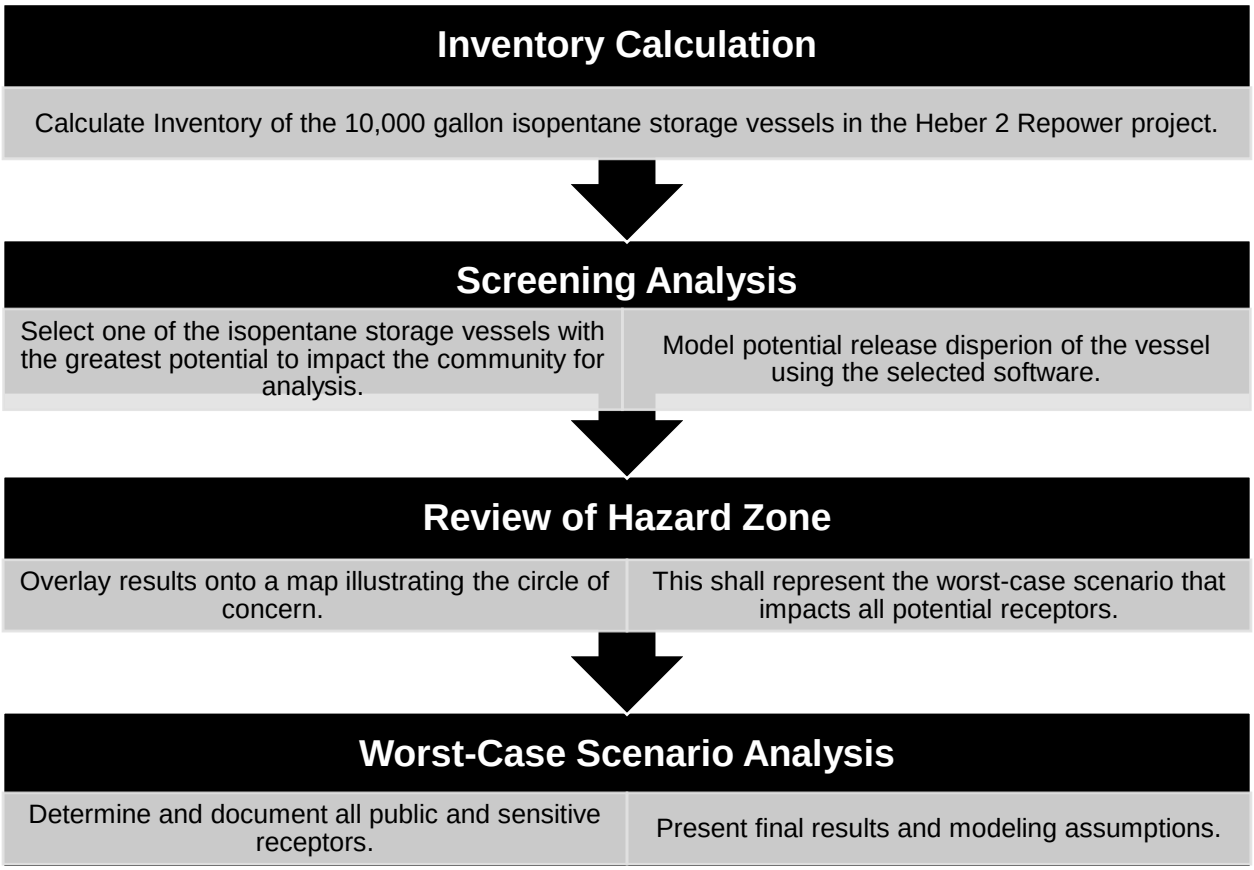
Figure 3: Worst-Case Scenario Selection Process



4.2 Flammable Release Potential Consequences

Several possible consequences of releases of flammable substances are discussed below. It should be noted that the following possible consequences apply to not only worst-case release analysis.

- **Flash Fire**. This event may result from dispersion of a flammable vapor cloud and ignition of the cloud following dispersion. Such a fire could flash back and could represent a severe heat radiation hazard to anyone in the area of the cloud. The lower flammability limit (LFL) endpoint, specified in the rule, would be appropriate for flash fires (vapor cloud fires).
- **Pool Fire**. Spill of a liquid whose boiling point is above ambient temperature may form a liquid pool, which could ignite and form a pool fire. The applicable endpoint specified in the rule is the heat radiation level of 5 kW/m^2.

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- **BLEVE.** A BLEVE (Boiling Liquid Expanding Vapor Explosion) is a potential release scenario associated with a large quantity of flammable materials kept at below their boiling points. A BLEVE that may lead to a fireball could produce intense heat. This event may occur if a vessel containing flammable material ruptures as a result of exposure to fire. Heat radiation from the fireball is the primary hazard and vessel fragments and overpressure from the explosion are generally considered unlikely. To estimate the distance to a radiant heat level that can cause second degree burns (a heat "dose" equivalent to the specified radiant heat endpoint of 5 kW/m^2 for 40 seconds). Consistent with the EPA's "Risk Management Program Guidance for Offsite Consequence Analysis" published guidance, BLEVEs are generally considered unlikely events and were therefore not considered a probable event for the Offsite Consequence Analysis.
- **Vapor Cloud Explosion.** For a vapor cloud explosion to occur, rapid release of a large quantity, turbulent conditions (caused by a turbulent release or congested conditions in the area of the release, or both), and other factors are generally necessary. The endpoint for vapor cloud explosions is 1 psi.
- **Jet Fire.** This may result from the puncture or rupture of a tank or pipeline containing a compressed or liquefied gas under pressure. The gas discharging from the hole can form a jet that "blows" into the air in the direction away from the hole; the jet then may ignite. Jet fires could contribute to BLEVEs and fireballs if they impinge on tanks of flammable substances. A large horizontal jet fire may have the potential to pose an offsite hazard.

For the flammable worst-case release scenario, a vapor cloud explosion was the most appropriate consequence, as defined by the EPA RMP rule.

4.3 Endpoints

As mentioned previously, for flammable materials, the endpoints specified by the EPA RMP are:

- Overpressure of 1 pound per square inch (psi) for vapor cloud explosions
- Radiant heat of 5 kilowatts per square meter (kW/m^2) for jet fires
- Lower flammability limit (LFL) for flash fires

The rule specifies endpoints for fires based on the heat radiation level that may cause second degree burns from a 40-second exposure and the LFL, which is the lowest concentration in air at which a substance will burn. For a vapor cloud explosion, the endpoint is 1 psi, which is the force

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to cause partial demolition of houses with potential serious injuries to people, or shattering glass windows with potential skin laceration from flying glass.

4.4 Modeling Assumptions

The EPA RMP regulation imposes several assumptions that were adhered to when performing the offsite consequence analysis of the worst-case release scenario. These are conservative assumptions for weather and release conditions. The distance to the endpoint estimated under worst-case conditions provides an estimate for the maximum possible area that might be affected by these unlikely conditions. It should be noted that EPA's intention for the vulnerability zone representing a worst-case release scenario is to provide a basis for discussion among the regulated industry, emergency responders, and the public, rather than a basis for any specific actions. The EPA RMP regulations, in conjunction with the RMP Guidance for Offsite Consequence Analysis[4], were used to model the worst-case release scenario and prescribe these atmospheric parameters.

- **Meteorological Parameters:** For the worst-case release analysis, the following assumptions were entered into ALOHA, as specific by the EPA RMP regulations / RMP Guidance for Offsite Consequence Analysis.
    - *Atmospheric stability*: F stability (very stable conditions)
    - *Wind speed:* 1.5 meters/second
    - *Ambient Temperature:* 77 ^{o}F
    - *Relative Humidity*: The typical relative humidity at the stationary source, which is 50%
- **Dispersion & Impact Modeling Parameters:**
    - *Height of Release:* Ground level, per EPA Rule requirement
    - *Surface Roughness:* Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations
    - *Vapor Cloud Explosion Impact:* A Vapor Cloud Explosion has been modeled with an endpoint of 1 psi

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- **Mitigation Systems:** Once a release has occurred, mitigation systems are means (structures, equipment, or activities) that help minimize the transport of material to the atmosphere. Mitigation systems can be characterized as passive or active systems.
    - *Passive mitigation systems do not require activation, an energy source, or movement of components to perform their intended function*
    - *Active mitigation systems do require activation, an energy source, and/or movement of components to perform their intended function*

It should be emphasized that the effectiveness of mitigation systems was taken into account when these systems were considered in the offsite consequence analysis. The effectiveness is determined based on how well the systems are designed and their abilities to respond reliably upon demand. The rule permits consideration of only passive mitigation systems for the worst-case release analysis provided that the systems are capable of withstanding the event triggering the release scenario and would still function as intended. For the worst-case release scenario, the secondary containment area built with concrete for each of the six isopentane vessels was considered as a passive mitigation measure in the offsite consequence analysis.

4.5 Worst-Case Release Scenario

One worst-case scenario (WCS) was developed for the facility. For the worst-case release scenario, one of the six 10,000-gallon storage vessels containing isopentane at the Ormat – Heber 2 Geothermal Complex Facility was considered. The storage vessel is capable of storing a maximum of 9,000 gallons of isopentane, taking into account administrative controls. According to the Chevron Philips Chemical Company safety data sheet, the density of isopentane is 5.14 lbs./gal, which yields a total mass of 46,260 pounds of isopentane held in the storage vessel. The worst-case scenario considers the catastrophic failure of one of the 10,000-gallon isopentane storage vessels, which would result in a release of the entire contents of the vessel, into the secondary containment area. All dispersion modeling parameters utilized in the worst-case release scenario modeling is listed in Table 4 below. A summary of the scenario is presented in Table 5. Appendix A of this report provides a detailed description of the worst-case release scenario, ALOHA modeling output, MARPLOT 5.1.1[5] output with population estimates, and maps displaying the vulnerability zone for a release from each tank, denoted by a circle superimposed on the map.

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Table 4: Worst Case Release Scenario Dispersion Modeling Parameters

PARAMETER	INPUT VALUE	NOTES
Isopentane Input Parameters		
Quantity Released	9,000 gallons	Entire contents of isopentane storage vessel assumed to be released and form an evaporating puddle in secondary containment area, which is involved in a vapor cloud explosion.
Meteorological Parameters		
Atmospheric Stability	F stability	As per 40 CFR §68.22 (b), "For the worst-case release analysis, the owner or operator shall use a wind speed of 1.5 meters per second and F atmospheric stability class"
Wind Speed	1.5 m/s	
Wind Direction	W	Wind Direction from the west based on the Wind Rose plot for Imperial, CA (closest city with wind rose plot available). Since the endpoint distance and circle of interest is presented in this report, the wind direction does not impact the analysis/distance to endpoint and instead is a generic input that ALOHA modeling software requires.
Measurement Height above Ground	10 m	Wind speed is assumed to be measured at this elevation, as this is the standard height at which the National Weather Service usually reports wind speed.
Ambient Temperature	77ºF (25°C)	As per 40 CFR §68.22 (c), "An owner or operator using the RMP Offsite

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PARAMETER	INPUT VALUE	NOTES
Relative Humidity	50%	Consequence Analysis Guidance may use 25 °C and 50 percent humidity as values for these variables"
Ground temperature	122ºF	As per 40 CFR §68.22 (g), "for worst case, [it] shall be considered to be released at the highest daily maximum temperature, based on data for the previous three years appropriate for the stationary source." Temperature data was sourced from Weather Underground [6] for Imperial, CA (closest available city with temperature history) and the highest daily maximum temperature from the previous 3 years was identified.
Dispersion and Impact Modeling Parameters		
Height of Release	Ground level	As per 40 CFR §68.22(d), "you must assume a ground level release" and as per the RMP Offsite Consequence Analysis Guidance Document, "this guidance assumes a ground-level release"
Topography/Surface Roughness	Open Country	Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations.

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PARAMETER	INPUT VALUE	NOTES
Level of Congestion	Congested	The level of congestion was assumed to be congested, which is a conservative assumption since greater turbulence (greater congestion) allows the flame front to accelerate, thereby generating a more powerful blast wave (i.e., greater overpressure). The immediate area within the facility is also considered to be congested with piping and equipment.
Isopentane Mitigation System		
Passive Mitigation	Secondary Containment Area	The volume released from a single Isopentane Storage Vessel is assumed to release into a concrete secondary containment area, which is contained around each storage vessel. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (Surface area = 480 ft^2).

Table 5: Worst-Case Scenario Results Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
WCS: 10,000-gallon Isopentane Storage Vessel Rupture/Release	Isopentane	Overpressure of 1 psi	92 yd / 276 ft / 0.052 mi

4.6 Worst-Case Analysis Considerations

The worst-case distances to the flammable endpoints are based on a number of very conservative assumptions. The following summarizes the assumptions:

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- The likelihood of a vessel rupture is extremely low. As a result, the release of entire inventory of a vessel is an unrealistic assumption.
- An overpressure of 1 psi is unlikely to have serious direct effects on people. This overpressure may cause property damage such as partial demolition of houses, which can result in injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

5.0 ALTERNATIVE RELEASE SCENARIO

Alternative scenarios are potential releases that may result in consequences whose footprints represented by the endpoints could extend beyond the plant boundary. For a release case to be considered an alternative scenario, two conditions must be met:

1. The likelihood of the alternative release scenarios should be higher than that of the worst-case release scenarios.
2. The distance to endpoint from an alternative release scenario must go beyond the plant fence line.

As put forth in Title 40 CFR Section 68.28(a):

> *The owner or operator shall identify and analyze…at least one alternative release scenario to represent all flammable substances held in a covered process*

Title 40 CFR Section 68.28 (b)(2) defines the scenarios typically considered, but not limited to, the following:

> *(i) Transfer hose releases due to splits or sudden hose uncoupling;*
>
> *(ii) Process piping releases from failures at flanges, joints, welds, valves and valve seals, and drains or bleeds*
>
> *(iii) Process vessel or pump release due to cracks, seal failure, or drain, bleed, or plug failure; and*
>
> *(iv) Vessel overfilling and spill, or over pressurization and venting through relief valves or rupture disks.*
>
> *(v) Shipping container mishandling and breakage or puncturing leading to a spill.*

For alternative release scenarios, active mitigation systems, such as interlocks, shutdown systems, pressure relieving devices, flares, emergency isolation systems, and fire water and deluge systems, as well as passive mitigation systems are considered, if they were applicable. In order to be credited, the mitigation systems considered must be capable of withstanding the event that triggers the release while remaining functional.

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5.1 Alternative Release Scenario Selection Process

The process of alternative release scenario identification is summarized as follows and depicted in Figure 4.

- **Selection of Candidate Alternative Release Scenario:** The process of alternative release scenario identification was initiated with the review of the worst-case release case. Additional vessels, containing various quantities of regulated substances, which considered having a higher likelihood of release, were then reviewed. In this process, all covered processes were reviewed and the candidate case for the alternative release scenario analysis was subsequently selected. The following criteria was utilized to identify the potential scenario:
    - Corrosion history and corrosive services
    - Past incidents and near misses
    - Potential equipment failure
    - Operating conditions
    - Potential for human error
    - Consequences considered in the unit Process Hazard Analysis
- **Analysis of the Selected Alternative Release Scenario:** Once the candidate scenario was selected, ALOHA was utilized to model the selected scenario. The vulnerability zone resulting from the analysis of the alternative release scenario was then reviewed. The release duration was limited by the length of time to release the entire contents of the single Isopentane Storage Vessel.
- **Alternative Release Scenario**: The alternative release scenario for the flammable substance was selected and modeled to evaluate potential offsite impacts. Documentation of this scenario included modeling calculations, parameters and assumptions.

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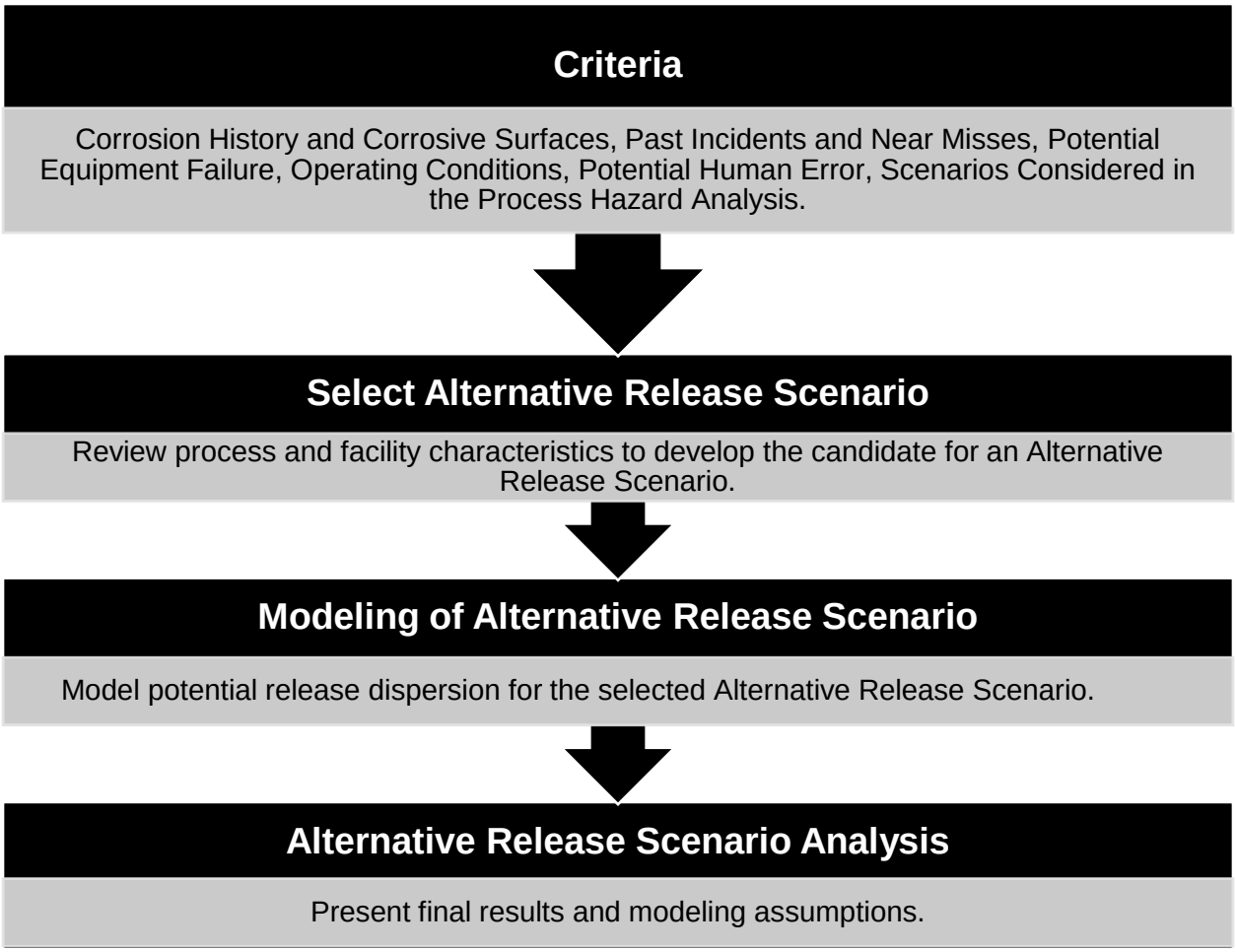
Figure 4: Alternative Release Scenario Selection Process



5.2 Modeling Assumptions

The EPA RMP regulation does not impose any mandatory assumptions for the OCA of the alternative release scenario. All dispersion modeling parameters utilized in the alternative release scenario modeling are listed in Table 6. For the alternative release scenario, a release due to a break in the product transfer hose connection during truck loading has been considered. Appendix B of this report provides a detailed description of the worst-case release scenario, ALOHA modeling output, MARPLOT 5.1.1 output with population estimates, and a map with the vulnerability zone denoted by a circle superimposed on the map.

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Table 6: Alternative Release Scenario Dispersion Modeling Parameters

Parameter	Input Value	Notes
Isopentane Input Parameters		
Quantity Released	46,260 lbs.	The most likely alternative release scenario involves the uncoupling of a transfer hose during truck loading operations. Calculations shown in Appendix B.
Release Rate	19,468 lbs./min	Calculations shown in Appendix B.
Release Duration	2.4 mins	The release duration is limited by the quantity stored in a single Isopentane Storage Vessel (9,000 gallons).
Meteorological Parameters		
Atmospheric Stability	D stability	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, “this guidance assumes wind speed of 3 meters per second and D stability”
Wind Speed	3.0 m/s	
Wind Direction	W	Wind Direction from the west based on the Wind Rose plot for Imperial, CA (closest city with wind rose plot available). Since the endpoint distance and circle of interest is presented in this report, the wind direction does not impact the analysis/distance to endpoint and instead is a generic input that ALOHA modeling software requires.

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Parameter	Input Value	Notes
Measurement Height above Ground	10 m	Wind speed is assumed to be measured at this elevation, as this is the standard height at which the National Weather Service usually reports wind speed.
Ambient Temperature	77ºF (25°C)	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, "this guidance assumes 25ºC and 50 percent humidity"
Relative Humidity	50%	
Dispersion and Impact Modeling Parameters		
Height of Release	Ground Level	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, "this guidance assumes a ground-level release"
Topography/Surface Roughness	Open Country	Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations.
Level of Congestion	Congested	The level of congestion was assumed to be congested, which is a conservative assumption since greater turbulence (greater congestion) allows the flame front to accelerate, thereby generating a more powerful blast wave (i.e., greater overpressure). The immediate area within the facility is also considered to be congested with piping and equipment.

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Parameter	Input Value	Notes
Isopentane Mitigation System		
Passive Mitigation	Secondary Containment Area	The amount released from the alternative release scenario is assumed to release into a concrete secondary containment area, which is contained around each storage vessel. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (Surface area = 480 ft^2).
Active Mitigation	None	

5.3 Alternative Release Scenario

A summary of the alternative release scenario is presented in Table 7. Appendix B of this report provides a detailed description of the alternative release scenario, ALOHA modeling outputs, MARPLOT 5.1.1 outputs with population estimates, and a map with circles representing the vulnerability zones.

Table 7: Alternative Release Scenario Result Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
ARS: Transfer Hose uncoupling from 10,000-gallon Isopentane Storage Vessel during Truck Loading Operations	Isopentane	Overpressure of 1 psi	57 yd / 171 ft / 0.032 mi

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5.4 Alternative Release Analysis Considerations

Typically, the same conservative assumptions apply for the alternative release analysis as for the worst-case release analysis. Although the alternative release scenario is intended to be more likely than the worst-case release scenario, the analysis of the alternative release scenario should not be expected to provide a realistic estimate of an area in which off-site impact may occur. The same conservative endpoints have been used for both the worst-case and the alternative release analysis. These endpoints are intended to represent exposure levels below which most members of the public will not experience serious long-term health effects.

6.0 OFFSITE IMPACTS

A summary of the off-site impacts from an accidental release, including population and sensitive receptors, is discussed in the following sub-sections.

6.1 Impacted Population

In order to determine the impacted population around the facility, the potential for exposure within the endpoint was determined. The furthest endpoint distances reached by the worst-case scenario and alternative release scenario along with the estimated impacted population are summarized in Table 8:

Table 8: Impacted Population for OCA Scenarios

SCENARIO	ENDPOINT DISTANCE	ESTIMATED IMPACTED POPULATION
WCS: 10,000-gallon Isopentane Storage Vessel Rupture/Release	92 yd / 276 ft / 0.052 mi	0
ARS: Transfer Hose uncoupling from 10,000-gallon Isopentane Storage Vessel during Truck Loading Operations	57 yd / 171 ft / 0.032 mi	0

The population was estimated using 2010 census tract data with the MARPLOT 5.1.1 software. When calculating population densities for large areas that encompass many tracts, the accuracy

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is rated as good; however, for small areas that encompass only two or three partial tracts, the population data may be skewed due to the unequal distribution within the tract. The use of MARPLOT 5.1.1 is pursuant to guidance endorsed by the US EPA. MARPLOT 5.1.1 requires the latitude and longitude of the facility in order to calculate the population. The latitude and longitude were estimated using Google Earth GPS[7] software and an aerial photo. In consideration of the unique case of bystanders along facility boarders during a vapor cloud explosion, vessels are placed far enough within company fencing that surrounding walkways and streets are free of severe impacts.

6.2 Offsite Sensitive Receptor Data Sources

Table 9 includes a list of websites and software used to locate offsite sensitive receptors. A few sites will perform a distance search in order to determine the eligibility of a possible receptor. For all other sites, a map interpolation determines whether the receptor falls within the circle of concern.

Table 9: Websites and Software Used

SOURCE	RECEPTORS THIS SOURCE IS USED TO IDENTIFY	METHOD OF DETERMINING ELIGIBILITY
Google Maps[8]	Used to identify all receptors	Distance search in conjunction with a map interpolation
Google Earth	This mapping software is used to locate all receptors. It also incorporates an internet search with the map to locate businesses.	Software will map the location of the receptor.

6.3 Offsite Sensitive Receptors

RMP requirements state that sensitive populations such as schools, hospitals, day-care centers, long-term health care facilities, prisons, residential areas, public use parks/recreational areas, and major commercial facilities, located within the “at risk” area must be identified. These sensitive

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populations include individuals who could not remove themselves from the exposure area without assistance. The sensitive populations also include industrial installations which may have a hazardous process that cannot be immediately left unattended. According to the EPA's General Risk Management Plan Guidance [9], "The basic test for identifying a public receptor is thus whether an area is a place where it is reasonable to expect that members of the public will routinely gather at least some of the time. Roads and parking lots are not included as such in the definition of 'public receptor.' Neither are places where people typically gather; instead, they are used to travel from one place to another or to park a vehicle while attending an activity elsewhere." Table 10 shows a summary of offsite population receptors and offsite environmental receptors for isopentane, within the circle of concern as determined by the worst-case and alternative release scenarios.

Table 10: Summary of Sensitive and Environmental Receptors

RECEPTOR	WCS (0.052 MI)	ARS (0.032 MI)
Population Receptors		
Schools	No	No
Residences	No	No
Hospitals	No	No
Prisons/Correction Facilities	No	No
Recreation Areas	No	No
Major Commercial, Office, or Industrial Areas	No	No
Child Daycare	No	No
Long-term Health Care (e.g., convalescent homes)	No	No
Other (Government Buildings)	No	No
Environmental Receptors		

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RECEPTOR	WCS (0.052 MI)	ARS (0.032 MI)
National or State Parks, Forests, or Monuments	No	No
Officially Designated Wildlife Sanctuaries, Preserves, or Refuges	No	No
Federal Wilderness Areas	No	No
Other (Landmark & Indian Reservations)	No	No

7.0 WORST-CASE RELEASE AND ALTERNATIVE RELEASE SCENARIO SUMMARY

The following sections outlines a summary of the parameters used for the one worst case release scenario and the one alternative release scenario analyzed for the Heber 2 Repower project.

7.1 Worst-Case Scenario

The worst-case scenario evaluated the release of the entire contents of one of the six 10,000-gallon isopentane storage vessels, containing 9,000 gallons of isopentane. The following table provides a summary of the parameters used for the worst-case scenario and the corresponding inputs.

Table 3: Worst-Case Scenario Parameter/Input Summary

Worst-Case Scenario	
Chemical	Isopentane
Model Used	ALOHA
Scenario	Vapor Cloud Explosion
Quantity Released (gal)	9,000 gallons
Endpoint Used	Overpressure of 1 psi
Distance to Endpoint	92 yd / 276 ft / 0.052 mi

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Worst-Case Scenario	
Estimated Residential Population within Distance to Endpoint (numbers)	0
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No
Other	None
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Secondary Containment Area	Yes
Other	No

7.2 Alternative Release Scenario

It was determined that a release due to a break in the isopentane transfer hose connection during truck loading, was the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. The following table provides a summary of the parameters that were used for alternative release scenario and the corresponding inputs.

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Table 4: Alternative Release Scenario Parameter/Input Summary

Alternative Release Scenario	
Chemical	Isopentane
Model Used	ALOHA
Scenario	Vapor Cloud Explosion
Quantity Released	46,260 lbs.
Endpoint Used	Overpressure of 1 psi
Distance to Endpoint	57 yd / 171 ft / 0.032 mi
Estimated Residential Population within Distance to Endpoint (numbers)	0
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No
Other	None
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Secondary Containment Area	Yes

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Alternative Release Scenario	
Other	No
Active Mitigation Considered	
Sprinkler Systems	No
Deluge Systems	No
Water Curtain	No
Excess Flow Valve	No
Other	No

8.0 FIVE YEAR ACCIDENT HISTORY

There have been no applicable CalARP/RMP/PSM releases of isopentane at the facility within the last five years, therefore, this section is not applicable.

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9.0 REFERENCES

1. Code of Federal Regulations (CFR), Title 40, Chapter I, Subchapter C, Part 68, Subpart B, Sections 68.20 to 68.42, “Hazard Assessment”; 2015, January 1.
2. California Code of Regulations (CCR), Title 19, Division 2, Chapter 4.5, Article 4, Sections 2750.1 to 2750.9, “Hazard Assessment”; 2015, January 1.
3. Areal Locations of Hazardous Atmospheres - ALOHA Version 5.4.7, U.S. Environmental Protection Agency, September 2016. http://www2.epa.gov/cameo/aloha-software
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7. Google ™ Earth, version 7.3.2.5776, Google, Inc. (2019)
8. Google ™ Maps, Google, Inc. (2019)
9. General Risk Management Program Guidance – Chapter 2: Applicability of Program Levels, U.S. Environmental Protection Agency, April 2004.

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APPENDIX A
WORST-CASE SCENARIO CALCULATIONS

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WORST-CASE SCENARIO (WCS)

The selected worst-case release scenario analyzes the hypothetical rupture of any one of the 10,000-gallon isopentane vessels, new or existing. Any one vessel can store up to 9,000 gallons of isopentane, taking into account administrative controls, which are in place to limit the quantity stored in each tank. Per requirement of the EPA rule for flammable substances, it was assumed that the whole quantity is released. The entire quantity is released into the secondary containment area, which is credited as a passive mitigation measure, to form an evaporating puddle, for which the vapors form a vapor cloud. If this vapor cloud ignited, the resultant blast could generate overpressure damage. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (surface area = 480 ft^2), and it assumed the secondary containment area ground type is concrete.

The ALOHA modeling calculation predicts that the area impacted by the endpoint, which is an overpressure of 1 psi, is a circle with approximately a 92-yard radius (276 ft / 0.052 mi). According to MARPLOT 5.1.1, there are 0 residents and 0 housing units within this vulnerability zone for all six vessels. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the ALOHA modeling output, as well as the MARPLOT results. These figures demonstrate Ormat's strategic placement of new storage vessels, showing that one explosion and release of all isopentane contents would not affect the other as demonstrated in the following figures. Each of the new vessels are at least 184 yards (twice the radius of concern) from one another and do not reach any of the three existing vessels. Only vessels 4 and 5 withhold the potential to experience interacting explosion impacts and has been addressed with the future implementation of a blast wall. This barrier will serve as a separation mechanism to prevent the explosion area of one vessel from triggering the release and ignition of the other.

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Figure 5: WCS ALOHA Modeling Results

```
SITE DATA:
  Location: HEBER, CALIFORNIA
  Building Air Exchanges Per Hour: 0.20 (unsheltered double storied)
  Time: September 14, 2020  1158 hours PDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: ISOPENTANE
  CAS Number: 78-78-4                    Molecular Weight: 72.15 g/mol
  PAC-1: 3000 ppm    PAC-2: 33000 ppm    PAC-3: 200000 ppm
  LEL: 14000 ppm     UEL: 76000 ppm
  Ambient Boiling Point: 82.1° F
  Vapor Pressure at Ambient Temperature: 0.91 atm
  Ambient Saturation Concentration: 904,803 ppm or 90.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 77° F
  Stability Class: F (user override)
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Evaporating Puddle (Note: chemical is flammable)
  Puddle Area: 480 square feet           Puddle Volume: 9000 gallons
  Ground Type: Concrete                  Ground Temperature: 122° F
  Initial Puddle Temperature: Air temperature
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 119 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 5,079 pounds

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Heavy Gas
  Red    : LOC was never exceeded --- (8.0 psi = destruction of buildings)
  Orange: 52 yards --- (3.5 psi = serious injury likely)
  Yellow: 92 yards --- (1.0 psi = shatters glass)
```


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Figure 6: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #1

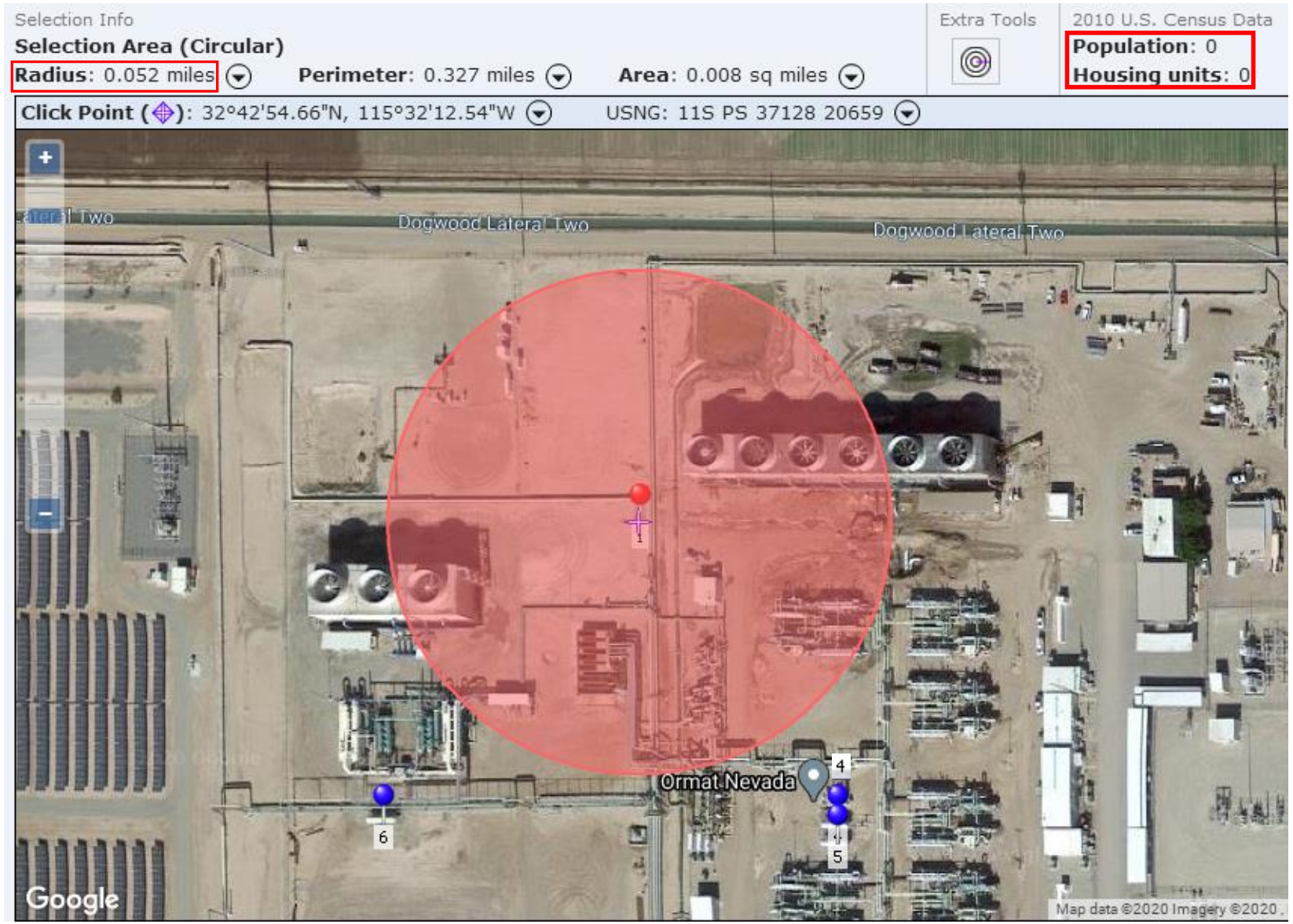

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Figure 7: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #2

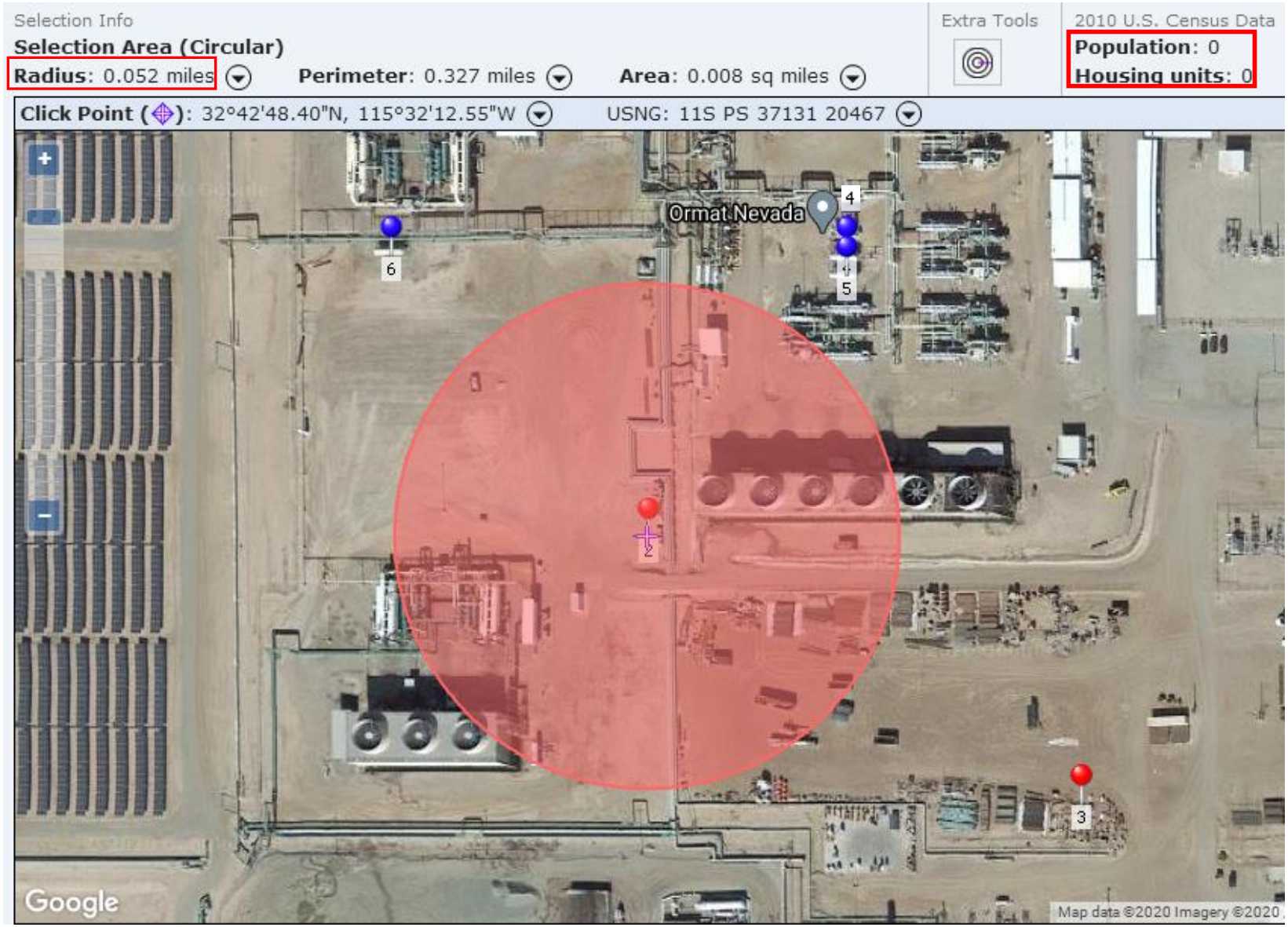

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Figure 8: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #3

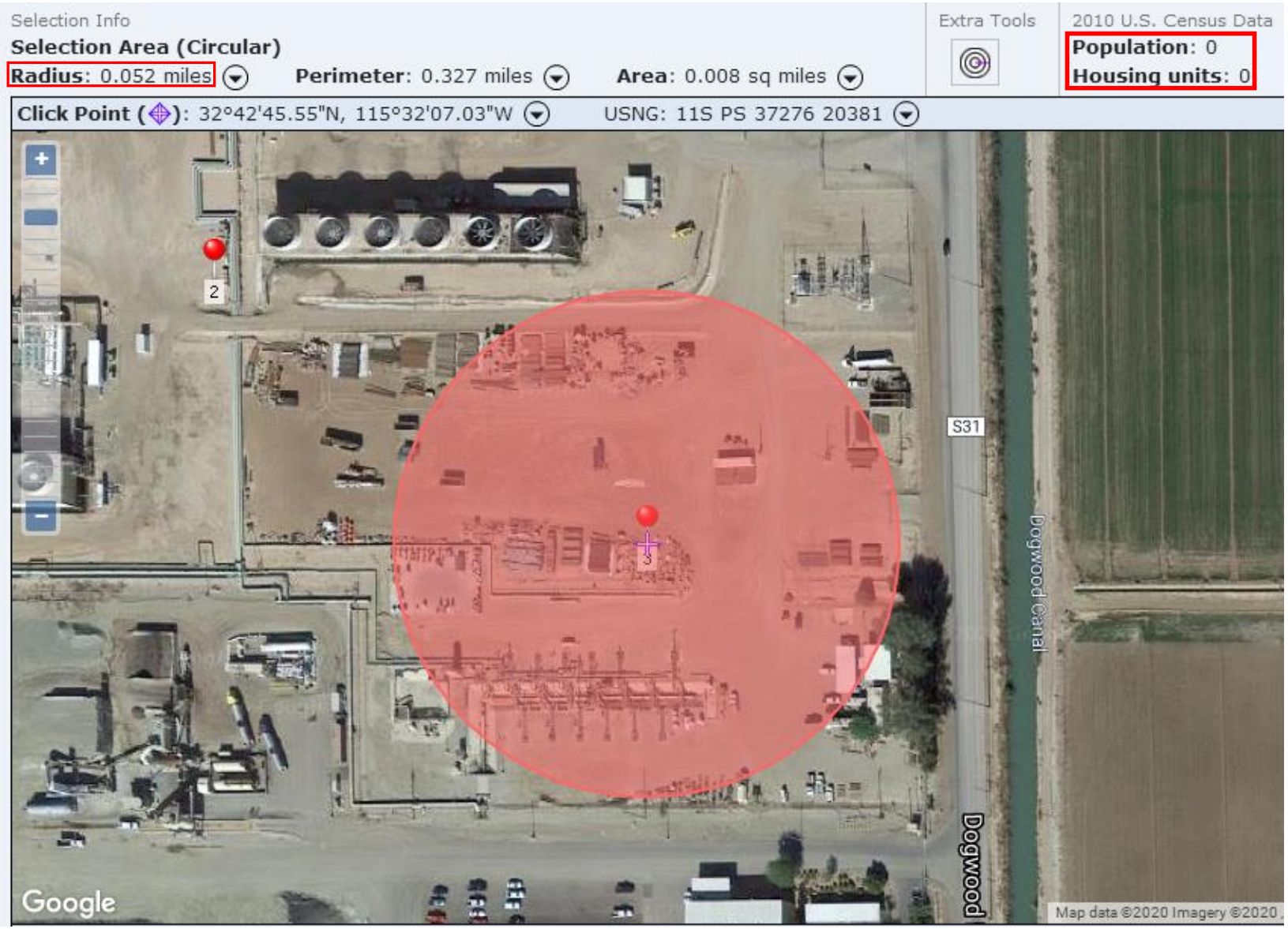

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Figure 9: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #4



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Figure 10: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #5

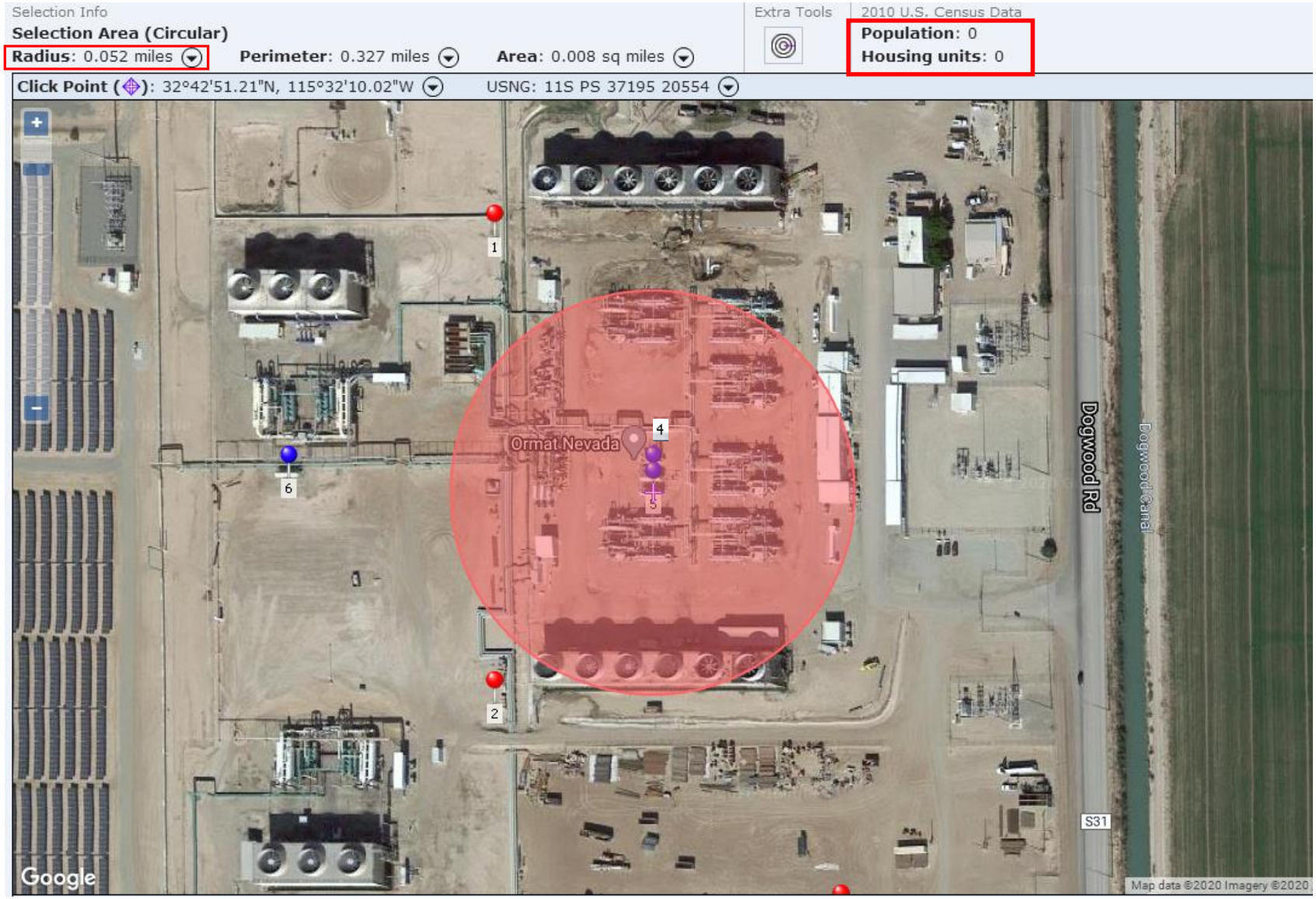

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Figure 11: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #6

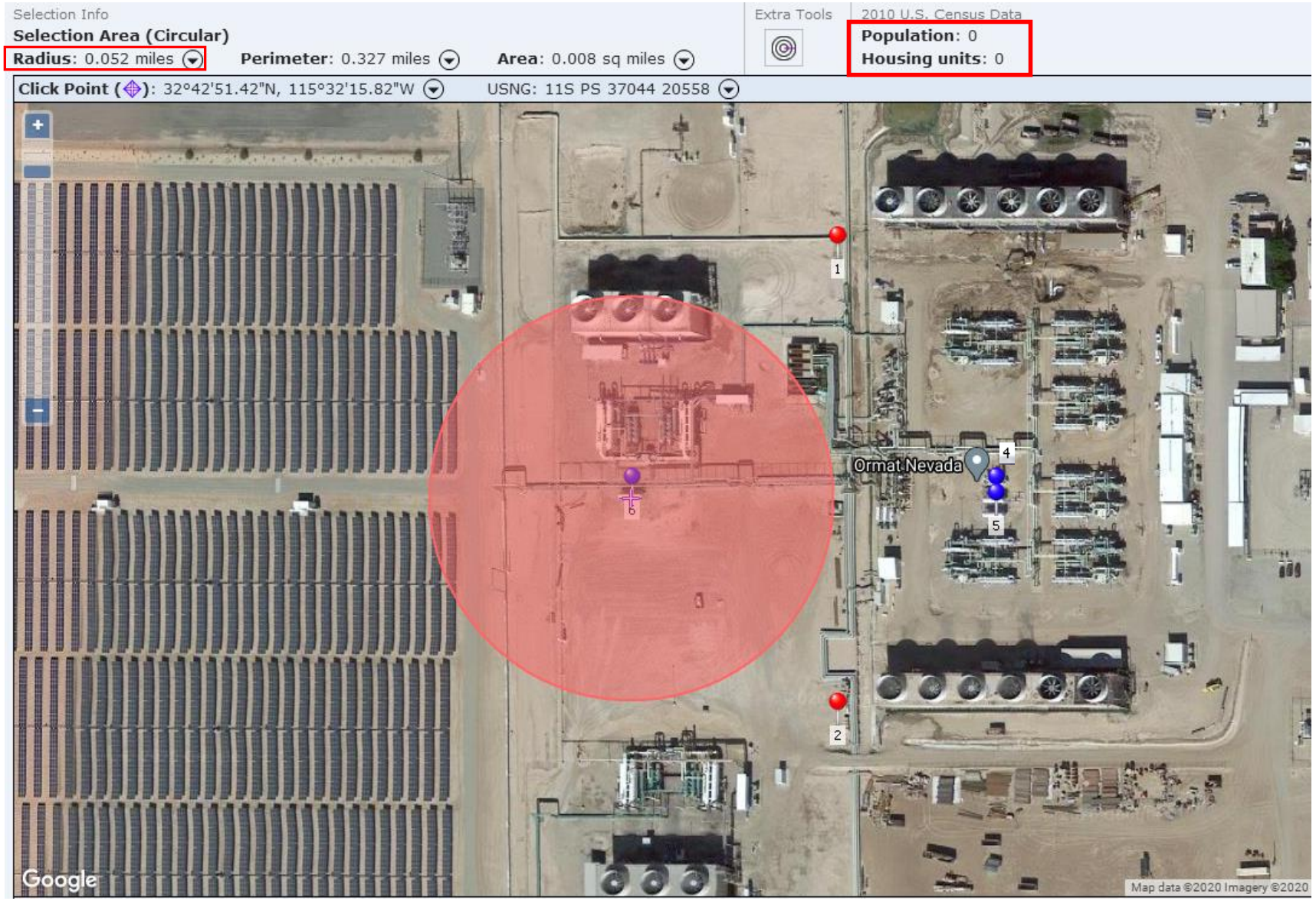

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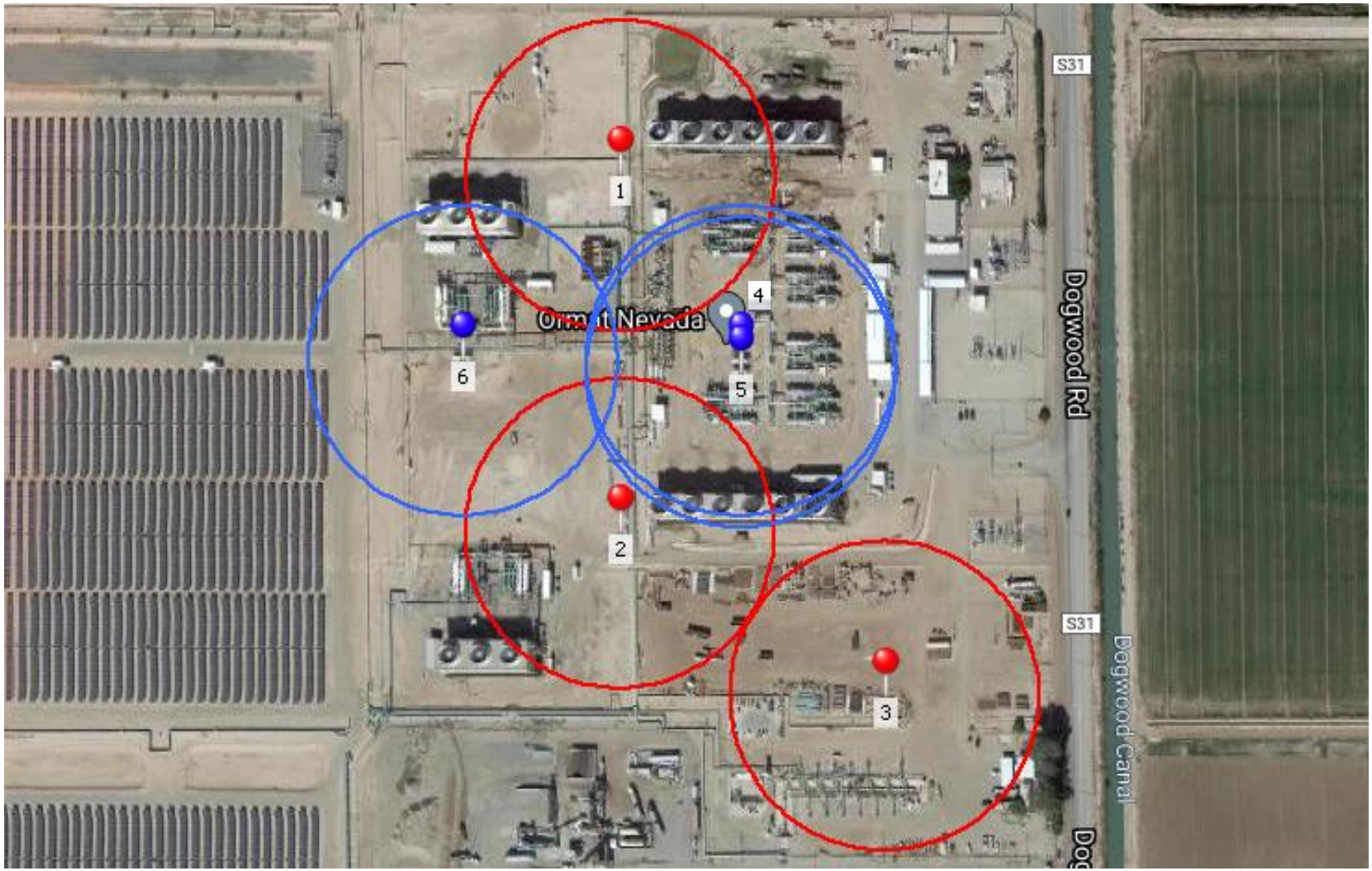
Figure 12: WCS Vulnerability Maps Overlaid for Isopentane Storage Vessels #1, #2, #3, #4, #5, & #6



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APPENDIX B
ALTERNATIVE SCENARIO CALCULATIONS

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ALTERNATIVE RELEASE SCENARIO (ARS)

The selected alternative release scenario is a release due to a break in the product (isopentane) transfer hose connection during truck loading. This was considered the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. It is assumed that the transfer hose uncouples during isopentane transfer operations and that it is released through an area of 12.6 square inches based on the transfer hose size. The release duration is limited by the volume in the Isopentane Storage Vessel (9,000 gallons), which is 2.4 minutes. In the evaluations of this alternative release scenario, the concrete secondary containment area composed was credited as a mitigation measure.

In order to calculate the release quantity for a transfer hose rupture, the release rate through the transfer hose must be calculated. The following equation, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis, illustrates the calculation of the release rate for flammable liquids under pressure through a transfer hose:

$$QR = A_h \times 6.82 \sqrt{\frac{11.7}{DF^2} \times LH + \frac{669}{DF} \times P_g}$$

Where:

- QR = Release rate (lbs./min)
- A_h= Hole or puncture area (square inches)
- DF = Density Factor, dimensionless, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis
- LH = Height of liquid level above hole (inches)
- P_g = Gauge pressure of the vessel (psig)

To calculate the release rate utilizing the above equation, the values for each of the following variables were calculated for isopentane:

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Hole Area

The transfer hose used in isopentane filling operations at both plants is 4 inches in diameter. Thus, the hole area is based upon the transfer hose rupturing and calculated using the following:

$$HA = \pi r^2 = 12.6 \text{ in}^2$$

Density Factor

The Density Factors are obtained from Appendix C of the EPA Risk Management Plan Guidance for Offsite Consequence Analysis. The Density Factor value for isopentane is 0.79.

Liquid Height

The height of the liquid level above the hole is determined by the nominal liquid level in the vessel. The isopentane transfer point is taken to be at the bottom of the tank. Assuming that the isopentane storage vessel is 33% full of isopentane, this equates to 2,970 gallons being stored in the vessel (397 ft^3). This is a conservative assumption as the storage tanks are normally empty and are only used for temporary storage of isopentane. According to the available tank data provided by the facility, the diameter of the Isopentane Storage Vessel is approximately 8 feet and length is 33.5 feet (tangent to tangent length). It should be noted that the Isopentane Storage Vessel is a horizontal vessel. In calculating the height of the liquid column within the tank, the Isopentane Storage Vessel was modeled as a cylinder, and thus the equation for volume of liquid within the tank is that of a horizontal cylinder. The equations below were used to find the height of the liquid column within the Isopentane Storage Vessel:

$$V_L = A_L \times L$$

$$A_L = R^2 \cos^{-1}\left(\frac{R - LH}{R}\right) - (R - LH)\sqrt{2R \cdot LH - LH^2}, \quad \therefore$$

$$V_L = L \times \left[R^2 \cos^{-1}\left(\frac{R - LH}{R}\right) - (R - LH)\sqrt{2R \cdot LH - LH^2}\right]$$

Where:

V_L = Volume of liquid within the Tank (ft^3)

A_L = Area of liquid (ft^2)

R = Radius of the Tank (ft.)

L = Length of the Tank (ft.)

LH = Height of the liquid within the Tank (ft.)

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Values for each variable listed in the equations above are provided below, with the exception of LH, as this is the variable to be calculated:

V_L = 2,970 gallons = 397 ft^3

R = 4 ft.

L = 33.5 ft.

By using the above values within the equation, the height of the liquid column within the Isopentane Storage Vessel can be calculated, which is approximately 2.3 ft (2.2857 ft) or 27.6 inches.

Pressure

The normal operating pressure of the isopentane motive fluid storage tank was identified to be 60 psig.

Modeling

Using these values, the release rate of isopentane can be determined. Please see the calculations below for determining the isopentane release rate:

$$QR = 12.6\ in^2 \times 6.82 \sqrt{\frac{11.7}{(0.79^2)} \times 27.6\ in + \frac{669}{0.79} \times 60\ psig}$$

$$QR = 19{,}468.3955\ \frac{lbs.}{min} \approx 19{,}468\ \frac{lbs.}{min}$$

Over the 2.4 minute release period, this results in a total of 46,260 lbs. released to the secondary containment area to form an evaporating puddle, for which the vapors form a vapor cloud. If this vapor cloud ignited, the resultant blast could generate overpressure damage.

The ALOHA modeling calculation predicts that the area impacted by the endpoint, which is overpressure of 1 psi, is a circle with approximately a 57-yard radius (171 ft / 0.032 mi). According to MARPLOT 5.1.1, there are 0 residents and 0 housing units within this vulnerability zone for all six vessels. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the ALOHA modeling output, as well as the MARPLOT results.

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Figure 10: ARS ALOHA Modeling Results

```
SITE DATA:
  Location: HEBER, CALIFORNIA
  Building Air Exchanges Per Hour: 0.33 (unsheltered double storied)
  Time: September 15, 2020  1152 hours PDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: ISOPENTANE
  CAS Number: 78-78-4                    Molecular Weight: 72.15 g/mol
  PAC-1: 3000 ppm    PAC-2: 33000 ppm    PAC-3: 200000 ppm
  LEL: 14000 ppm     UEL: 76000 ppm
  Ambient Boiling Point: 82.1° F
  Vapor Pressure at Ambient Temperature: 0.91 atm
  Ambient Saturation Concentration: 904,803 ppm or 90.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 3 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 77° F
  Stability Class: D (user override)
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Evaporating Puddle (Note: chemical is flammable)
  Puddle Area: 480 square feet           Puddle Mass: 46260 pounds
  Ground Type: Concrete                  Ground Temperature: 77° F
  Initial Puddle Temperature: Air temperature
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 176 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 6,152 pounds

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Heavy Gas
  Red    : LOC was never exceeded --- (8.0 psi = destruction of buildings)
  Orange: 28 yards --- (3.5 psi = serious injury likely)
  Yellow: 57 yards --- (1.0 psi = shatters glass)
```


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Figure 13: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #1

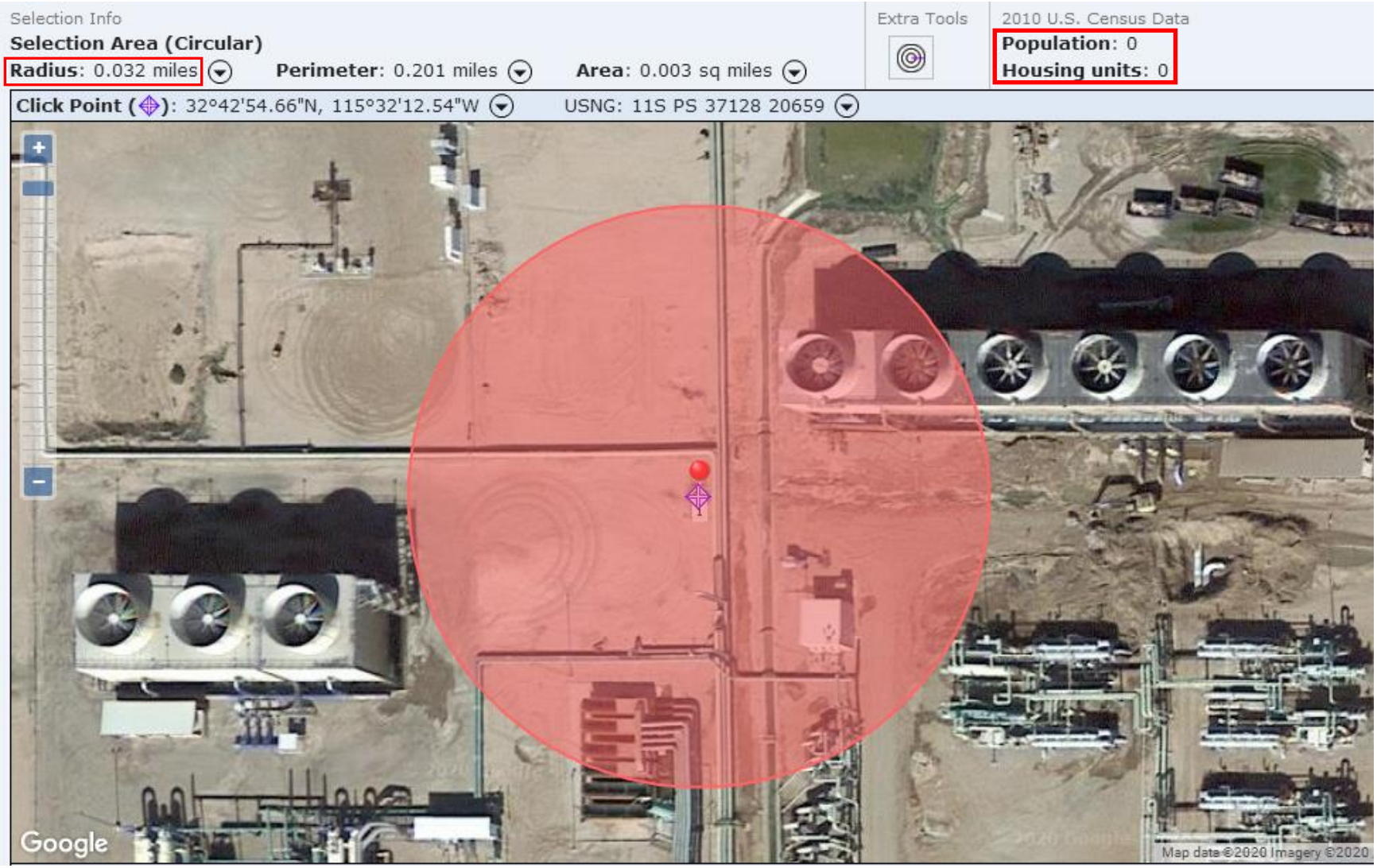

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Figure 14: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #2

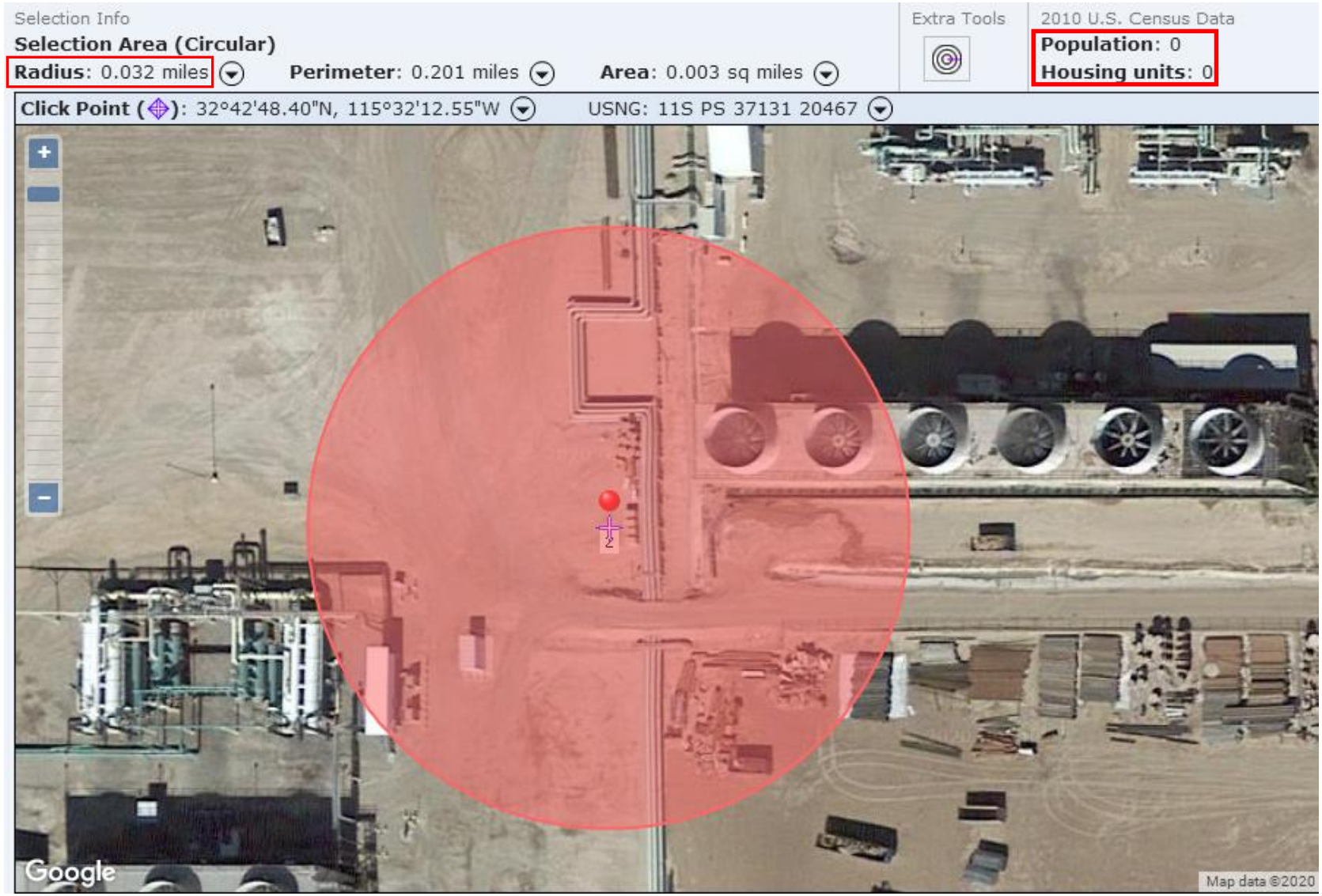

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Figure 15: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #3

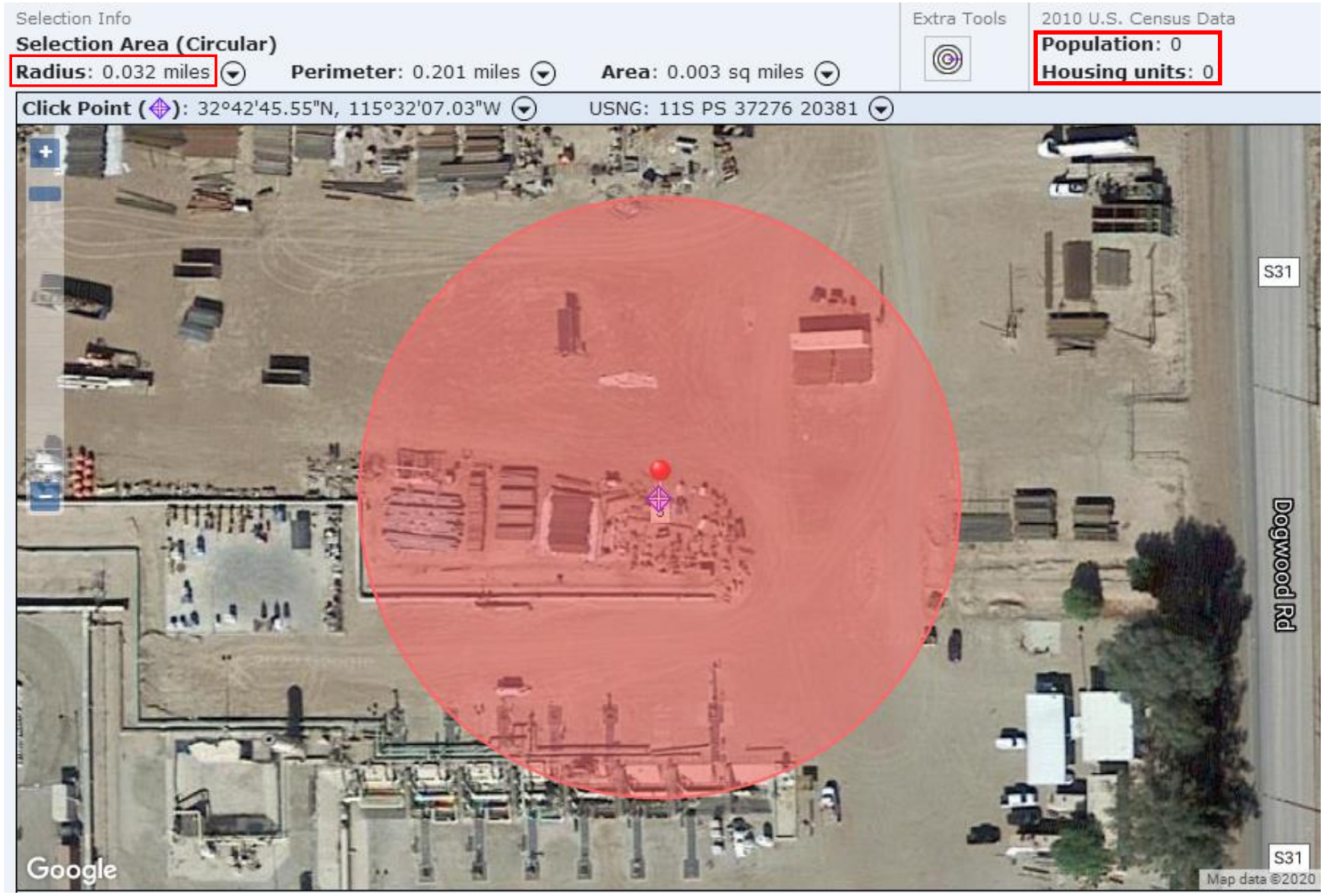

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Figure 16: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #4

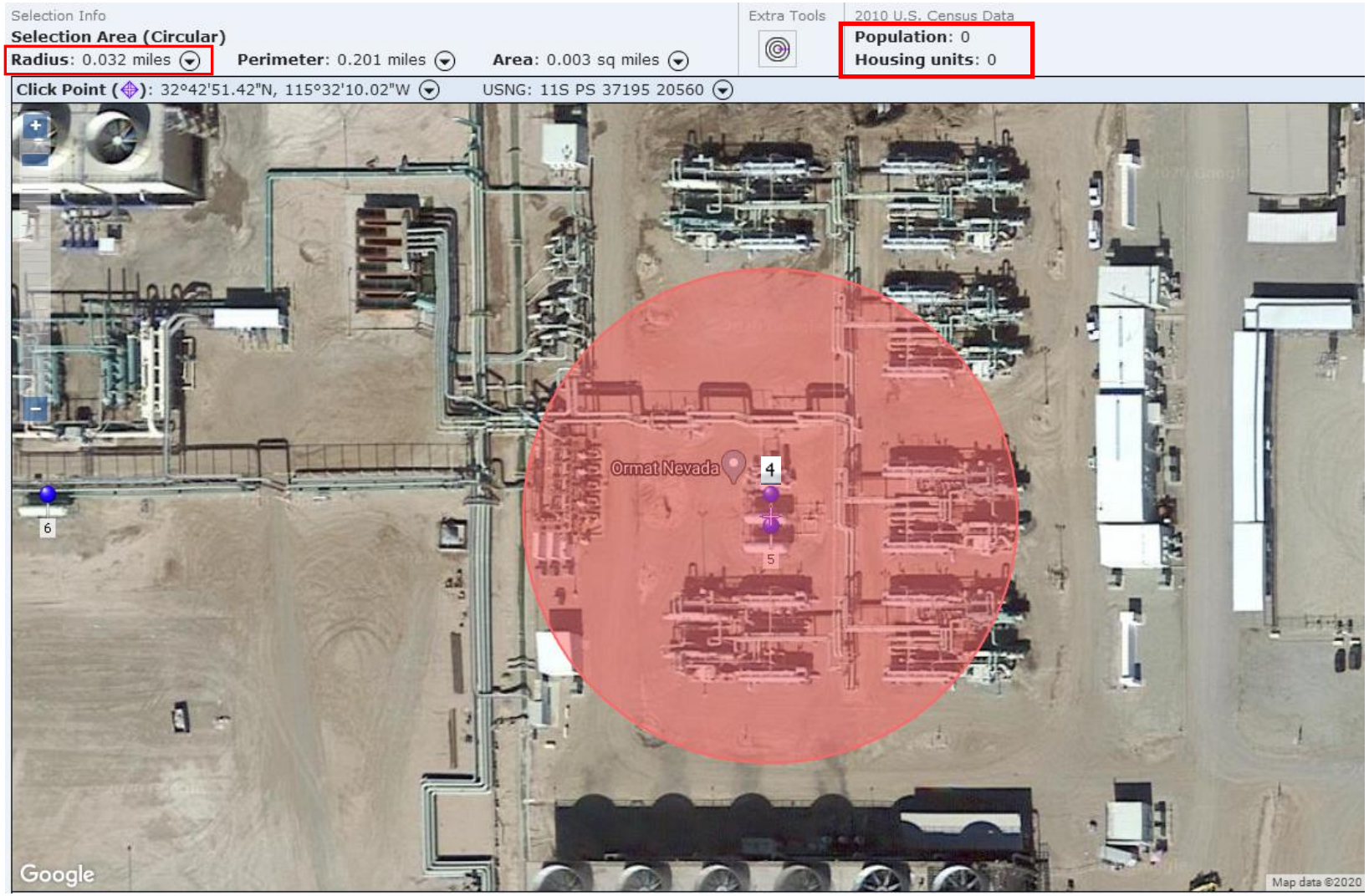

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Figure 17: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #5

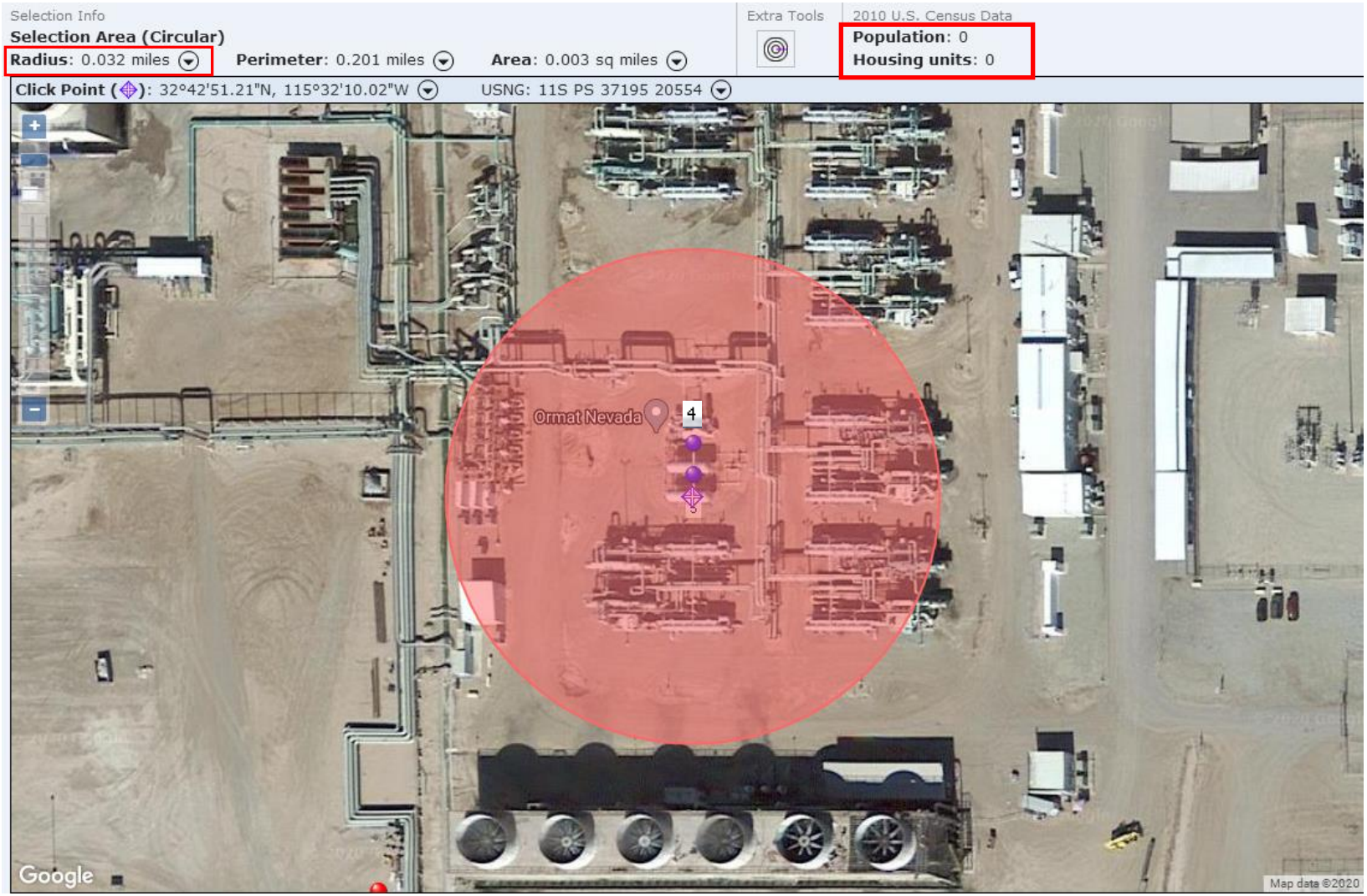

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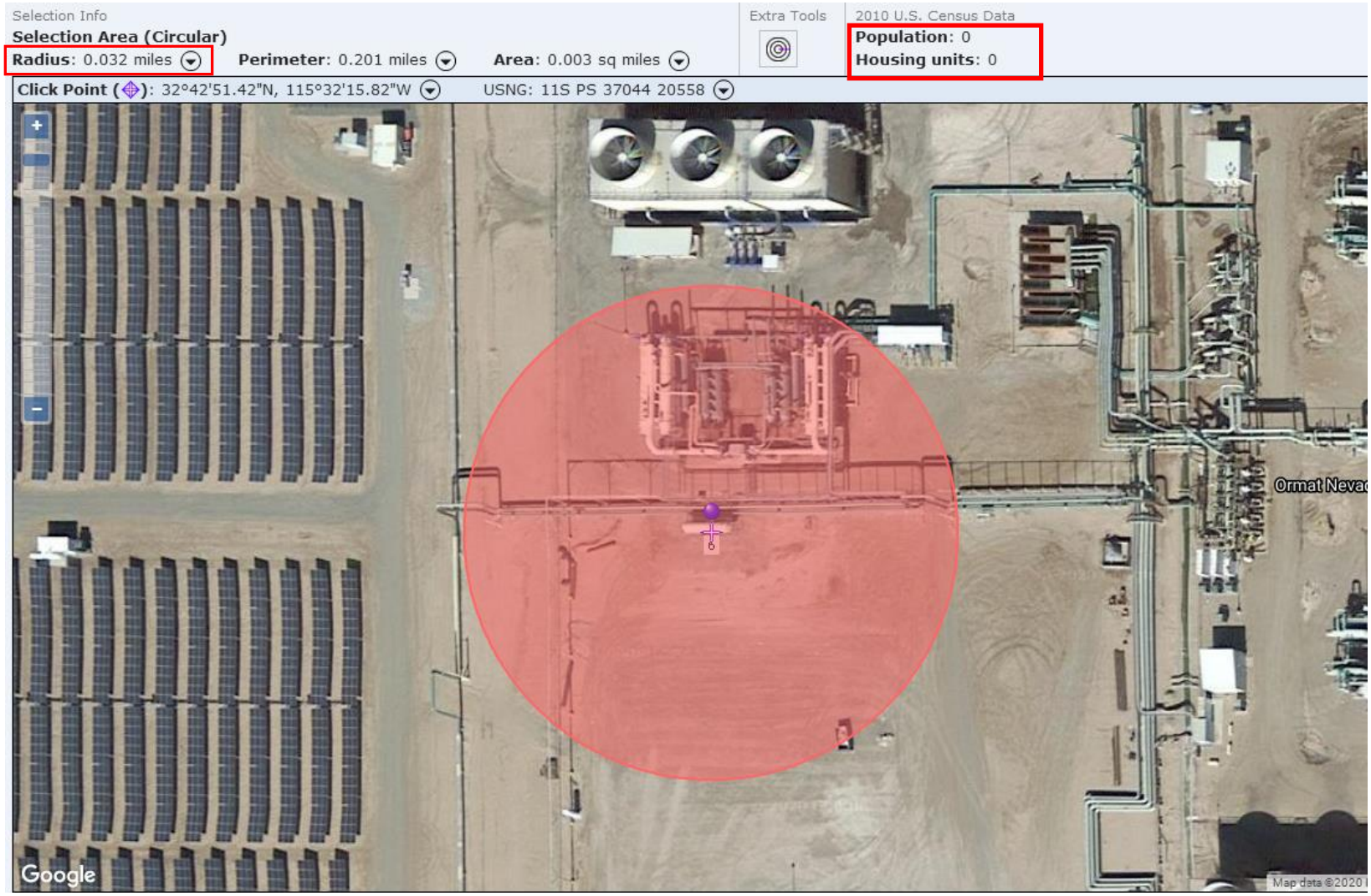
Figure 18: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #6



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Attachment A

Table of Present and Proposed Geothermal Energy Generation by Unit at the Heber 2 Complex

Catalyst
ENVIRONMENTAL SOLUTIONS

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Present and Proposed Geothermal Energy Generation by Unit at the Heber 2 Complex

Heber 2 Complex Generation Unit	Current Net Generation (MW)	Current Gross Generation (MW)	Proposed Net Generation (MW)	Proposed Gross Generation (MW)
Heber 2	11 MW	22 MW	27 MW	39 MW
Heber South	9 MW	12 MW	9 MW	12 MW
Goulds 2	8 MW	10 MW	8 MW	10 MW
TOTAL HEBER 2 COMPLEX	**28 MW**	**44 MW**	**44 MW**	**61 MW**

Proposed new generation: 16 MW (net), 17 MW (gross); all to occur through repowering the Heber 2 unit with no changes to Heber South and Goulds 2.

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Attachment B

Site Plan with Adjusted Isopentane Tank Locations

Catalyst
ENVIRONMENTAL SOLUTIONS

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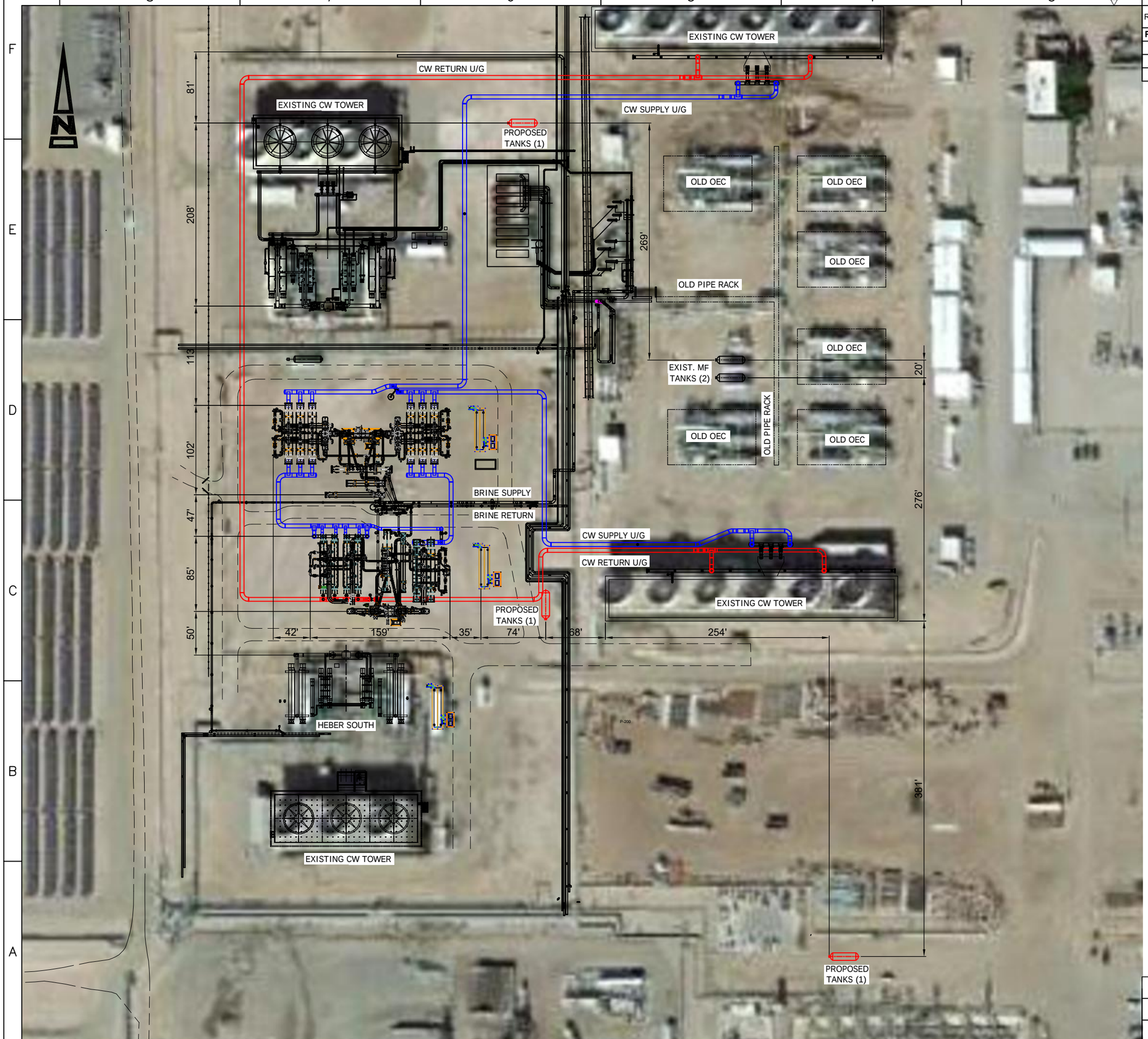

REV	DESCRIPTION	DATE	BY	CHK	ENG	PRJ
P1	PRELIMINARY	16.SEP.2020	S.S.		A.S.	S.H.

NOTE:

1. THE ARRANGEMENT AND SIZES PRESENTED ARE PRELIMINARY AND INDICATIVE ONLY AND SUBJECT TO CHANGED ON DESIGN OPTIMIZATION , DETAILED DESIGN AND ACTUAL EQUIPMENT PURCHASED (MANUFACTURED).
2. DIMENSIONS ARE IN MM [FEET], ELEVATIONS ARE IN MM FEET]

0 100' 200' 300'

GRAPHIC SCALE (FEET)

APPROVED: A.S.
CHECKED:
DESIGNER: S.S. 16.JAN.2020

ORMAT

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TITLE: HEBER II REPOWER
GENERAL ARRANGEMENT
POWER PLANT ON MAP

DRAWING NO. 7.910.00.001.0 | SHEET 1 OF 1 | REV. P1

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Attachment C

Hazard Memorandum and Hazard Assessment

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MEMO

To: County of Imperial

From: Chambers Group, Inc.

Date: 9/23/20

RE: Hazards Associated with Proposed Isopentane Storage at the Heber 2 Facility in Heber, CA

Chambers Group, Inc. has prepared the following transmittal to accompany the attached Updated Hazard Assessment addressing the storage of the regulated substance, isopentane, on the Heber 2 Repower Project site in Heber, California. Risk Management Professionals, Inc. (RMP), produced an initial Hazard Assessment for the Heber 2 Repower Project on July 10, 2019 and revised on October 18, 2019 to address potential hazards associated with isopentane. Following comments from the public expressing safety concerns, RMP produced an updated Hazard Assessment using a more precise modeling software, incorporating a concrete containment area as passive mitigation, and rearranging the new vessels into a safer layout. Both technical assessments were conducted in compliance with the Hazard Assessment Offsite Consequence Analysis requirements of the Environmental Protection Agency (EPA) "Risk Management Plan" regulations (40 CFR § 68.65) and California Code of Regulations "California Accidental Release Prevention (CalARP) Program" (19 CCR 2750.1 to 2750.9).

RMP has developed an updated worst-case modeling scenario for the isopentane proposed to be stored at the Heber 2 facility. According to the EPA Risk Management Plan regulations, the worst-case release is defined as "the release of the largest quantity of a regulated substance from a vessel failure that results in the greatest distance to a specified endpoint" (40 CFR § 68.3). To determine the worst-case release quantity, the EPA regulations dictate "for substances in vessels, you must assume of the release largest amount in a single vessel" (40 CFR § 68.25). In compliance with these regulations, RMP modeled the worst-case scenario as the catastrophic failure of one 10,000-gallon isopentane storage vessel. With the incorporation of a concrete containment area as passive mitigation, the endpoint radius resulting from the release of one vessel was determined to stay within the property boundary and not to reach any new or existing vessels. The EPA's Offsite Consequences Analysis process is recognized by professionals in the field as being highly conservative.

In addition to being consistent with EPA regulations, the modeling provided represents a sufficient worst-case scenario to be utilized in emergency planning and impact analysis. During normal operations, the isopentane tanks are not filled to capacity; in fact, they are rarely filled. Isopentane is used only as backup fuel during plant outages, which occur up to approximately one week per year. Therefore, a quantity of isopentane in excess of the quantity modeled occurs less than 2 percent of the entire year. The remaining over 98 percent of the year, at most the tanks are partially filled to approximately 15 percent capacity or alternatively, only one tank is completely full, and the remaining tanks are empty. Further, the modeling incorporates extremely conservative assumptions with regards to atmospheric conditions which further provide an analysis that would cover an extreme catastrophic event.

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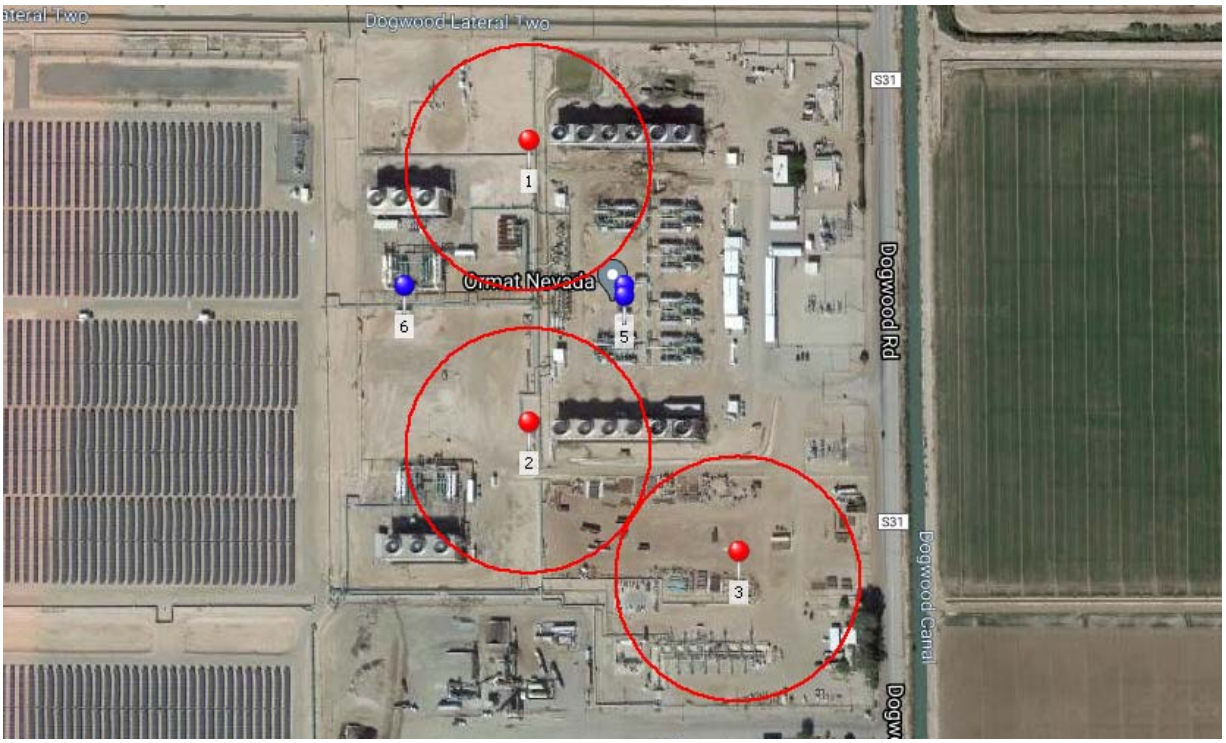
Moreover, Ormat will implement several safety- control measures into the isopentane storage system that would further reduce the potential for both initial tank failure and multi-tank failure:

- Each tank will be equipped with an automated water suppression system.
- Each tank will be equipped with two flame detectors and one gas detector (for a total of 6 flame detectors and 3 gas detectors for the three tanks).
- In the case of an isopentane leak, the gas detector(s) will detect it immediately and send a notification to the operator at the control room (manned 24/7) in order to mobilize fixing the leak.
- In case of a fire, the flame detector(s) will detect it and immediately start the automatic fire suppression system.
- In case of a fire, there will also be a horn and strobe system that will turn on automatically to alert the plant employees.

Due to the conservative Offsite Consequences Analysis process; taking into consideration:

- a concrete containment area as passive mitigation,
- vessels rarely filled to 90% capacity,
- and isopentane safety- control measures,

areas of concern are limited to inside facility boarders, thus producing zero sensitive receptors. Furthermore, Ormat can go as far as to say that according to the figure below, the explosion area of one new vessel (red) will not reach any of the existing vessels (blue), nor overlap with the explosion area resulting from the other new vessels.



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ORMAT, HEBER 2
GEOTHERMAL POWER GENERATION FACILITIES
HEBER, CALIFORNIA

Hazard Assessment

Revision	Date	Description
0.0	September 24, 2020	Initial Issue – Concrete Secondary Containment Area and Relocating New Storage Vessels

Risk Management Professionals, Inc.
Two Venture Plaza, Suite 500, Irvine, California 92618
Phone: 949-282-0123 – E-mail: Client.Services@RMPCorp.com

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Appendix A: Worst-Case Scenario Calculations

Appendix B: Alternative Case Scenario Calculations

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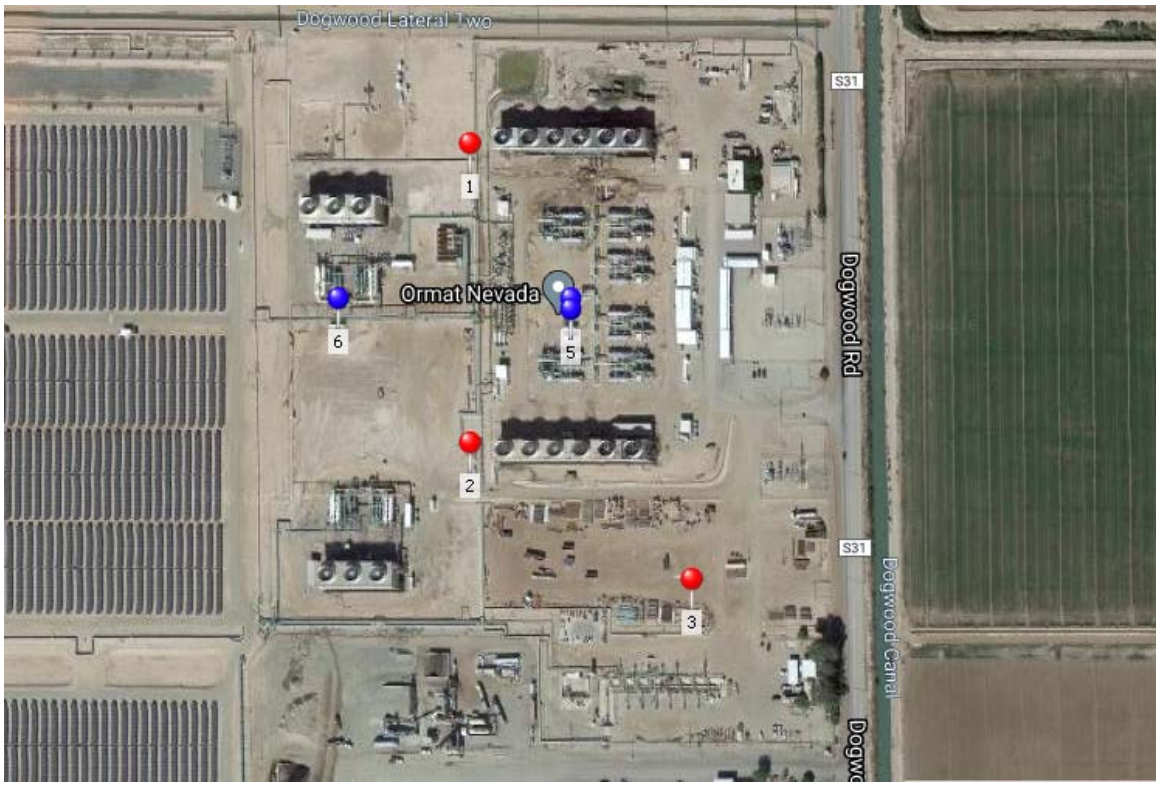
1.0 FACILITY OVERVIEW

This technical assessment was conducted to fulfill the Hazard Assessment Offsite Consequence Analysis (OCA) requirements of the following regulations:

- 40 CFR §68.65 – Environmental Protection Agency (EPA) "Risk Management Plan (RMP)"[1]
- 19 CCR 2750.1 to 2750.9 – California Code of Regulation "California Accidental Release Prevention (CalARP) Program"[2]

This assessment is completed for the **Ormat– Heber 2 Geothermal Complex** Facility located in Heber, California. The facility's location at 855 Dogwood Road, Heber, CA 92249 is illustrated in Figure 1 below. The blue markers depict the locations of the three existing 10,000-gallon vessels and red markers for three new 10,000-gallon isopentane vessels that are being added to the facility as part of the Repower project. The coordinates for each vessel's location are presented in Table 1 and Table 2 on the following page.

Figure 1: Aerial View of the Facility Location



The following page presents a closer view of the facility's storage vessel locations, as well as tables displaying the approximate locations of the three new and three existing storage vessels.

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Figure 2: Aerial View of the Storage Vessel Locations



Table 1: Ormat—Heber 2 New Storage Vessel Coordinates

NEW VESSELS	FORMAT	LATITUDE	LONGITUDE
Isopentane Vessel 1	Degrees/Minutes/Seconds	32°42'54.66"N	115°32'12.54"W
Isopentane Vessel 2	Degrees/Minutes/Seconds	32°42'48.40"N	115°32'12.55"W
Isopentane Vessel 3	Degrees/Minutes/Seconds	32°42'45.55"N	115°32'07.03"W

Table 2: Ormat—Heber 2 Existing Storage Vessel Coordinates

EXISTING VESSELS	FORMAT	LATITUDE	LONGITUDE
Isopentane Vessel 4	Degrees/Minutes/Seconds	32°42'51.42"N	115°32'10.02"W
Isopentane Vessel 5	Degrees/Minutes/Seconds	32°42'51.21"N	115°32'10.02"W
Isopentane Vessel 6	Degrees/Minutes/Seconds	32°42'51.42"N	115°32'15.82"W

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2.0 COVERED PROCESS

The ***Ormat – Heber 2 Geothermal Complex*** has three geothermal electrical generating plants in Heber, CA. Heber 2 consists of the H2, Gould-2 (G-2), and Heber South binary processes. The projects use the renewable geothermal resources of the Heber Known Geothermal Resource Area (KGRA) to generate electrical power.

The Heber 2 Geothermal Project produces electricity by using a vaporized motive fluid to spin a turbine connected to a generator. In the H2 binary processes, isopentane is the motive fluid.

The covered processes at the facility are listed below.

Table 3: Ormat—Heber 2 Geothermal Complex Facility Covered Process

PLANT	REGULATED SUBSTANCE	MAXIMUM INVENTORY IN SINGLE VESSEL (GAL)[A]	TANK TYPE	VESSEL STORAGE INVENTORY
Heber 2	Isopentane	9,000	Storage	10,000-gallon tank

[A] This value represents the maximum amount stored in a single vessel, taking into account administrative controls, which are in place to limit the quantity stored.

This hazard assessment will focus on the regulated substance, isopentane, in Heber 2. The facility is classified as Prevention Program 3 and is regulated by the Environmental Protection Agency's Risk Management Program (EPA RMP) for Chemical Accidental Release Prevention in accordance with the Code of Federal Regulations, Title 40, Chapter I, Subchapter C, Part 68, Subpart B Sections 68.20 to 68.42 (40 CFR §68.20 - 68.42)[1] for isopentane, because it is held on site in excess of 10,000 lbs. The geothermal power plant utilizes isopentane as the motive fluid in the generation of electricity.

3.0 LEVEL OF CONCERN

To address potential health effects for the worst-case release scenario, the following are the key endpoints of concern for the EPA RMP as defined in Title 40 CFR Section 68.22(2):

(i) Explosion. An overpressure of 1 psi.

(ii) Radiant heat/exposure time. A radiant heat of 5 kW/m^2 for 40 seconds.

(iii) Lower flammability limit. A lower flammability limit as provided in NFPA documents or other generally recognized sources.

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The distance from the point of release to the endpoint identified above defines a radius circle of concern for which consequences are reported in the Risk Management Plan.

4.0 WORST-CASE SCENARIO

The US EPA RMP determines the worst-case release quantity in Title 40 CFR Part 68.25(b) as follows:

> *The worst-case release quantity shall be the greater of the following:*
>
> *(1) For substances in a vessel, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity;*
>
> *(2) For substances in pipes, the greatest amount in a pipe, taking into account administrative controls that limit the maximum quantity.*

Given the substance released is a flammable, the US EPA RMP gives further guidelines in 68.25 (f):

> *Worst-Case scenario-flammable liquids. The owner or operator shall assume that the quantity of the substance, as determined under paragraph (b) of this section and the provisions below, vaporizes resulting in a vapor cloud explosion. A yield factor of 10 percent of the available energy released in the explosion shall be used to determine the distance to the explosion endpoint if the model used is based on TNT equivalent methods.*
>
> *(1) For regulated flammable substances that are normally liquids at ambient temperature, the owner or operator shall assume that the entire quantity in the vessel or pipe as determined under paragraph (b) of this section, is spilled instantaneously to form a liquid pool. For liquids at temperatures below their atmospheric boiling point, the volatilization rate shall be calculated at the condition specified in paragraph (d) of this section.*
>
> *(2) The owner or operator shall assume that the quantity which becomes vapor in the first 10 minutes is involved in the vapor cloud explosion.*

Furthermore, vapor cloud explosions are considered a conservative analysis as Chapter 4: OCA of the General Risk Management Program Guidance states:

> *As in the case of the worst-case release analysis for toxic substances, the worst-case distance to the endpoint for flammable substances is based on a number of very*

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conservative assumptions. Release of the total quantity of a flammable substance in a vessel or pipe into a vapor cloud generally would be highly unlikely. Vapor cloud explosions are also unlikely events; in an actual release, the flammable gas or vapor released to air might disperse without ignition, or it might burn instead of exploding, with more limited consequences. The endpoint of 1 psi is intended to be conservative and protective; it does not define a level at which severe injuries or death would be commonly expected. An overpressure of 1 psi is unlikely to have serious direct effects on people; this overpressure may cause property damage such as partial demolition of houses, which can result in injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

EPA requires the assessment of a suitable worst-case scenario based on a thorough review of vessels and storage tanks to determine the single vessel with the largest quantity of the regulated substance. However, in this particular Hazard Assessment, the worst-case scenario instead analyzes a release from the three new 10,000-gallon isopentane storage vessels, despite the fact that any one of these vessels is not the single largest vessel at the facility. This updated Hazard Assessment was performed to account for the modifications made to Heber 2 as part of the facility's Repower project and thus, an exclusive examination of the three new 10,000-gallon storage vessels was performed rather than a review of the single largest vessel.

The Areal Locations of Hazardous Atmospheres (ALOHA)[3] modeling software was used to determine the distance to the endpoint for the worst-case release scenario analysis. The vulnerability zone resulting from this analysis was then reviewed. A vulnerability zone is defined as a circle whose center is the point of release and its radius is the length of the endpoint, which is predicted by the dispersion model (e.g., ALOHA).

4.1 Worst-Case Scenario Selection Process

The process of worst-case release scenario identification is summarized as follows. Figure 3 on the following page depicts the steps in this process.

- **Inventory Calculation**: The first step was to perform the inventory calculations for the 10,000-gallon storage vessels in the covered units and systems.
- **Screening Analysis**: The 10,000-gallon isopentane storage vessels' location was screened. ALOHA modeling software was used to model the scenario and determine the dispersion endpoints for the worst-case release scenario. This was performed to determine the vulnerability zone associated with the worst-case release scenario.

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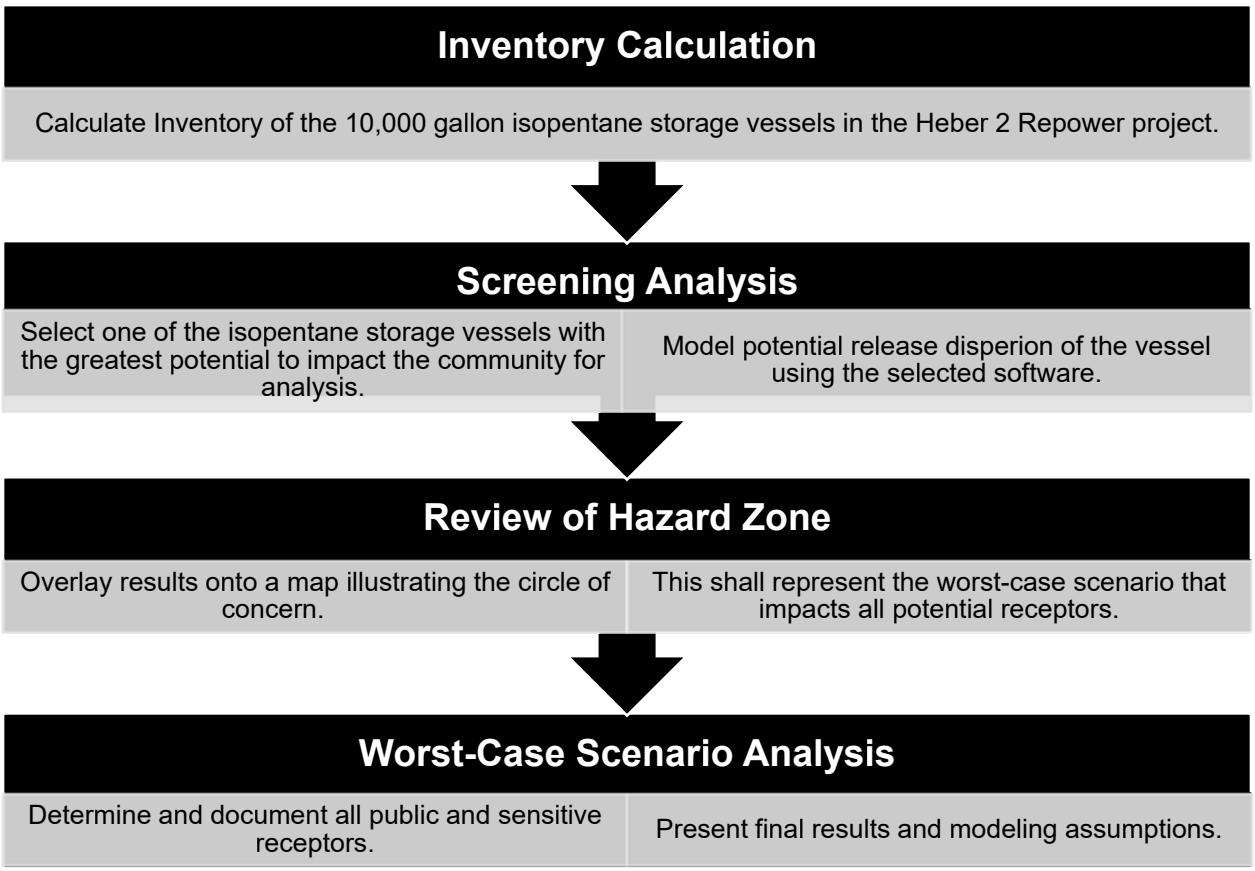
- **Review of the Vulnerability Zone**: The vulnerability zone resulting from the previous step was reviewed and is representative for the plant's worst-case scenario.
- **Worst-Case Analysis**: To document the worst-case scenario, the potential public receptors within the vulnerability zone were identified. All modeling inputs, calculations and assumptions are documented.

Figure 3: Worst-Case Scenario Selection Process



4.2 Flammable Release Potential Consequences

Several possible consequences of releases of flammable substances are discussed below. It should be noted that the following possible consequences apply to not only worst-case release analysis.

- **Flash Fire**. This event may result from dispersion of a flammable vapor cloud and ignition of the cloud following dispersion. Such a fire could flash back and could represent a

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severe heat radiation hazard to anyone in the area of the cloud. The lower flammability limit (LFL) endpoint, specified in the rule, would be appropriate for flash fires (vapor cloud fires).

- **Pool Fire**. Spill of a liquid whose boiling point is above ambient temperature may form a liquid pool, which could ignite and form a pool fire. The applicable endpoint specified in the rule is the heat radiation level of 5 kW/m^2.
- **BLEVE.** A BLEVE (Boiling Liquid Expanding Vapor Explosion) is a potential release scenario associated with a large quantity of flammable materials kept at below their boiling points. A BLEVE that may lead to a fireball could produce intense heat. This event may occur if a vessel containing flammable material ruptures as a result of exposure to fire. Heat radiation from the fireball is the primary hazard and vessel fragments and overpressure from the explosion are generally considered unlikely. To estimate the distance to a radiant heat level that can cause second degree burns (a heat "dose" equivalent to the specified radiant heat endpoint of 5 kW/m^2 for 40 seconds). Consistent with the EPA's "Risk Management Program Guidance for Offsite Consequence Analysis" published guidance, BLEVEs are generally considered unlikely events and were therefore not considered a probable event for the Offsite Consequence Analysis.
- **Vapor Cloud Explosion.** For a vapor cloud explosion to occur, rapid release of a large quantity, turbulent conditions (caused by a turbulent release or congested conditions in the area of the release, or both), and other factors are generally necessary. The endpoint for vapor cloud explosions is 1 psi.
- **Jet Fire.** This may result from the puncture or rupture of a tank or pipeline containing a compressed or liquefied gas under pressure. The gas discharging from the hole can form a jet that "blows" into the air in the direction away from the hole; the jet then may ignite. Jet fires could contribute to BLEVEs and fireballs if they impinge on tanks of flammable substances. A large horizontal jet fire may have the potential to pose an offsite hazard.

For the flammable worst-case release scenario, a vapor cloud explosion was the most appropriate consequence, as defined by the EPA RMP rule.

4.3 Endpoints

As mentioned previously, for flammable materials, the endpoints specified by the EPA RMP are:

- Overpressure of 1 pound per square inch (psi) for vapor cloud explosions

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- Radiant heat of 5 kilowatts per square meter (kW/m^2) for jet fires
- Lower flammability limit (LFL) for flash fires

The rule specifies endpoints for fires based on the heat radiation level that may cause second degree burns from a 40-second exposure and the LFL, which is the lowest concentration in air at which a substance will burn. For a vapor cloud explosion, the endpoint is 1 psi, which is the force to cause partial demolition of houses with potential serious injuries to people, or shattering glass windows with potential skin laceration from flying glass.

4.4 Modeling Assumptions

The EPA RMP regulation imposes several assumptions that were adhered to when performing the offsite consequence analysis of the worst-case release scenario. These are conservative assumptions for weather and release conditions. The distance to the endpoint estimated under worst-case conditions provides an estimate for the maximum possible area that might be affected by these unlikely conditions. It should be noted that EPA's intention for the vulnerability zone representing a worst-case release scenario is to provide a basis for discussion among the regulated industry, emergency responders, and the public, rather than a basis for any specific actions. The EPA RMP regulations, in conjunction with the RMP Guidance for Offsite Consequence Analysis[4], were used to model the worst-case release scenario and prescribe these atmospheric parameters.

- **Meteorological Parameters:** For the worst-case release analysis, the following assumptions were entered into ALOHA, as specific by the EPA RMP regulations / RMP Guidance for Offsite Consequence Analysis.
  - *Atmospheric stability*: F stability (very stable conditions)
  - *Wind speed:* 1.5 meters/second
  - *Ambient Temperature:* 77 ° F
  - *Relative Humidity*: The typical relative humidity at the stationary source, which is 50%
- **Dispersion & Impact Modeling Parameters:**
  - *Height of Release:* Ground level, per EPA Rule requirement

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- *Surface Roughness:* Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations
- *Vapor Cloud Explosion Impact:* A Vapor Cloud Explosion has been modeled with an endpoint of 1 psi

- **Mitigation Systems:** Once a release has occurred, mitigation systems are means (structures, equipment, or activities) that help minimize the transport of material to the atmosphere. Mitigation systems can be characterized as passive or active systems.
  - *Passive mitigation systems do not require activation, an energy source, or movement of components to perform their intended function*
  - *Active mitigation systems do require activation, an energy source, and/or movement of components to perform their intended function*

It should be emphasized that the effectiveness of mitigation systems was taken into account when these systems were considered in the offsite consequence analysis. The effectiveness is determined based on how well the systems are designed and their abilities to respond reliably upon demand. The rule permits consideration of only passive mitigation systems for the worst-case release analysis provided that the systems are capable of withstanding the event triggering the release scenario and would still function as intended. For the worst-case release scenario, the secondary containment area built with concrete was considered as a passive mitigation measure in the offsite consequence analysis.

4.5 Worst-Case Release Scenario

One worst-case scenario (WCS) was developed for the facility. For the worst-case release scenario, one of the new 10,000-gallon storage vessels containing isopentane at the Ormat – Heber 2 Geothermal Complex Facility was considered. The storage vessel is capable of storing a maximum of 9,000 gallons of isopentane, taking into account administrative controls. According to the Chevron Philips Chemical Company safety data sheet, the density of isopentane is 5.14 lbs./gal, which yields a total mass of 46,260 pounds of isopentane held in the storage vessel. The worst-case scenario considers the catastrophic failure of one of the 10,000-gallon isopentane storage vessels, which would result in a release of the entire contents of the vessel, into the secondary containment area. All dispersion modeling parameters utilized in the worst-case release scenario modeling is listed in Table 4 below. A summary of the scenario is presented in

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Table 5. Appendix A of this report provides a detailed description of the worst-case release scenario, ALOHA modeling output, MARPLOT 5.1.1[5] output with population estimates, and maps displaying the vulnerability zone for a release from each tank, denoted by a circle superimposed on the map.

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Table 4: Worst Case Release Scenario Dispersion Modeling Parameters

PARAMETER	INPUT VALUE	NOTES
Isopentane Input Parameters		
Quantity Released	9,000 gallons	Entire contents of isopentane storage vessel assumed to be released and form an evaporating puddle in secondary containment area, which is involved in a vapor cloud explosion.
Meteorological Parameters		
Atmospheric Stability	F stability	As per 40 CFR §68.22 (b), "For the worst-case release analysis, the owner or operator shall use a wind speed of 1.5 meters per second and F atmospheric stability class"
Wind Speed	1.5 m/s	
Wind Direction	W	Wind Direction from the west based on the Wind Rose plot for Imperial, CA (closest city with wind rose plot available). Since the endpoint distance and circle of interest is presented in this report, the wind direction does not impact the analysis/distance to endpoint and instead is a generic input that ALOHA modeling software requires.
Measurement Height above Ground	10 m	Wind speed is assumed to be measured at this elevation, as this is the standard height at which the National Weather Service usually reports wind speed.
Ambient Temperature	77ºF (25˚C)	As per 40 CFR §68.22 (c), "An owner or operator using the RMP Offsite

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PARAMETER	INPUT VALUE	NOTES
Relative Humidity	50%	Consequence Analysis Guidance may use 25 °C and 50 percent humidity as values for these variables"
Ground temperature	122ºF	As per 40 CFR §68.22 (g), "for worst case, [it] shall be considered to be released at the highest daily maximum temperature, based on data for the previous three years appropriate for the stationary source." Temperature data was sourced from Weather Underground [6] for Imperial, CA (closest available city with temperature history) and the highest daily maximum temperature from the previous 3 years was identified.
Dispersion and Impact Modeling Parameters		
Height of Release	Ground level	As per 40 CFR §68.22(d), "you must assume a ground level release" and as per the RMP Offsite Consequence Analysis Guidance Document, "this guidance assumes a ground-level release"
Topography/Surface Roughness	Open Country	Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations.

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PARAMETER	INPUT VALUE	NOTES
Level of Congestion	Congested	The level of congestion was assumed to be congested, which is a conservative assumption since greater turbulence (greater congestion) allows the flame front to accelerate, thereby generating a more powerful blast wave (i.e., greater overpressure). The immediate area within the facility is also considered to be congested with piping and equipment.
Isopentane Mitigation System		
Passive Mitigation	Secondary Containment Area	The volume released from a single Isopentane Storage Vessel is assumed to release into a concrete secondary containment area, which is contained around each storage vessel. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (Surface area = 480 ft^2).

Table 5: Worst-Case Scenario Results Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
WCS: 10,000-gallon Isopentane Storage Vessel Rupture/Release	Isopentane	Overpressure of 1 psi	92 yd / 276 ft / 0.052 mi

4.6 Worst-Case Analysis Considerations

The worst-case distances to the flammable endpoints are based on a number of very conservative assumptions. The following summarizes the assumptions:

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- The likelihood of a vessel rupture is extremely low. As a result, the release of entire inventory of a vessel is an unrealistic assumption.
- An overpressure of 1 psi is unlikely to have serious direct effects on people. This overpressure may cause property damage such as partial demolition of houses, which can result in injuries to people, and shattering of glass windows, which may cause skin laceration from flying glass.

5.0 ALTERNATIVE RELEASE SCENARIO

Alternative scenarios are potential releases that may result in consequences whose footprints represented by the endpoints could extend beyond the plant boundary. For a release case to be considered an alternative scenario, two conditions must be met:

1. The likelihood of the alternative release scenarios should be higher than that of the worst-case release scenarios.
2. The distance to endpoint from an alternative release scenario must go beyond the plant fence line.

As put forth in Title 40 CFR Section 68.28(a):

> *The owner or operator shall identify and analyze…at least one alternative release scenario to represent all flammable substances held in a covered process*

Title 40 CFR Section 68.28 (b)(2) defines the scenarios typically considered, but not limited to, the following:

> *(i) Transfer hose releases due to splits or sudden hose uncoupling;*
>
> *(ii) Process piping releases from failures at flanges, joints, welds, valves and valve seals, and drains or bleeds*
>
> *(iii) Process vessel or pump release due to cracks, seal failure, or drain, bleed, or plug failure; and*
>
> *(iv) Vessel overfilling and spill, or over pressurization and venting through relief valves or rupture disks.*
>
> *(v) Shipping container mishandling and breakage or puncturing leading to a spill.*

For alternative release scenarios, active mitigation systems, such as interlocks, shutdown systems, pressure relieving devices, flares, emergency isolation systems, and fire water and deluge systems, as well as passive mitigation systems are considered, if they were applicable. In order to be credited, the mitigation systems considered must be capable of withstanding the event that triggers the release while remaining functional.

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5.1 Alternative Release Scenario Selection Process

The process of alternative release scenario identification is summarized as follows and depicted in Figure 4.

- **Selection of Candidate Alternative Release Scenario:** The process of alternative release scenario identification was initiated with the review of the worst-case release case. Additional vessels, containing various quantities of regulated substances, which considered having a higher likelihood of release, were then reviewed. In this process, all covered processes were reviewed and the candidate case for the alternative release scenario analysis was subsequently selected. The following criteria was utilized to identify the potential scenario:
    - Corrosion history and corrosive services
    - Past incidents and near misses
    - Potential equipment failure
    - Operating conditions
    - Potential for human error
    - Consequences considered in the unit Process Hazard Analysis
- **Analysis of the Selected Alternative Release Scenario:** Once the candidate scenario was selected, ALOHA was utilized to model the selected scenario. The vulnerability zone resulting from the analysis of the alternative release scenario was then reviewed. The release duration was limited by the length of time to release the entire contents of the single Isopentane Storage Vessel.
- **Alternative Release Scenario**: The alternative release scenario for the flammable substance was selected and modeled to evaluate potential offsite impacts. Documentation of this scenario included modeling calculations, parameters and assumptions.

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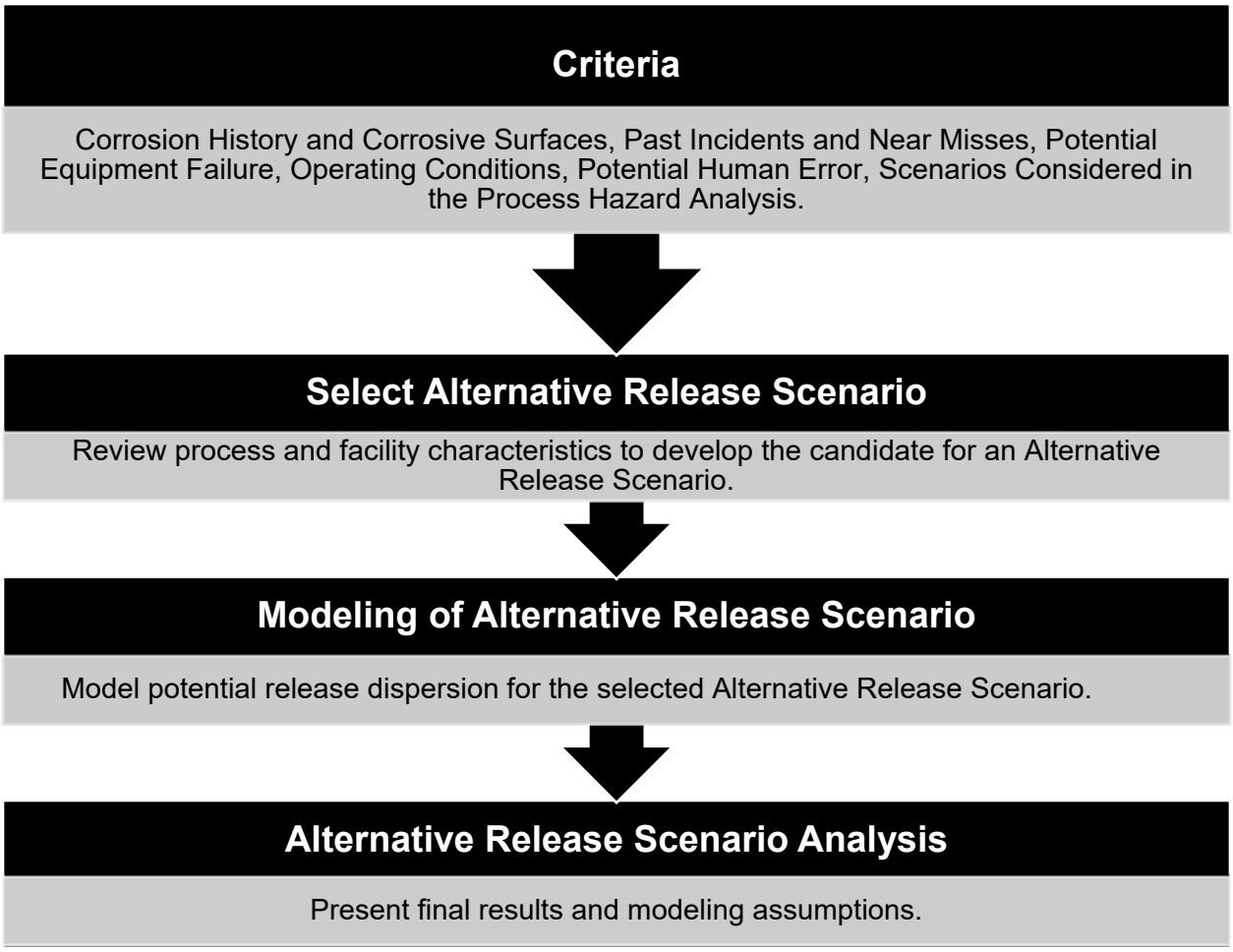
Figure 4: Alternative Release Scenario Selection Process



5.2 Modeling Assumptions

The EPA RMP regulation does not impose any mandatory assumptions for the OCA of the alternative release scenario. All dispersion modeling parameters utilized in the alternative release scenario modeling are listed in Table 6. For the alternative release scenario, a release due to a break in the product transfer hose connection during truck loading has been considered. Appendix B of this report provides a detailed description of the worst-case release scenario, ALOHA modeling output, MARPLOT 5.1.1 output with population estimates, and a map with the vulnerability zone denoted by a circle superimposed on the map.

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Table 6: Alternative Release Scenario Dispersion Modeling Parameters

Parameter	Input Value	Notes
Isopentane Input Parameters		
Quantity Released	46,260 lbs.	The most likely alternative release scenario involves the uncoupling of a transfer hose during truck loading operations. Calculations shown in Appendix B.
Release Rate	19,468 lbs./min	Calculations shown in Appendix B.
Release Duration	2.4 mins	The release duration is limited by the quantity stored in a single Isopentane Storage Vessel (9,000 gallons).
Meteorological Parameters		
Atmospheric Stability	D stability	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, “this guidance assumes wind speed of 3 meters per second and D stability”
Wind Speed	3.0 m/s	
Wind Direction	W	Wind Direction from the west based on the Wind Rose plot for Imperial, CA (closest city with wind rose plot available). Since the endpoint distance and circle of interest is presented in this report, the wind direction does not impact the analysis/distance to endpoint and instead is a generic input that ALOHA modeling software requires.

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Parameter	Input Value	Notes
Measurement Height above Ground	10 m	Wind speed is assumed to be measured at this elevation, as this is the standard height at which the National Weather Service usually reports wind speed.
Ambient Temperature	77ºF (25˚C)	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, “this guidance assumes 25ºC and 50 percent humidity”
Relative Humidity	50%	
Dispersion and Impact Modeling Parameters		
Height of Release	Ground Level	As per EPA RMP Offsite Consequence Analysis Guidance, for an alternative scenario, “this guidance assumes a ground-level release”
Topography/Surface Roughness	Open Country	Open Country, meaning there are no obstacles in the immediate area; obstacles including buildings or trees, as defined by the EPA RMP regulations.
Level of Congestion	Congested	The level of congestion was assumed to be congested, which is a conservative assumption since greater turbulence (greater congestion) allows the flame front to accelerate, thereby generating a more powerful blast wave (i.e., greater overpressure). The immediate area within the facility is also considered to be congested with piping and equipment.

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Parameter	Input Value	Notes
Isopentane Mitigation System		
Passive Mitigation	Secondary Containment Area	The amount released from the alternative release scenario is assumed to release into a concrete secondary containment area, which is contained around each storage vessel. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (Surface area = 480 ft^2).
Active Mitigation	None	

5.3 Alternative Release Scenario

A summary of the alternative release scenario is presented in Table 7. Appendix B of this report provides a detailed description of the alternative release scenario, ALOHA modeling outputs, MARPLOT 5.1.1 outputs with population estimates, and a map with circles representing the vulnerability zones.

Table 7: Alternative Release Scenario Result Summary

RELEASE SCENARIO	REGULATED SUBSTANCE	ENDPOINT	ENDPOINT DISTANCE
ARS: Transfer Hose uncoupling from 10,000-gallon Isopentane Storage Vessel during Truck Loading Operations	Isopentane	Overpressure of 1 psi	57 yd / 171 ft / 0.032 mi

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5.4 Alternative Release Analysis Considerations

Typically, the same conservative assumptions apply for the alternative release analysis as for the worst-case release analysis. Although the alternative release scenario is intended to be more likely than the worst-case release scenario, the analysis of the alternative release scenario should not be expected to provide a realistic estimate of an area in which off-site impact may occur. The same conservative endpoints have been used for both the worst-case and the alternative release analysis. These endpoints are intended to represent exposure levels below which most members of the public will not experience serious long-term health effects.

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6.0 OFFSITE IMPACTS

A summary of the off-site impacts from an accidental release, including population and sensitive receptors, is discussed in the following sub-sections.

6.1 Impacted Population

In order to determine the impacted population around the facility, the potential for exposure within the endpoint was determined. The furthest endpoint distances reached by the worst-case scenario and alternative release scenario along with the estimated impacted population are summarized in Table 8:

Table 8: Impacted Population for OCA Scenarios

SCENARIO	ENDPOINT DISTANCE	ESTIMATED IMPACTED POPULATION
WCS: 10,000-gallon Isopentane Storage Vessel Rupture/Release	92 yd / 276 ft / 0.052 mi	0
ARS: Transfer Hose uncoupling from 10,000-gallon Isopentane Storage Vessel during Truck Loading Operations	57 yd / 171 ft / 0.032 mi	0

The population was estimated using 2010 census tract data with the MARPLOT 5.1.1 software. When calculating population densities for large areas that encompass many tracts, the accuracy is rated as good; however, for small areas that encompass only two or three partial tracts, the population data may be skewed due to the unequal distribution within the tract. The use of MARPLOT 5.1.1 is pursuant to guidance endorsed by the US EPA. MARPLOT 5.1.1 requires the latitude and longitude of the facility in order to calculate the population. The latitude and longitude were estimated using Google Earth GPS[7] software and an aerial photo. In consideration of the unique case of bystanders along facility boarders during a vapor cloud explosion, vessels are placed far enough within company fencing that surrounding walkways and streets are free of severe impacts.

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6.2 Offsite Sensitive Receptor Data Sources

Table 9 includes a list of websites and software used to locate offsite sensitive receptors. A few sites will perform a distance search in order to determine the eligibility of a possible receptor. For all other sites, a map interpolation determines whether the receptor falls within the circle of concern.

Table 9: Websites and Software Used

SOURCE	RECEPTORS THIS SOURCE IS USED TO IDENTIFY	METHOD OF DETERMINING ELIGIBILITY
Google Maps[8]	Used to identify all receptors	Distance search in conjunction with a map interpolation
Google Earth	This mapping software is used to locate all receptors. It also incorporates an internet search with the map to locate businesses.	Software will map the location of the receptor.

6.3 Offsite Sensitive Receptors

RMP requirements state that sensitive populations such as schools, hospitals, day-care centers, long-term health care facilities, prisons, residential areas, public use parks/recreational areas, and major commercial facilities, located within the "at risk" area must be identified. These sensitive populations include individuals who could not remove themselves from the exposure area without assistance. The sensitive populations also include industrial installations which may have a hazardous process that cannot be immediately left unattended. According to the EPA's General Risk Management Plan Guidance [9], "The basic test for identifying a public receptor is thus whether an area is a place where it is reasonable to expect that members of the public will routinely gather at least some of the time… Roads and parking lots are not included as such in the definition of 'public receptor.' Neither are places where people typically gather; instead, they are used to travel from one place to another or to park a vehicle while attending an activity elsewhere." Table 10 shows a summary of offsite population receptors and offsite environmental

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receptors for isopentane, within the circle of concern as determined by the worst-case and alternative release scenarios.

Table 10: Summary of Sensitive and Environmental Receptors

RECEPTOR	WCS (0.052 MI)	ARS (0.032 MI)
Population Receptors		
Schools	No	No
Residences	No	No
Hospitals	No	No
Prisons/Correction Facilities	No	No
Recreation Areas	No	No
Major Commercial, Office, or Industrial Areas	No	No
Child Daycare	No	No
Long-term Health Care (e.g., convalescent homes)	No	No
Other (Government Buildings)	No	No
Environmental Receptors		
National or State Parks, Forests, or Monuments	No	No
Officially Designated Wildlife Sanctuaries, Preserves, or Refuges	No	No
Federal Wilderness Areas	No	No
Other (Landmark & Indian Reservations)	No	No

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7.0 WORST-CASE RELEASE AND ALTERNATIVE RELEASE SCENARIO SUMMARY

The following sections outlines a summary of the parameters used for the one worst case release scenario and the one alternative release scenario analyzed for the Heber 2 Repower project.

7.1 Worst-Case Scenario

The worst-case scenario evaluated the release of the entire contents of one of the new 10,000-gallon isopentane storage vessels, containing 9,000 gallons of isopentane. The following table provides a summary of the parameters used for the worst-case scenario and the corresponding inputs.

Table 3: Worst-Case Scenario Parameter/Input Summary

Worst-Case Scenario	
Chemical	Isopentane
Model Used	ALOHA
Scenario	Vapor Cloud Explosion
Quantity Released (gal)	9,000 gallons
Endpoint Used	Overpressure of 1 psi
Distance to Endpoint	92 yd / 276 ft / 0.052 mi
Estimated Residential Population within Distance to Endpoint (numbers)	0
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No
Other	None

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Worst-Case Scenario	
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Secondary Containment Area	Yes
Other	No

7.2 Alternative Release Scenario

It was determined that a release due to a break in the isopentane transfer hose connection during truck loading, was the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. The following table provides a summary of the parameters that were used for alternative release scenario and the corresponding inputs.

Table 4: Alternative Release Scenario Parameter/Input Summary

Alternative Release Scenario	
Chemical	Isopentane
Model Used	ALOHA
Scenario	Vapor Cloud Explosion
Quantity Released	46,260 lbs.
Endpoint Used	Overpressure of 1 psi
Distance to Endpoint	57 yd / 171 ft / 0.032 mi
Estimated Residential Population within Distance to Endpoint (numbers)	0

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Alternative Release Scenario	
Public Receptors within Distance to Endpoint	
Schools	No
Residences	No
Hospitals	No
Prison/Correctional Facilities	No
Recreational Areas	No
Major Commercial, Office, or Industrial Areas	No
Other	None
Environmental Receptors within Distance to Endpoint	
National or State Parks, Forests, or Monuments	No
Officially Designated Wildlife Sanctuaries, Preserves or Refuges	No
Federal Wilderness Area	No
Other	No
Passive Mitigation Considered	
Secondary Containment Area	Yes
Other	No
Active Mitigation Considered	
Sprinkler Systems	No
Deluge Systems	No
Water Curtain	No
Excess Flow Valve	No
Other	No

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8.0 FIVE YEAR ACCIDENT HISTORY

There have been no applicable CalARP/RMP/PSM releases of isopentane at the facility within the last five years, therefore, this section is not applicable.

9.0 REFERENCES

1. Code of Federal Regulations (CFR), Title 40, Chapter I, Subchapter C, Part 68, Subpart B, Sections 68.20 to 68.42, “Hazard Assessment”; 2015, January 1.
2. California Code of Regulations (CCR), Title 19, Division 2, Chapter 4.5, Article 4, Sections 2750.1 to 2750.9, “Hazard Assessment”; 2015, January 1.
3. Areal Locations of Hazardous Atmospheres - ALOHA Version 5.4.7, U.S. Environmental Protection Agency, September 2016. http://www2.epa.gov/cameo/aloha-software
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7. Google ™ Earth, version 7.3.2.5776, Google, Inc. (2019)
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9. General Risk Management Program Guidance – Chapter 2: Applicability of Program Levels, U.S. Environmental Protection Agency, April 2004.

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APPENDIX A
WORST-CASE SCENARIO CALCULATIONS

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WORST-CASE SCENARIO (WCS)

The selected worst-case release scenario analyzes the hypothetical rupture of any one of the 10,000-gallon isopentane vessel, introduced as part of the Heber 2 facility's Repower project. Any one vessel can store up to 9,000 gallons of isopentane, taking into account administrative controls, which are in place to limit the quantity stored in each tank. Per requirement of the EPA rule for flammable substances, it was assumed that the whole quantity is released. The entire quantity is released into the secondary containment area, which is credited as a passive mitigation measure, to form an evaporating puddle, for which the vapors form a vapor cloud. If this vapor cloud ignited, the resultant blast could generate overpressure damage. The secondary containment area dimensions are 40 ft length, 12 ft width, 3.5 ft depth (surface area = 480 ft^2), and it assumed the secondary containment area ground type is concrete.

The ALOHA modeling calculation predicts that the area impacted by the endpoint, which is an overpressure of 1 psi, is a circle with approximately a 92-yard radius (276 ft / 0.052 mi). According to MARPLOT 5.1.1, there are 0 residents and 0 housing units within this vulnerability zone for all three vessels. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the ALOHA modeling output, as well as the MARPLOT results. These figures demonstrate Ormat's strategic placement of new storage vessels, showing that one explosion and release of all isopentane contents would not affect the other. Each of the new vessels are at least 184 yards (twice the radius of concern) from one another and do not reach any of the three existing vessels.

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Figure 5: WCS ALOHA Modeling Results

```
SITE DATA:
  Location: HEBER, CALIFORNIA
  Building Air Exchanges Per Hour: 0.20 (unsheltered double storied)
  Time: September 14, 2020  1158 hours PDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: ISOPENTANE
  CAS Number: 78-78-4                    Molecular Weight: 72.15 g/mol
  PAC-1: 3000 ppm    PAC-2: 33000 ppm    PAC-3: 200000 ppm
  LEL: 14000 ppm     UEL: 76000 ppm
  Ambient Boiling Point: 82.1° F
  Vapor Pressure at Ambient Temperature: 0.91 atm
  Ambient Saturation Concentration: 904,803 ppm or 90.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 1.5 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 77° F
  Stability Class: F (user override)
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Evaporating Puddle (Note: chemical is flammable)
  Puddle Area: 480 square feet           Puddle Volume: 9000 gallons
  Ground Type: Concrete                  Ground Temperature: 122° F
  Initial Puddle Temperature: Air temperature
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 119 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 5,079 pounds

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Heavy Gas
  Red    : LOC was never exceeded --- (8.0 psi = destruction of buildings)
  Orange: 52 yards --- (3.5 psi = serious injury likely)
  Yellow: 92 yards --- (1.0 psi = shatters glass)
```


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Figure 6: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #1

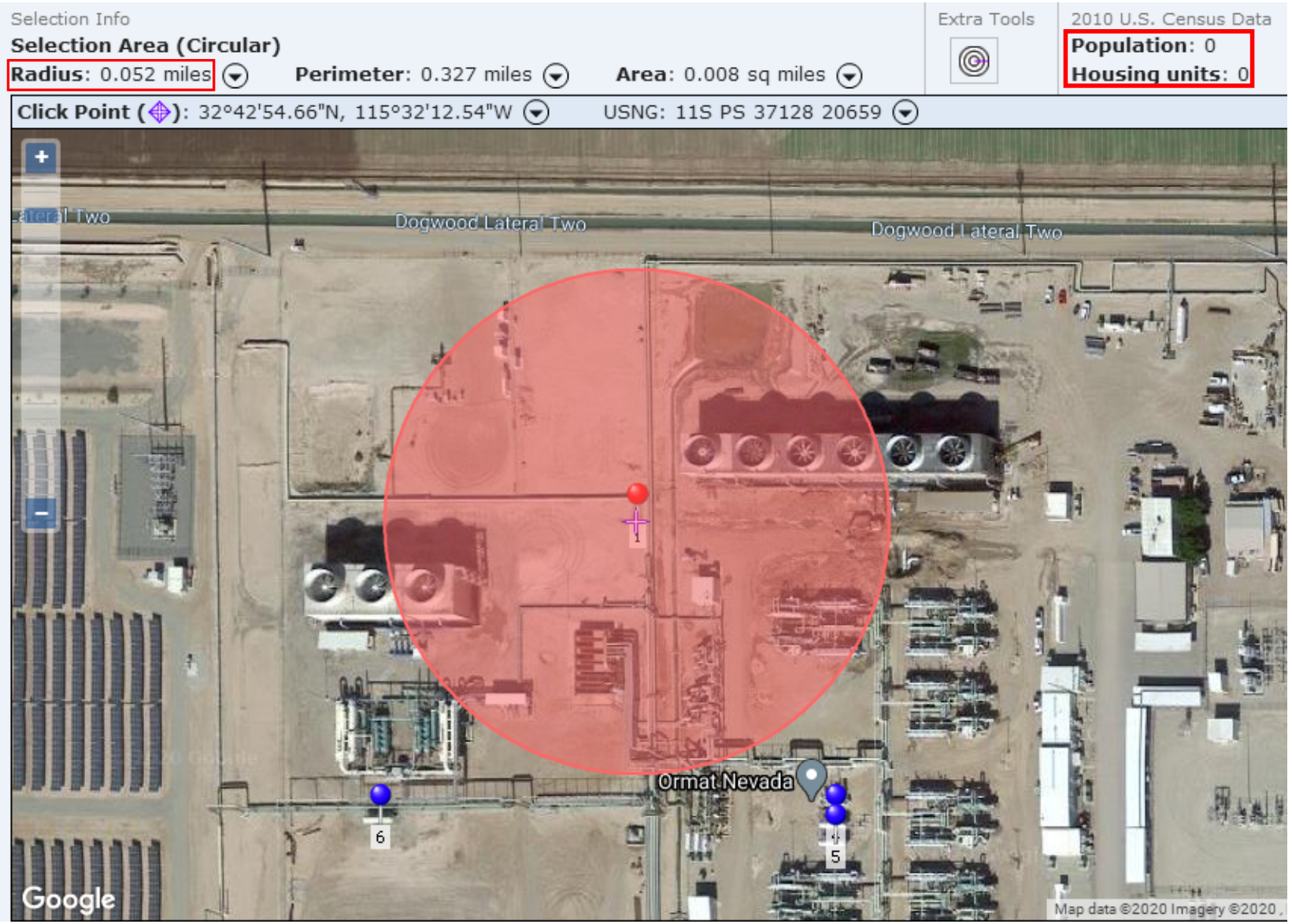

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Figure 7: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #2

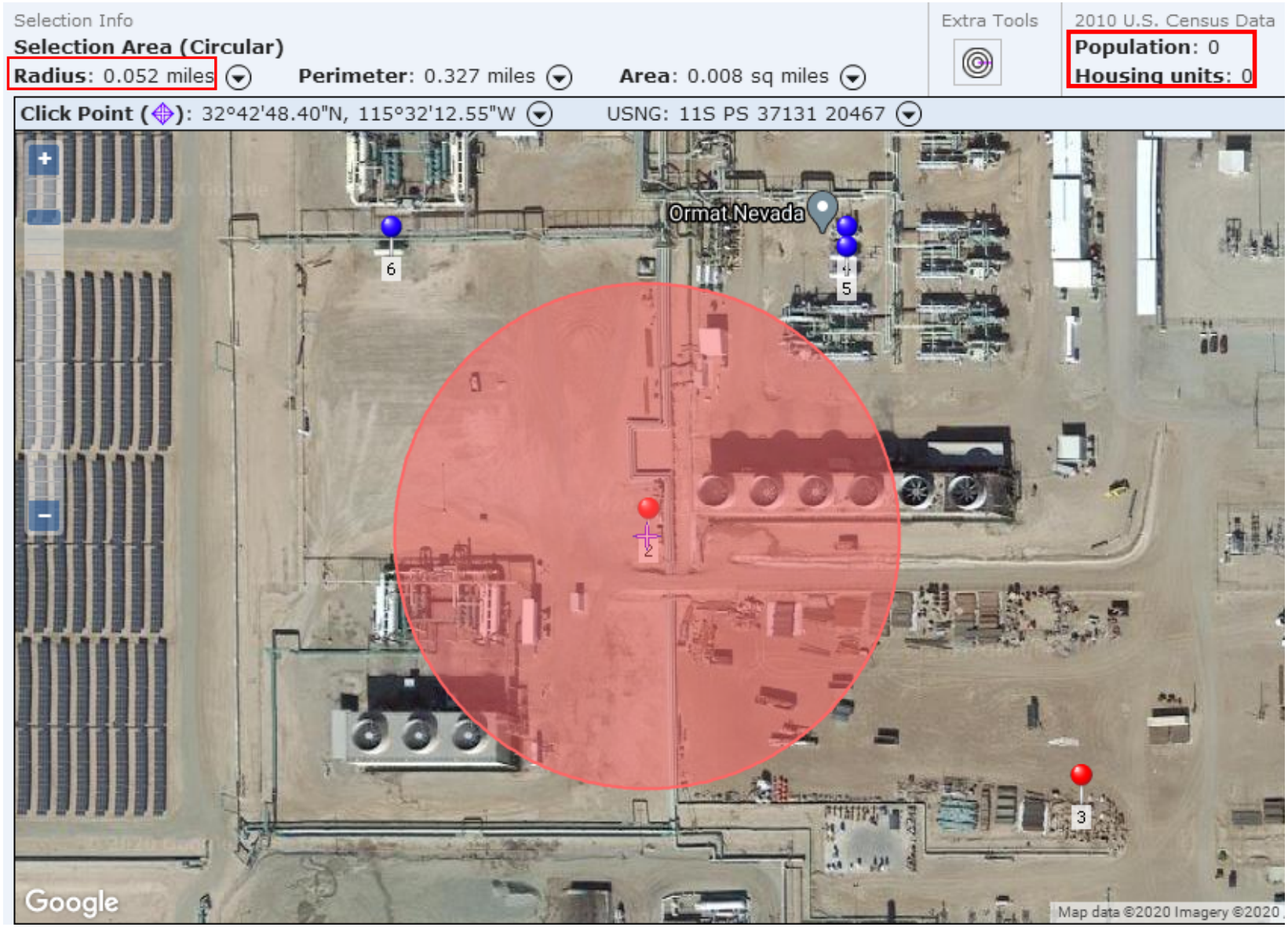

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Figure 8: WCS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #3

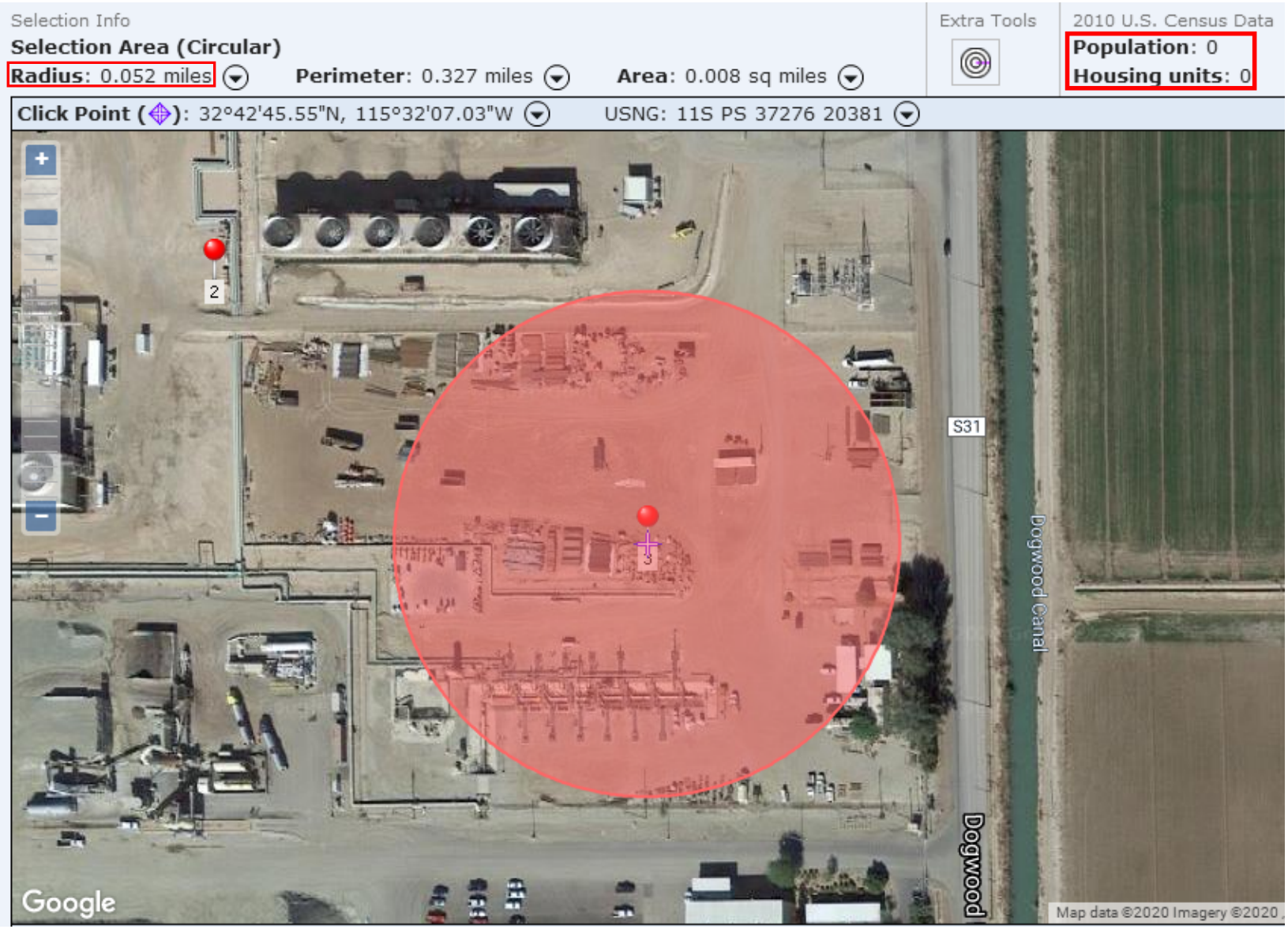

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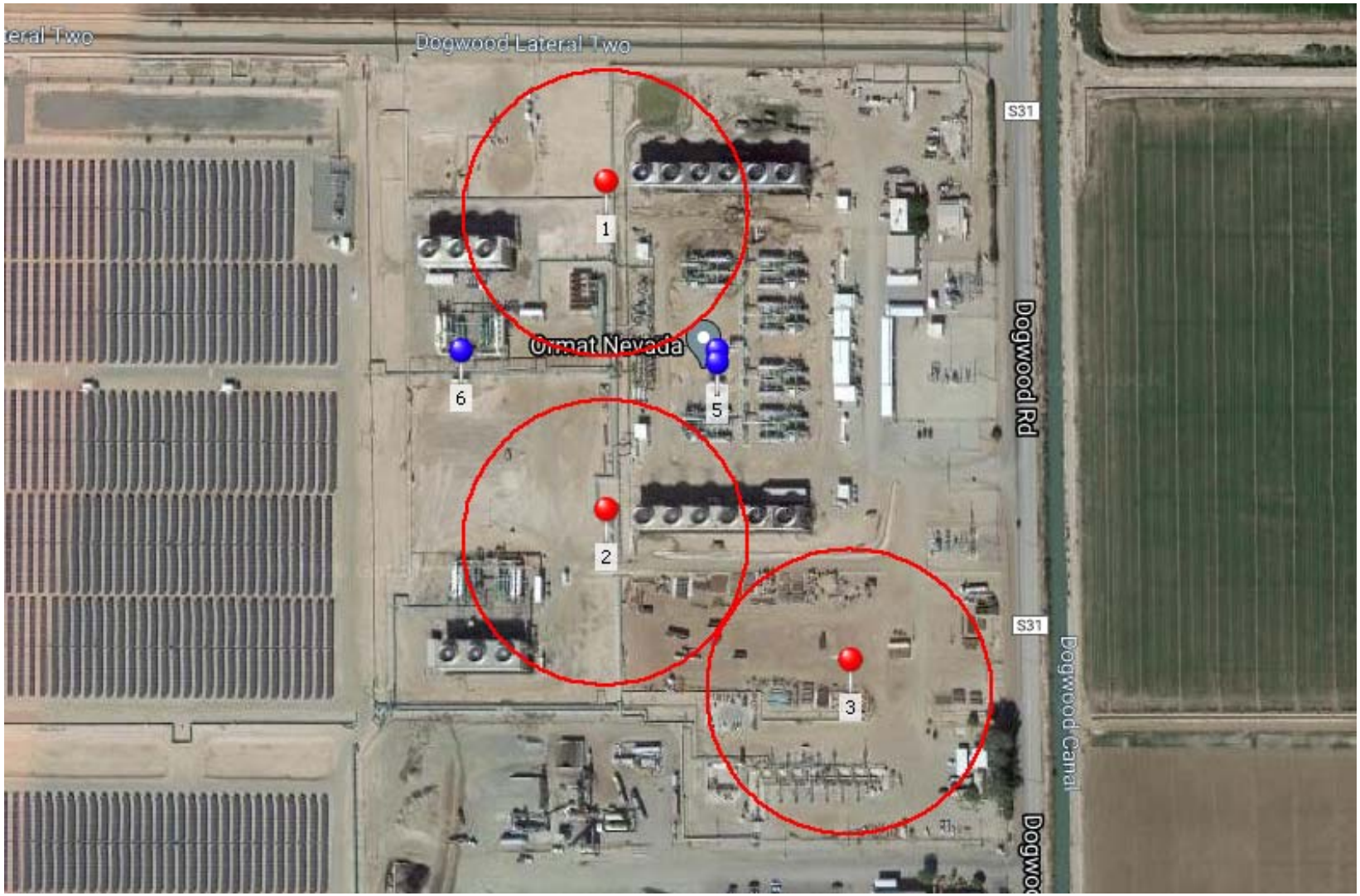
Figure 9: WCS Vulnerability Maps Overlaid for Isopentane Storage Vessels #1, #2, #3



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APPENDIX B
ALTERNATIVE SCENARIO CALCULATIONS

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ALTERNATIVE RELEASE SCENARIO (ARS)

The selected alternative release scenario is a release due to a break in the product (isopentane) transfer hose connection during truck loading. This was considered the most likely release scenario due to human factors associated with manned transfer operations, as well as reliability issues in industry related to hose degradation and coupling failures. It is assumed that the transfer hose uncouples during isopentane transfer operations and that it is released through an area of 12.6 square inches based on the transfer hose size.. The release duration is limited by the volume in the Isopentane Storage Vessel (9,000 gallons), which is 2.4 minutes. In the evaluations of this alternative release scenario, the concrete secondary containment area composed was credited as a mitigation measure.

In order to calculate the release quantity for a transfer hose rupture, the release rate through the transfer hose must be calculated. The following equation, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis, illustrates the calculation of the release rate for flammable liquids under pressure through a transfer hose:

$$QR = A_h \times 6.82 \sqrt{\frac{11.7}{DF^2} \times LH + \frac{669}{DF} \times P_g}$$

Where:

- QR = Release rate (lbs./min)
- A_h= Hole or puncture area (square inches)
- DF = Density Factor, dimensionless, obtained from the EPA Risk Management Plan Guidance for Offsite Consequence Analysis
- LH = Height of liquid level above hole (inches)
- P_g = Gauge pressure of the vessel (psig)

To calculate the release rate utilizing the above equation, the values for each of the following variables were calculated for isopentane:

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Hole Area

The transfer hose used in isopentane filling operations at both plants is 4 inches in diameter. Thus, the hole area is based upon the transfer hose rupturing and calculated using the following:

$$HA = \pi r^2 = 12.6 \text{ in}^2$$

Density Factor

The Density Factors are obtained from Appendix C of the EPA Risk Management Plan Guidance for Offsite Consequence Analysis. The Density Factor value for isopentane is 0.79.

Liquid Height

The height of the liquid level above the hole is determined by the nominal liquid level in the vessel. The isopentane transfer point is taken to be at the bottom of the tank. Assuming that the isopentane storage vessel is 33% full of isopentane, this equates to 2,970 gallons being stored in the vessel (397 ft^3). This is a conservative assumption as the storage tanks are normally empty and are only used for temporary storage of isopentane. According to the available tank data provided by the facility, the diameter of the Isopentane Storage Vessel is approximately 8 feet and length is 33.5 feet (tangent to tangent length). It should be noted that the Isopentane Storage Vessel is a horizontal vessel. In calculating the height of the liquid column within the tank, the Isopentane Storage Vessel was modeled as a cylinder, and thus the equation for volume of liquid within the tank is that of a horizontal cylinder. The equations below were used to find the height of the liquid column within the Isopentane Storage Vessel:

$$V_L = A_L \times L$$

$$A_L = R^2 \cos^{-1}\left(\frac{R - LH}{R}\right) - (R - LH)\sqrt{2R \cdot LH - LH^2}, \quad \therefore$$

$$V_L = L \times \left[R^2 \cos^{-1}\left(\frac{R - LH}{R}\right) - (R - LH)\sqrt{2R \cdot LH - LH^2}\right]$$

Where:

V_L = Volume of liquid within the Tank (ft^3)

A_L = Area of liquid (ft^2)

R = Radius of the Tank (ft.)

L = Length of the Tank (ft.)

LH = Height of the liquid within the Tank (ft.)

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Values for each variable listed in the equations above are provided below, with the exception of LH, as this is the variable to be calculated:

V_L = 2,970 gallons = 397 ft^3

R = 4 ft.

L = 33.5 ft.

By using the above values within the equation, the height of the liquid column within the Isopentane Storage Vessel can be calculated, which is approximately 2.3 ft (2.2857 ft) or 27.6 inches.

Pressure

The normal operating pressure of the isopentane motive fluid storage tank was identified to be 60 psig.

Modeling

Using these values, the release rate of isopentane can be determined. Please see the calculations below for determining the isopentane release rate:

$$QR = 12.6\ in^2 \times 6.82 \sqrt{\frac{11.7}{(0.79^2)} \times 27.6\ in + \frac{669}{0.79} \times 60\ psig}$$

$$QR = 19{,}468.3955\ \frac{lbs.}{min} \approx 19{,}468\ \frac{lbs.}{min}$$

Over the 2.4 minute release period, this results in a total of 46,260 lbs. released to the secondary containment area to form an evaporating puddle, for which the vapors form a vapor cloud. If this vapor cloud ignited, the resultant blast could generate overpressure damage.

The ALOHA modeling calculation predicts that the area impacted by the endpoint, which is overpressure of 1 psi, is a circle with approximately a 57-yard radius (171 ft / 0.032 mi). According to MARPLOT 5.1.1, there are 0 residents and 0 housing units within this vulnerability zone for all three vessels. The table and figures on the following pages illustrate the scenario modeling parameter summary, scenario circle for the release, the ALOHA modeling output, as well as the MARPLOT results.

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Figure 10: ARS ALOHA Modeling Results

```
SITE DATA:
  Location: HEBER, CALIFORNIA
  Building Air Exchanges Per Hour: 0.33 (unsheltered double storied)
  Time: September 15, 2020  1152 hours PDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: ISOPENTANE
  CAS Number: 78-78-4                    Molecular Weight: 72.15 g/mol
  PAC-1: 3000 ppm    PAC-2: 33000 ppm    PAC-3: 200000 ppm
  LEL: 14000 ppm     UEL: 76000 ppm
  Ambient Boiling Point: 82.1° F
  Vapor Pressure at Ambient Temperature: 0.91 atm
  Ambient Saturation Concentration: 904,803 ppm or 90.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 3 meters/second from W at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 77° F
  Stability Class: D (user override)
  No Inversion Height                    Relative Humidity: 50%

SOURCE STRENGTH:
  Evaporating Puddle (Note: chemical is flammable)
  Puddle Area: 480 square feet           Puddle Mass: 46260 pounds
  Ground Type: Concrete                  Ground Temperature: 77° F
  Initial Puddle Temperature: Air temperature
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 176 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 6,152 pounds

THREAT ZONE:
  Threat Modeled: Overpressure (blast force) from vapor cloud explosion
  Type of Ignition: ignited by spark or flame
  Level of Congestion: congested
  Model Run: Heavy Gas
  Red    : LOC was never exceeded --- (8.0 psi = destruction of buildings)
  Orange: 28 yards --- (3.5 psi = serious injury likely)
  Yellow: 57 yards --- (1.0 psi = shatters glass)
```


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Figure 11: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #1

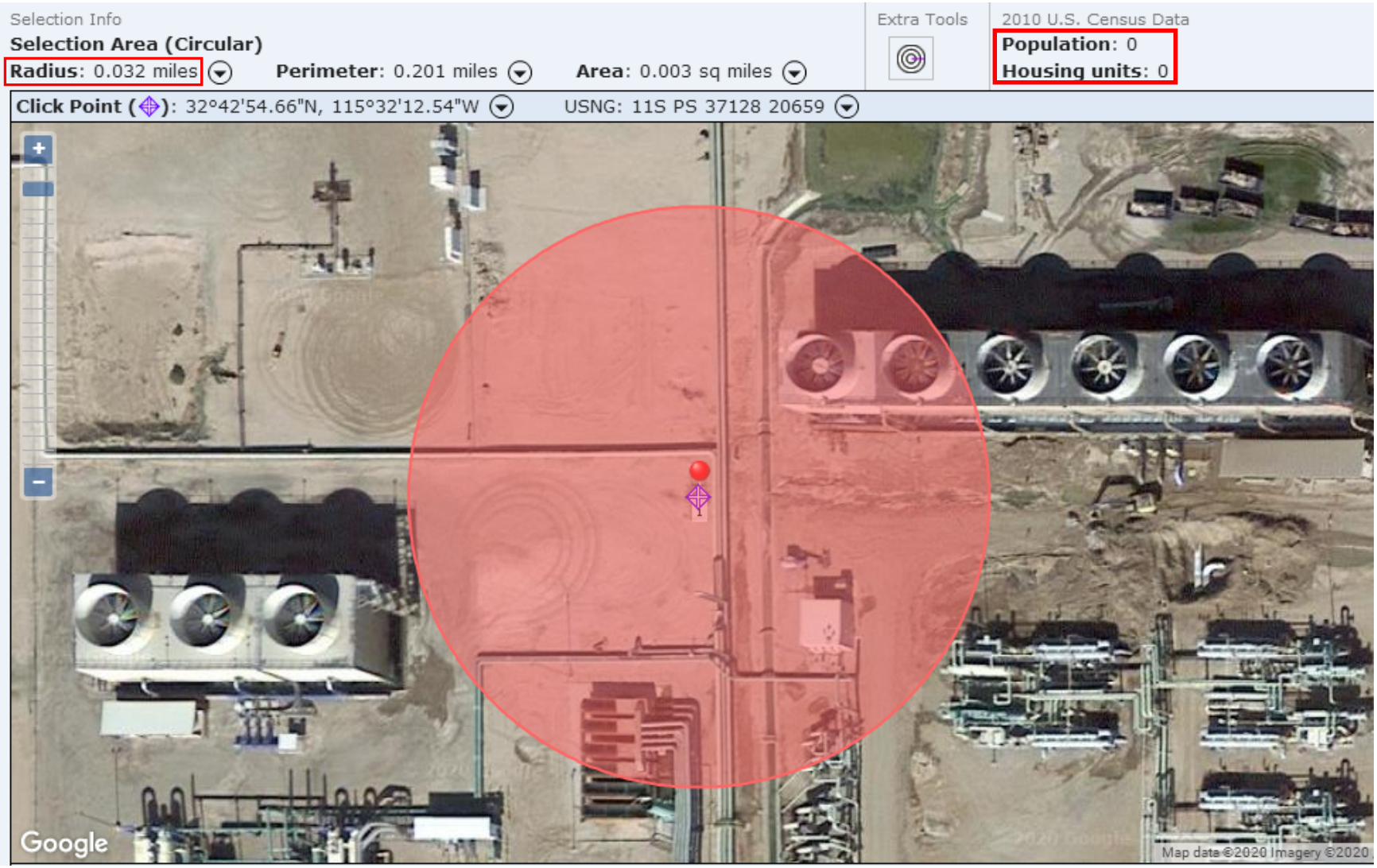

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Figure 12: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #2

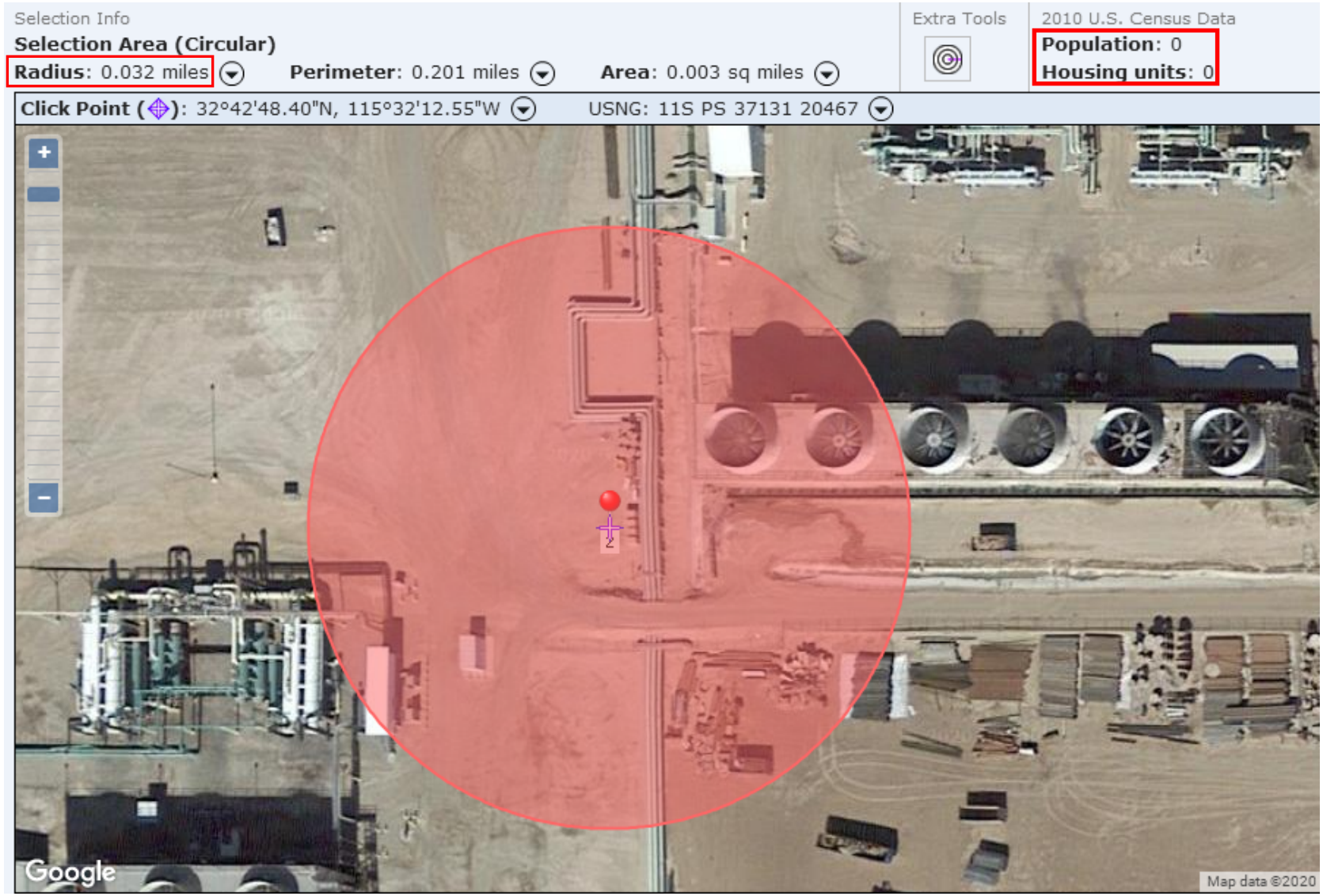

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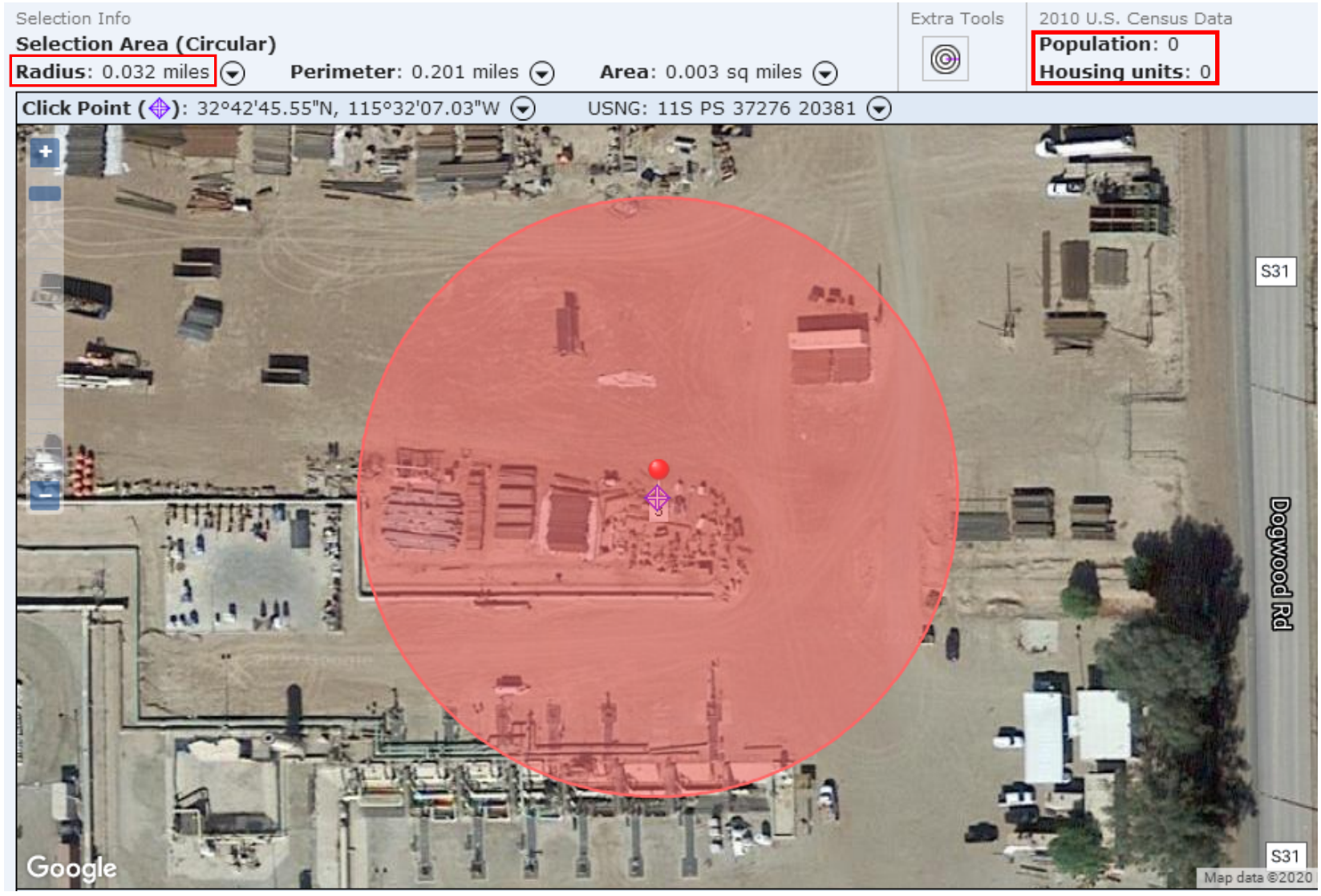
Figure 9: ARS MARPLOT 5.1.1 Map for Isopentane Storage Vessel #3



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Attachment D

California Department of Conservation Concurrence

Catalyst
ENVIRONMENTAL SOLUTIONS

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From: Welty, Curtis@DOC [mailto:Curtis.Welty@conservation.ca.gov]
Sent: Wednesday, July 22, 2020 10:27 AM
To: Melissa Wendt <mwendt@ORMAT.COM>
Subject: Heber 2 Repower Project

Dear Melissa,

On June 23rd, you sent an email (below) to Charlene Wardlow concerning a review of CEQA documents and the possibility of a letter of review for those documents. Your request eventually made its way to me.

As Charlene noted in her reply to you, we usually get notices about these CEQA documents through the State Clearinghouse and our CEQA staff in Sacramento does a preliminary review and sends a request for comment to the district office (me, in this case) if there is the possibility of issues that CalGEM might want to make comment on.

I reviewed the document that Ben Pogue linked in another email. From that review, I see that the proposed work will take place within the main area of the existing facility and that there are no wells in that area. Since CalGEM's basic responsibility is all about wells, there appears to be no probable impact related to wells for the Heber 2 Repower Project.

Thank you and if you have any questions about this matter please contact me

Take care,

Curtis M. Welty, PG
Associate Oil and Gas Engineer
California Geologic Energy Management Division
Southern District

California Department of Conservation
3780 Kilroy Airport Way, Suite 400
Long Beach, CA 90806
T: (562) 637-4410
C: (714) 294-4396
E: curtis.welty@conservation.ca.gov

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Attachment E

Air Quality Memorandum

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ENVIRONMENTAL SOLUTIONS

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AIR SCIENCES INC.
DENVER • PORTLAND • LOS ANGELES

HEBER 2 REPOWER PROJECT AIR EMISSIONS ADDITIONAL INFORMATION

PREPARED FOR: Melissa Wendt, Ormat

PREPARED BY: Joel Firebaugh, Air Sciences Inc.

PROJECT NO.: 346-2-1

COPIES: Ben Pogue, Catalyst Environmental Solutions

DATE: September 24, 2020

This memorandum includes additional information regarding the Heber 2 Re-Power Project (Project) air emissions not included in the Application for Authority to Construct submitted to Imperial County Air Pollution Control District in November 2019 or in the Air Sciences memo "Air Quality Analysis Summary for the ORMAT Heber 2 Re-Power Project" dated August 12, 2019. The following sections discuss emissions from construction activities, greenhouse gas emissions, and historical actual emissions.

1.0 Construction Emissions

Construction activities for the Project are expected to last up to eight months. Heavy construction equipment, including semi-truck trailers, flatbed trucks, excavators/bulldozers, roller, and a crane will be used at the Project site. Smaller powered equipment, such as drills, compressors, and welding equipment will also be used. Construction activities will be limited to 7:00am through 7:00pm.

The total Project disturbance is approximately 2.5 acres, entirely within the existing Heber 2 site. The Project site was developed and graded during the original construction of the Heber 2 facilities in 1992, and its current condition is exposed soil and gravel. To ensure the proposed facilities are situated on safe and stable surfaces, minor excavation and compaction activities will be performed. Fugitive dust emissions due to construction activities will be negligible. Water will be applied during excavation and compaction with sufficient frequency to minimize emissions. Construction vehicles will be limited to five miles per hour on unpaved surfaces and water will be applied to minimize vehicle fugitive dust emissions.

Air emissions from construction will be caused by fuel combustion by the construction equipment. A summary of construction emissions is presented in Table 1. Detailed construction emission calculations are included in the updated emission inventory provided with this memorandum.

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Table 1. Construction Emissions Summary (hourly and total tons for the Project)

	PM		NOX		CO		SO2		VOC	
Emission Source	**lb/hr**	**tons**	**lb/hr**	**tons**	**lb/hr**	**tons**	**lb/hr**	**tons**	**lb/hr**	**tons**
Fuel Combustion	0.35	0.51	5.47	7.99	4.93	7.20	0.008	0.011	1.03	1.50

2.0 Greenhouse Gas Emissions

The Project is expected to emit only small amounts of greenhouse gases (GHG) from construction activities and operations. GHG emissions during construction will come from fuel combustion by the construction equipment. GHG emissions from operations are generated by emergency diesel engines. Note that the proposed changes at Heber 2 do not affect GHG emissions from operations. The existing and proposed geothermal power generating units do not burn fuel and do not emit GHG. Table 2 provides a summary of GHG emissions from the Project, in units of tons per year of carbon dioxide equivalent (CO_2e). Detailed GHG emission calculations are included in the updated emission inventory provided with this memorandum.

Table 2. Greenhouse Gas Emissions Summary

Project Phase	**CO_2e tons per year[1]**
Construction	982
Operations	42

[1]The listed GHG emissions for construction are the total estimated emissions, in tons, for the duration of the 8-month construction phase of the project.

3.0 Historical Actual Emissions of Isopentane

The isopentane emissions increase for the Project was calculated based on the worst-case estimated future potential to emit and the previous two years of actual emissions data for the facility. The worst-case quarter from the historical actual emissions data was used as the baseline emissions case for comparison with the worst-case future potential to emit to calculate the emissions increase.

The emissions increase has been recalculated in Table 3 below, this time using the two-year average isopentane emissions from the historical actual data as the baseline emissions case.

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Table 3. Isopentane Emissions Increase

	Facility Total Isopentane Emissions	
	lb / day	**tons / year**
Historical Actual Emissions (Average 2017-2018)	62.6	14.9
Future Potential Emissions	59.7	10.9
Emissions Increase	-3.0	-4.0

The emissions increase shown in Table 3 is negative, which indicates an expected decrease in potential isopentane emissions from the Project.

EEC ORIGINAL PKG

Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 1 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: September 24, 2020

Ormat Heber 2: 2019 Re-Power Project - Facility-Wide Air Emissions Summary

Facility-wide Daily Emissions Estimate (lbs/day)

Emission Source	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC[1]	Isopentane[1]
OECs + Motive Fluid Tanks							59.7	59.7
Cooling Towers	76.9	9.2	9.2					
Diesel Engines[2]	1.3	1.3	1.3	29.0	5.6	0.016	3.7	
Facility Total Emissions	78	10.5	10.5	29.0	5.6	0.016	63.3	59.7

[1]Isopentane emissions are reported separately, but they are also included in the VOC emission estimate.

[2]Daily diesel engine emissions are based on one hour per day for maintenance and testing.

Facility-wide Annual Emissions Estimate (tons/year)

Emission Source	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC*	Isopentane*
OECs + Motive Fluid Tanks							10.9	10.9
Cooling Towers	14.0	1.7	1.7					
Diesel Engines	0.027	0.027	0.027	0.63	0.11	3.6E-4	0.068	
Facility Total Emissions	14.1	1.7	1.7	0.63	0.11	3.6E-4	11.0	10.9

*Isopentane emissions are reported separately, but they are also included in the VOC emission estimate.

Emissions Increase - Isopentane

	Facility Total Isopentane Emissions	
	lbs/day	*tons/year*
Previous Actual Emissions (average 2017-2018)	62.6	14.9
Projected Actual Emissions	59.7	10.9
Increase	-3.0	-4.0

Isopentane Permitted Emission Limits - (Purging, Fugitive and Maintenance)

	Current Permit	Proposed Limits
	lbs/day	*lbs/day*
1st Quarter	185	171
2nd Quarter	137	137
3rd Quarter	137	137
4th Quarter	218	202

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 2 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: September 24, 2020

Isopentane Emission Calculations

Emission Units

OEC / ITLU	Rating (MW, each)	# of Units	Gross Power *MW (total)*	MF Volume* *gallons (total)*	GF Flow Rate* *gal/hr*	Permitting Status
Heber 2	6	6	36.0	72,000		Will be shut down and replaced by new OEC-1 and OEC-2
Goulds 2	10	1	10.0	22,500		Existing - no change
Heber South	12	1	12.0	25,500		Existing - no change
OEC-1	14.01	1	14.0	35,000	12,200	New unit
OEC-2	25.43	1	25.4	28,000	12,200	New unit
MF Tanks	Size (gal, each)			*gallons (total)*		
Existing	10,000	3		30,000		Existing - no change
New	10,000	3		30,000		New tanks

** MF is motive fluid (isopentane) and GF is geothermal fluid (brine)*

Actual Isopentane Emissions (Previous 2 Years)

		Maintenance		Purging		Fugitive		Facility Total	
	# of days	*gallons*	*lbs/day*	*gallons*	*lbs/day*	*gallons*	*lbs/day*	*lbs/day*	*tons/year*
2017 - 1st Qtr	90	300	17.2	0.02	0.001	1,636	94.1	111.3	
2017 - 2nd Qtr	91	240	13.6	0.04	0.002	123	7.0	20.7	
2017 - 3rd Qtr	92	400	22.5	0.05	0.003	1,616	90.9	113.4	
2017 - 4th Qtr	92	100	5.6	0.02	0.001	1,337	75.2	80.8	14.9
2018 - 1st Qtr	90	0	0.0	0.00	0.000	0	0.0	0.0	
2018 - 2nd Qtr	91	0	0.0	0.00	0.000	0	0.0	0.0	
2018 - 3rd Qtr	92	400	22.5	0.06	0.003	1,688	95.0	117.5	
2018 - 4th Qtr	92	250	14.1	0.02	0.001	770	43.3	57.4	8.0

Isopentane Density	
620	mg/ml
0.00835	(lb/gal)/(mg/ml)
5.17	lb/gal

Site-Specific Isopentane Emission Factor Calculation

Previous 2 Years Emissions	Basis	Isopentane Emissions *lbs/day*	Isopentane Emissions *tons/year*	Existing Isopentane Volume *gallons*	Units Included	Calculated Site-Specific Emission Factor
Maintenance	worst-case quarter	11.9	2.7	120,000	OECs	0.10 *(lb/day)/1,000 gal MF*
Purging	worst-case quarter	0.0034	0.0003	120,000	OECs	2.8E-5 *(lb/day)/1,000 gal MF*
Fugitive	worst-case quarter	95.0	12.2	150,000	OECs + MF tanks	0.63 *(lb/day)/1,000 gal MF*
Total		106.9	14.9			

Heber 2 Re-Power Isopentane Emission Estimate - After proposed changes

OEC Units & MF Tanks	MF Volume (new) *gallons*	Emission Factor *(lb/day)/1,000 gal*	Expected Reduction Due to Fewer Emission Units	Isopentane Emissions *lbs/day*	Isopentane Emissions *tons/year*	Change in Emissions *lbs/day*	Change in Emissions *tons/year*
Maintenance	111,000	0.10	50%	5.5	1.0	-6.4	-1.7
Purging	111,000	2.8E-5	0%	0.0	0.0	0.0	0.0
Fugitive	171,000	0.63	50%	54.1	9.9	-40.8	-2.3
Total				59.7	10.9	-47.3	-4.0

EEC ORIGINAL PKG

Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh
	PROJECT NO: 346-2	PAGE: 3 OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: September 24, 2020

Cooling Towers Emission Calculations (Existing - no change)

Site Data		Reference
Total solids in recirculating water	3,950 ppm	Heber 1 OEC-14 ATC Application
Water Density at 84.9 F	8.31 lb/gal	
Droplets larger than 10 μm	88%	Heber 1 OEC-14 ATC Application
Droplets larger than 2.5 μm	88%	Heber 1 OEC-14 ATC Application

Cooling Tower Emissions

	Water Flow		PM		PM_{10}		$PM_{2.5}$	
Description	*gal/min*	Drift Rate	*lb/day*	*ton/yr*	*lb/day*	*ton/yr*	*lb/day*	*ton/yr*
3-Cell Cooling Tower	41,250	0.0010%	19.50	3.56	2.340	0.43	2.340	0.43
3-Cell Cooling Tower	41,250	0.0005%	9.75	1.78	1.170	0.21	1.170	0.21
6-Cell Cooling Tower	63,000	0.0008%	23.82	4.35	2.859	0.52	2.859	0.52
6-Cell Cooling Tower	63,000	0.0008%	23.82	4.35	2.859	0.52	2.859	0.52
Total			76.9	14.0	9.23	1.7	9.23	1.7

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Air Sciences Inc.	PROJECT TITLE: Ormat Heber 2	BY: J. Firebaugh	
	PROJECT NO: 346-2	PAGE: 4	OF: 4 SHEET: Emis_Calcs
AIR EMISSION CALCULATIONS	SUBJECT: 2019 Re-Power Emissions	DATE: September 24, 2020	

Diesel Engines Emission Calculations (Existing - no change)

Diesel Engines

Type	Engine Make & Model	Engine Power	Operating Hours	Emission Factors
Emergency Generator	Cummins KTA19G2	685 hp	50 hrs/yr	AP-42 Table 3.4-1, Existing Permit Limits
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	305 hp	35 hrs/yr	AP-42 Table 3.3-1
Emergency Pump	John Deere 6090HF485	350 hp	50 hrs/yr	EPA Certification Data
Fire Pump	Clarke JW6H-UF40 (John Deere 6081HF001)	300 hp	35 hrs/yr	CA Tier 2, Fire Pumps

Emission Factors

Reference	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC	Units
PTO #2217A-4 Emission Limits - Cummins KTA19G2				14.3	1.5			*lb/hr*
AP-42 Table 3.4-1 (Diesel engines >600hp)	7.0E-4	7.0E-4	7.0E-4	0.024	0.0055	1.1E-5	7.1E-4	*lb/hp-hr*
AP-42 Table 3.3-1 (Diesel engines <600hp)	0.0022	0.0022	0.0022	0.031	0.0067	1.1E-5	0.0025	*lb/hp-hr*
EPA Cert. Data for JD Family 6JDXL09.0102	0.10	0.10	0.100	3.5	0.50	0.0049	0.10	*g/kW-hr*
CA Tier 2, Fire Pumps (300 ≤ hp < 600)	0.15	0.15	0.15	4.8	2.6	0.0049	4.8	*g/hp-hr*

SO_2 Emission Factor Calculation (mass balance):

7,000 Btu	1 lb diesel	15 lb S	1.998 lb SO2	=	1.09E-05 lb SO_2/hp-hr
1 hp-hr	19,300 Btu	1,000,000 lb diesel	1 lb S		

Diesel Properties	Typical CI Engine BSFC (AP-42)	Units Conversions
15 ppm S (ULSD)	7,000 Btu/hp-hr	1.341 hp/kW
7.1 lb/gal (AP-42)		453.592 g/lb
19,300 Btu/lb (AP-42)		1.998 g SO_2/g S

Diesel Engine Emissions - Daily (lbs/day)

Type	Engine Make & Model	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC
Emergency Generator	Cummins KTA19G2	0.5	0.5	0.5	14.3	1.5	0.0074	0.48
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	0.7	0.7	0.7	9.5	2.0	0.0033	0.77
Emergency Generator	John Deere 6090H	0.1	0.1	0.1	2.0	0.29	0.0028	0.058
Emergency Pump	Clarke JW6H-UF40	0.1	0.1	0.1	3.2	1.7	0.0024	2.4
Total		1.3	1.3	1.3	29.0	5.6	0.016	3.7

*Daily diesel engine emissions are based on one hour per day for maintenance and testing.

Diesel Engine Emissions - Annual (tons/year)

Type	Engine Make & Model	PM	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2	VOC
Emergency Generator	Cummins KTA19G2	0.012	0.012	0.012	0.36	0.039	1.9E-4	0.012
Fire Pump	Detroit Diesel DDFP-L6AT-7017V	0.012	0.012	0.012	0.17	0.036	5.8E-5	0.013
Emergency Generator	John Deere 6090H	0.0014	0.0014	0.0014	0.050	0.0072	7.1E-5	0.0014
Emergency Pump	Clarke JW6H-UF40	0.0017	0.0017	0.0017	0.056	0.030	4.3E-5	0.041
Total		0.027	0.027	0.027	0.63	0.11	3.6E-4	0.068

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Attachment F

CEQA Deskbook Reference Evaluation for Related Activities in a CEQA Document

Catalyst
ENVIRONMENTAL SOLUTIONS

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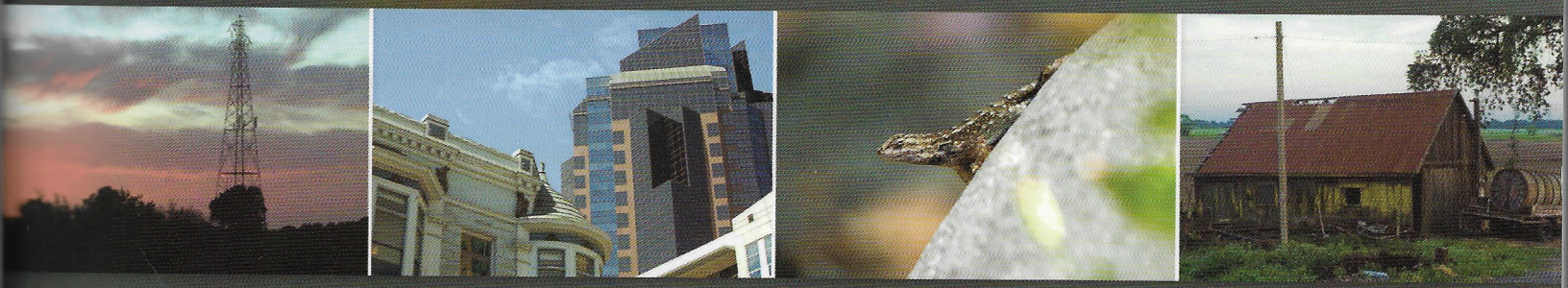
Updates available at www.solano.com

CEQA deskbook

A STEP-BY-STEP GUIDE ON HOW TO COMPLY WITH THE CALIFORNIA ENVIRONMENTAL QUALITY ACT

Third Edition



RONALD E. BASS | KENNETH M. BOGDAN | TERRY RIVASPLATA

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Figure 2-2. Evaluation of Related Activities in a CEQA Document Illustrative Case Examples

When must related activities be evaluated in the same CEQA document?

When "Action B" is a reasonably foreseeable consequence of "Action A"

Bozung v. Local Agency Formation Commission (1975) 13 Cal. 3d 263 (successive government approvals for the same underlying project must be considered together); *Laurel Heights Improvement Association v. Regents of the University of California* (1988) 47 Cal.3d 376 (future phases of a single building must be evaluated in the EIR on the first phase because they are foreseeable)

When "Action B" is a future expansion of "Action A" and will be significant because it will likely change the scope, nature, and impacts of "Action A"

Laurel Heights Improvement Association v. Regents of the University of California (1988) 47 Cal.3d 376 (future phases of a single building must be evaluated in the EIR on the first phase because they will contribute to the project's impacts)

When "Action A" cannot proceed without essential public services that would be provided by "Action B"

Santiago County Water District v. County of Orange (1981) 118 Cal. App. 3d 818 (EIR on a mining project must include impacts of water delivery system to serve the project); *San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus* (1995) 27 Cal. App. 4th 713 (EIR on a housing project must include impacts of additional sewer capacity to serve the project)

When "Action A" and "Action B" are integral parts of the same project

No Oil, Inc. v. City of Los Angeles (1987) 196 Cal. App. 3d 223 (Pipelines to deliver oil must be evaluated in an EIR for an oil drilling project)

When may related activities be deferred to a future CEQA document? *

When "Action A" is being evaluated at a time when meaningful information about "Action B" is not capable of being obtained (e.g., is " remote and speculative")

No Oil, Inc. v. City of Los Angeles (1987) 196 Cal. App. 3d 223 (information about pipeline locations was not yet available and did not have to be evaluated in an EIR on an oil drilling project)

When information about "Action B" is not necessary to make an intelligent decision whether to proceed with "Action A"

No Oil, Inc. v. City of Los Angeles (1987) 196 Cal. App. 3d 223 (detailed information about pipelines to deliver oil was not necessary for a decision to be made whether to approve an oil drilling project)

When "Action A" is being evaluated in a first-tier EIR and "Action B" will be evaluated in a second-tier EIR.

Rio Vista Farm Bureau Center v. County of Solano (1992) 5 Cal. App. 4th 351 (program EIR on hazardous waste management plan need not evaluate project-specific impacts of activities that will be subject to future, second-tier EIRs)

When "Action A" merely establishes criteria for "Action B" but does not commit to its implementation

Rio Vista Farm Bureau Center v. County of Solano (1992) 5 Cal. App. 4th 351 (EIR on hazardous waste management plan need not evaluate future facilities that might be developed under the plan)

When "Action B" is independent of, and not a contemplated future part of, "Action A"

Christward Ministry v. County of San Diego (1993) 13 Cal. App. 4th 31 (EIR for a proposed landfill expansion need not evaluate impacts of other solid waste projects in the county)

When "Action A" is part of a large highway project with logical termination points and independent utility and does not foreclose consideration of alternatives

Del Mar Terrace Conservancy, Inc. v. City Council of the City of San Diego (10 Cal. App 4th. 712) (EIR on 1.8 mile highway project was appropriate because it had independent use for local and state service even if no other phases were constructed)

* **When a Lead Agency elects to exclude or limit the evaluation of related activities, it should include the following in the CEQA document:**

1) A description of the potential future activities and how they relate to the proposed project
2) A brief explanation of the types of impacts that those related actions might produce
3) A discussion of why it is not necessary or possible to evaluate the related actions at the current time
4) An explanation of when, and in what type of CEQA document, the related actions will be evaluated (e.g., second-tier EIR)

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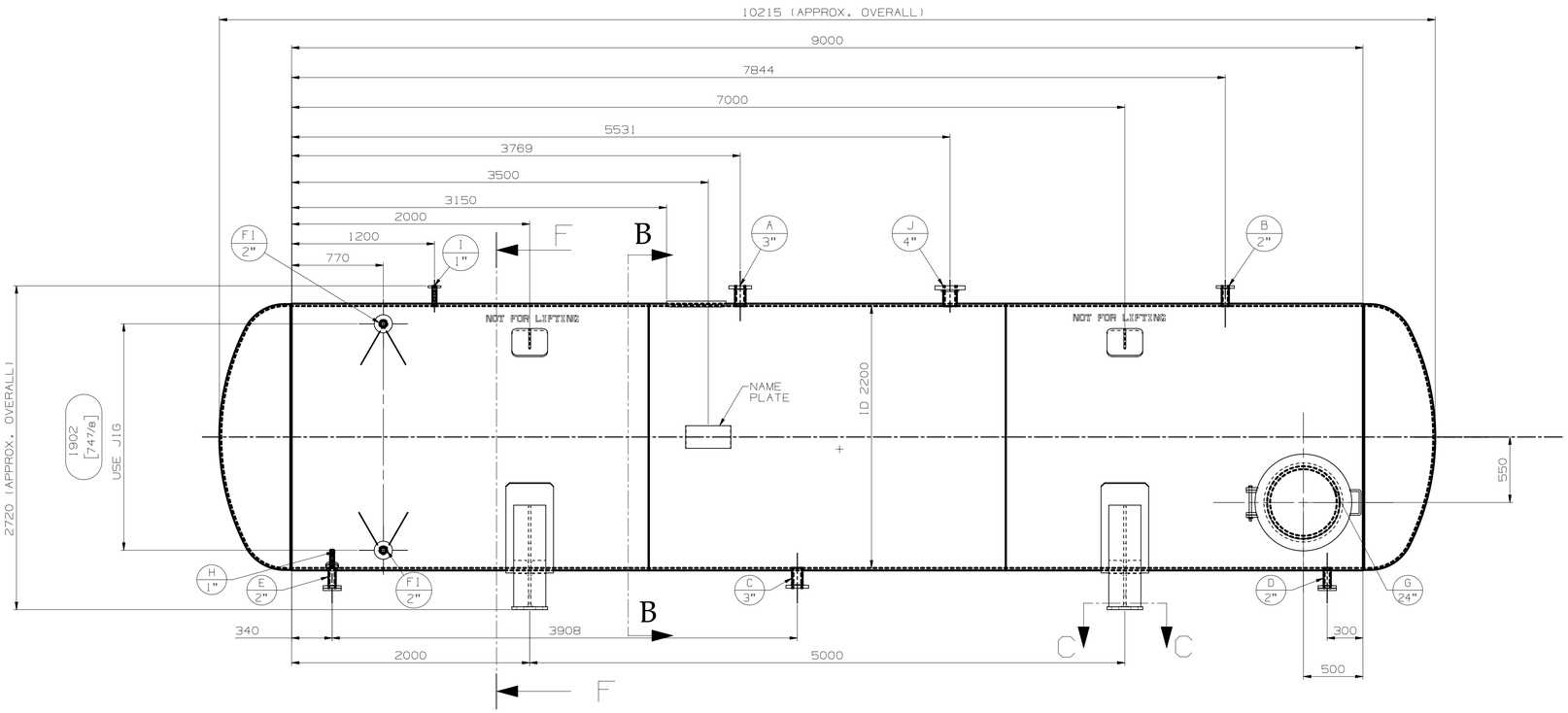
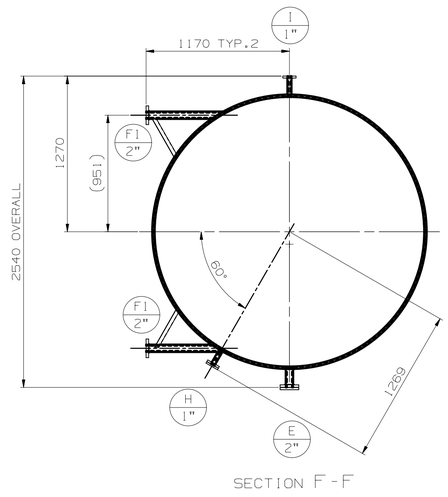
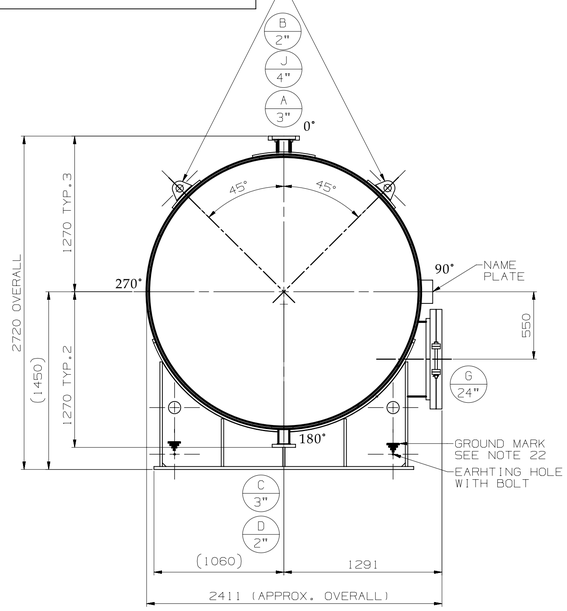


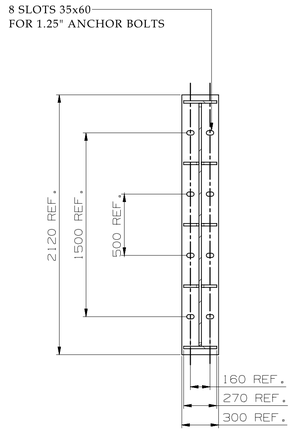
DO NOT LIFT AT THIS POINT.
FOR LASHING ONLY



SECTION F-F



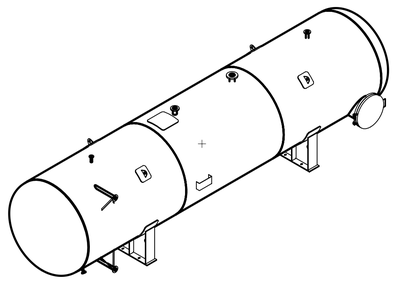
SECTION B-B



SECTION C-C
TYP.2

J	4"	1	SCH 160 (13.49mm)	S.O.R.F	300#	LEVEL TRANSMITTER	
I	1"	1	SCH 160 (8.74mm)	S.O.R.F	150#	PRESSURE INDICATION	
H	1"	1	SCH 160 (8.74mm)	S.O.R.F	150#	TEMPERATURE INDICATOR	
G	24"	1	SCH 80 (30.96mm)	S.O.R.F	150#	MANHOLE	W/DAVIT
F2	2"	1	SCH 160 (8.74mm)	S.O.R.F	150#	LEVEL GAUGE	
F1	2"	1	SCH 160 (8.74mm)	S.O.R.F	150#	LEVEL GAUGE	
E	2"	1	SCH 160 (8.74mm)	S.O.R.F	150#	DRAIN	W/BLIND
D	2"	1	SCH 160 (8.74mm)	S.O.R.F	150#	DRAIN	W/BLIND
C	3"	1	SCH 160 (11.13mm)	S.O.R.F	150#	INLET/OUTLET	
B	2"	1	SCH 160 (8.74mm)	S.O.R.F	150#	PRESSURE EQUALIZATION	
A	3"	1	SCH 160 (11.13mm)	S.O.R.F	150#	RELIEF	
	SIZE	QTY.	NOZZLE NECK	TYPE	RATING	SERVICE	REMARKS

NOZZLES SCHEDULE SERVICE



GENERAL NOTES

1. INPUT DESIGN DATA

		SHELL
DESIGN PRESSURE	[psig]	120/FV
DESIGN TEMPERATURE	[°F]	234/122
MAWP	[psig]	120/FV
AT TEMPERATURE	[°F]	234/122
MDMT	[°F]	32
AT PRESSURE	[psig]	120/FV

		SHELL
DESIGN PRESSURE	[barg]	8.3/FV
DESIGN TEMPERATURE	[°C]	112/10
MAWP	[barg]	8.3/FV
AT TEMPERATURE	[°C]	112/10
MDMT	[°C]	0
AT PRESSURE	[barg]	8.3/FV

CORROSION ALLOWANCE

	SHELL
CORROSION ALLOWANCE	0.063"(1.6mm)

2. ADDITIONAL INPUT

	YES	NO
ASME CERTIFICATION MARK WITH "U" DESIGNATOR	×	
REGISTRATION AT NATIONAL BOARD	×	

	NOT REQUIRED, EXEMPTED BY		
IMPACT TEST	UG-20(f)	UCS-66	UHA-51
	N/A	×	N/A
PWHT	UCS-56		UHA-32
	×		N/A

	REQUIRED, FOR ITEMS
IMPACT TEST	FOR SA-516/70
PWHT	N/A

3. ABRASIVE BLASTING BEFOR WELDING.
ALL CARBON STEEL PLATE SHALL BE BLASTED TO SSPC-SP-10/CLASS 2½
4. TACK WELDING PROC.24.3.6.009
5. WELDING PROC.24.3.6.009
6. P.T.EXAMINATION PROC.21.1.8.010
7. RADIOGRAPHY: NONE

JOINT EFFICIENCY TABLE

	SHELL	CAPS
LONGITUDINAL SEAMS	0.7	0.85
CIRCUMFERENTIAL SEAMS	0.65	0.65

8. MACHINING INSPECTION PROC.21.1.8.019
10. DIMENSIONAL CHECK AND TOLERANCES..PROC.21.1.8.013
11. BUBLE TEST PROC.21.1.8.009
12. BOLTS TIGHTENING PROC.21.1.8.042
13. HYDROSTATIC TEST PROC.21.1.8.008,
HOLDING TIME 1 HOUR

	SHELL			
HYDROSTATIC PRESSURE (psig/barg)	160/11			
HYDROSTATIC TEST POSITION	HORIZONTAL	×	VERTICAL	-

14. ALL FLANGES TO ASME / ANSI B.16.5/ASME B/16.47 SERIES A
ALL BOLTS & NUTS TO BE HOT DIP Zn COATED (galvanized)
15. DRAINING,DRYING & NYTROGEN PURGING PROC.24.3.8.036
16. FINAL CLEANING.....PROC.24.1.8.018
17. PAINTING PROC.24.3.7.080
18. FINAL INSPECTION AND TESTING PROC.21.1.8.081
19. SHIPMENT AND STORAGE PROC.21.1.8.017
20. TELLTALE HOLES 1/4" ON ALL REINFORCEMENT & PAD PLATES
21. DIMENSIONS ARE IN mm
22. APPLY GROUND MARK NEAR GROUND POINT
23. NOTE "NOT FOR LIFTING" 50 MM ABOVE EACH LUG
RED COLOR, RAL 3020,
MINIMUM HEIGHT OF THE LETTERS IS 60 MM
24. WEIGHTS AND VOLUME:
VOLUME: 37500 L / 9906 GAL
EMPTY WEIGHT: 12900 KG / 28440 LBS
HYDROTEST WEIGHT: 50400 KG / 111113 LBS
OPERATION WEIGHT: 36375 KG / 80182 LBS

REV.	DESCRIPTION	DATE	BY	CHK	APP
1	WEIGHTS AND VOLUME UPDATED	06-02-2020	Or Yashar	Maxim Yoffe	

Document ID: 138375 (0.909.51.720.0_1_sht1.pdf) 29 EA, Galit Sharvit, Approved for production

MTL.:	SURFACE ROUGHNESS:	BREAK SHARP EDGES:	GENERAL TOLERANCES:
CODE MATERIAL:	FINISH:		WEIGHT: kg

	HOPV DEP. MANAGER: Ehud Ben Shlomo	ORMAT®	THIS DRAWING IS THE PROPERTY OF ORMAT AND MUST NOT BE COPIED OR REISSUED WITHOUT PERMISSION	TITLE: MOTIVE FLUID TANK (9906 GAL)
	HOPV DESIGN ENGINEER: Maxim Yoffe			
	HOPV DESIGNER: Or Yashar 22-Dec-2019			DRAWING NO: 0.909.51.720.0 1/3 · DRWG REV: 1 · SHEET REV: A

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MEMO

To: County of Imperial

From: Chambers Group, Inc.

Date: 10/20/20

RE: Hazards Associated with Proposed Isopentane Storage at the Heber 2 Facility in Heber, CA

Chambers Group, Inc. has prepared the following transmittal to accompany the attached Updated Hazard Assessment addressing the storage of the regulated substance, isopentane, on the Heber 2 Repower Project site in Heber, California. Risk Management Professionals, Inc. (RMP), produced an initial Hazard Assessment for the Heber 2 Repower Project on July 10, 2019 and revised on October 18, 2019 to address potential hazards associated with isopentane. Following comments from the public expressing safety concerns, RMP produced an updated Hazard Assessment using a more precise modeling software, incorporating a concrete containment area as passive mitigation, and rearranging the new vessels into a safer layout. Both technical assessments were conducted in compliance with the Hazard Assessment Offsite Consequence Analysis requirements of the Environmental Protection Agency (EPA) "Risk Management Plan" regulations (40 CFR § 68.65) and California Code of Regulations "California Accidental Release Prevention (CalARP) Program" (19 CCR 2750.1 to 2750.9).

RMP has developed an updated worst-case modeling scenario for the isopentane currently and soon to be stored at the Heber 2 facility. According to the EPA Risk Management Plan regulations, the worst-case release is defined as "the release of the largest quantity of a regulated substance from a vessel failure that results in the greatest distance to a specified endpoint" (40 CFR § 68.3). To determine the worst-case release quantity, the EPA regulations dictate "for substances in vessels, the greatest amount held in a single vessel, taking into account administrative controls that limit the maximum quantity" must be analyzed (40 CFR § 68.25). In compliance with these regulations, RMP modeled the worst-case scenario as the catastrophic failure of one 10,000-gallon isopentane storage vessel. With the incorporation of a concrete containment area as passive mitigation, the endpoint radius resulting from the release of one vessel was determined to stay within the property boundary and not to reach any new (#1, #2, and #3) or existing (#4, #5, and #6) vessels. The only overlap of concern is in regard to vessel locations #4 and #5 where they reside in one another's areas of impact. However, plans to construct a blast wall between the two existing tanks will eliminate this concern. Regardless, the EPA's Offsite Consequences Analysis process is recognized by process safety professionals as being highly conservative, rendering these scenarios very unlikely.

In addition to being consistent with EPA regulations, the modeling provided represents a sufficient worst-case scenario to be utilized in emergency planning and impact analysis. During normal operations, the isopentane tanks are not filled to capacity; in fact, they are rarely filled. Isopentane is used only as backup fuel during plant outages, which occur up to approximately one week per year. Therefore, a quantity of isopentane in excess of the quantity modeled occurs less than 2 percent of the entire year. The remaining over 98 percent of the year, at most the tanks are partially filled to approximately 15 percent capacity or alternatively, only one tank is completely full, and the remaining tanks are empty. Further, the modeling incorporates extremely conservative assumptions with regards to atmospheric conditions which further provide an analysis addresses a highly unlikely catastrophic failure of the tanks.

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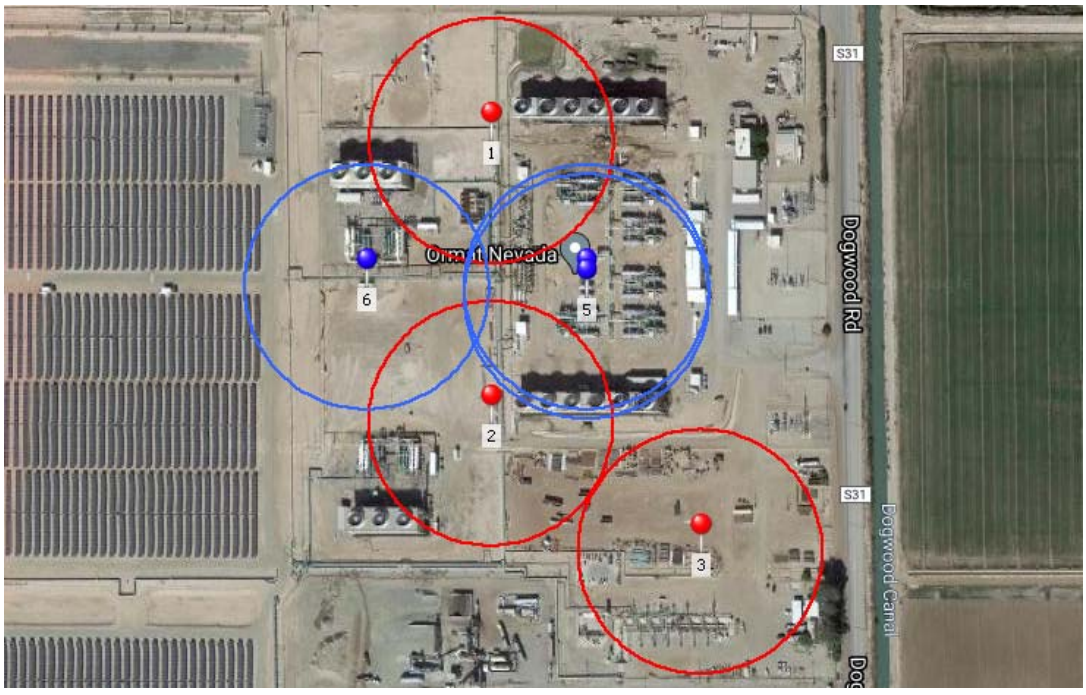
Moreover, ORMAT will implement several safety- control measures into the isopentane storage system that would further reduce the potential for both initial tank failure and multi-tank failure:

- Each tank will be equipped with an automated water suppression system.
- Each tank will be equipped with two flame detectors and one gas detector (for a total of 6 flame detectors and 3 gas detectors for the three tanks).
- In the case of an isopentane leak, the gas detector(s) will detect it immediately and send a notification to the operator at the control room (manned 24/7) in order to mobilize fixing the leak.
- In case of a fire, the flame detector(s) will detect it and immediately start the automatic fire suppression system.
- In case of a fire, there will also be a horn and strobe system that will turn on automatically to alert the plant employees.

Due to the conservative Offsite Consequences Analysis process; taking into consideration:

- concrete containment areas as passive mitigation,
- vessels rarely filled to 90% capacity,
- isopentane safety- control measures,
- and a blast wall

areas of concern are generally limited to inside facility boarders, thus producing zero sensitive receptors. Furthermore, ORMAT can go as far as to say that according to the figure below, the explosion area of one new vessel (red) will not reach any of the existing vessels (blue), nor overlap with the explosion area resulting from the other new vessels. The only overlap of explosion area would be for the existing tanks 4 and 5, which were permitted by the County. However, as discussed above, ORMAT proposes to install a blast wall between tanks 4 and 5 to minimize any chance of a cascading tank failure.



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Responses to Heber 2 IS/ND Comments and Recommended Clarifications and Supplements

Date:	9/28/20
To:	Imperial County Planning Department
From:	Ben Pogue (Catalyst) on Behalf of ORMAT/SIGC
RE:	CURE Comment Letter on Heber 2 IS/ND

Introduction and Purpose

The purpose of this memorandum is to provide clarifying information to the Imperial County Planning Department (ICPD) and its affiliate departments in response to comments submitted by Adams Broadwell Joseph & Cardoza (ABJC) on behalf of California Unions for Reliable Energy (CURE) on the Initial Study and Negative Declaration (IS/ND) for the Heber 2 Repower Project (Project). The two primary sections of this memorandum include a summary outline of the CURE letter and a comment summary matrix with responses.

As discussed below, in response to comments received from the Imperial County Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed below. CEQA contemplates the move from ND to Mitigated Negative Declaration (MND) based on comments on the IS/ND , and we support the County in revising the CEQA decision to a MND and recirculating the IS/MND for a 30 day public review period.

CURE Comment Letter Issues Outline

This outline provides the basis of issues raised in the CURE comment letter. Those headings in bold represent primary issues, with the sub-issues outlined below. The issues identified in this outline are summarized and responded to in the comment matrix in the following section.

I. **Statement of Interest**
II. **An EIR Must be Prepared**
III. **The IS/ND Fails to Adequately Describe the Project**
    a. The IS/ND's Description of the Project's Construction Activities is Inadequate and Flawed
    b. The IS/ND Fails to Describe Emissions from Reclamation Activities
    c. The IS/ND's Numerous Errors Prohibits the Public from Fully Evaluating the Project's Impacts
IV. **The IS/ND Fails to Accurately Describe the Project's Baseline Conditions**
    a. The IS/ND Fails to Accurately Describe the Project's Baseline Generating Capacity and Associated Impacts, As Well As Its Baseline Emissions
    b. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site
V. **The County Has Violated CEQA by Piecemealing Environmental Review and Permitting for the Expansion of the Heber Geothermal Facilities as Separate Projects**
VI. **Substantial Evidence Supports a Fair Argument that the Project May Have Significant Impacts Which Must be Analysed in an EIR**

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a. There is a Fair Argument that Construction Emissions from the Project Could Have a Significant Impact on Public Health and the Environment
b. There is a Fair Argument that the Project Could Result in Significant Impacts to Public Health from Valley Fever
c. The IS/ND's Methods for Evaluating a Hazard Analysis and the Possibility of Accidents or Explosions at the Site Are Inadequate and Unsupported.
d. There is a Fair Argument that Extending the Life of the Project Could Result in Geologic Impacts
e. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project
f. The IS/ND Fails to Disclose the Project's Construction or Operational GHG Emissions, and Relies on an Inapplicable Significance Threshold
g. There is a Fair Argument that the Project Will Have Significant Impacts on Water Supply

VII. The IS/ND Concedes that Mitigation is Required

a. The IS/ND Fails to Consider Feasible Mitigation to Reduce Potentially Significant Impacts to Less than Significant Levels for Construction and Operations

VIII. The IS/ND Fails to Properly Evaluate Potentially Significant Cumulative Impacts.

IX. The Project May Require a CEC License.

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Comment Summaries and Responses

CURE Letter Section	Substantive Comment Summary	Response
I. Statement of Interest	ABJC discloses its representation of its client, the California Unions for Reliable Energy (CURE). The IS/ND fails to meet the basic requirements of CEQA. The County must prepare an EIR.	No substantive technical comment provided. Comment lauds renewable energy development and subsequently criticizes the Heber 2 Repower Project. The IS/ND was based on site specific and technically substantiated information on the baseline conditions of the Project site and potential impacts. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. The following Mitigation Measure HAZ-1 is considered: HAZ-1: To minimize the potential for a cascading failure event of the new isopentane tanks and to limit any potential impacts within the existing Heber 2 Complex fence line, the three isopentane tanks shall be located as set forth in Attachment B. Further, diking and impoundment of the proposed isopentane tanks shall be installed consistent with the Hazard Memorandum (Attachment C) to minimize the magnitude and extent of a tank failure, and the detailed design of the project shall ensure that the Project's features satisfy the design criteria assumed in the Hazard Assessment (Attachment C). As observed in Figure 9 of the Hazard Assessment (Attachment C), the area of potential effect for each new isopentane tank would not overlap, thus preventing a consequential catastrophic event. CEQA contemplates the move from ND to MND based on comments on the IS/ND, and we support the County in revising the CEQA decision to a MND and recirculating the IS/MND for a 30-day public review period. See following comments explaining why a MND is appropriate, instead of the EIR CURE requests.
II. An EIR Must Be Prepared	CURE attempts to employ the "fair argument rule" under CEQA that an EIR must be prepared to address significant impacts, but does not site any specific IS/ND sections or analyses.	The proposed Project site is entirely within the existing and permitted plant boundary, and is entirely void of any vegetation, habitat, waterbodies, and existing facilities. The purpose of the Project is to repower the Heber 2 geothermal facilities by replacing old ORMAT Energy Converters (OECs) with state-of-the-art OECs that run more efficiently and emit less emissions, and install three new isopentane tanks to support operations. No facilities are

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		proposed outside of the existing facility's fence line. Due to the Project's limited nature, no significant environmental impacts were anticipated. The IS confirmed that the Heber 2 Project would not result in any significant impacts and no mitigation was required, thus the issuance of an ND. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed below. CEQA contemplates the move from ND to MND based on comments on the IS/ND. This comment identifies air quality, cumulative air quality, public health, water supply, biological resources, and impacts form hazardous materials are not technically substantiated. See responses included in Issue VI below that elaborates on these specific resources and discussions on the information and methods used to reach significance conclusions in the MND.
III. The IS/ND Fails to Accurately Describe the Project	CURE sites that CEQA prohibits the "piecemealing" of a larger project into many smaller projects, resulting in numerous environmental reviews for a single project.	A subsidiary of ORMAT is proposing to upgrade and develop additional geothermal energy generation at the Heber 1 plant, approximately 1 mile to the east of the Heber 2 site. The Heber 1 and Heber 2 facilities are physically and electrically separate, as they do not share any facilities, including geothermal production wells, pipeline, OECs, isopentane tanks, or transmission facilities. These geothermal energy facilities were developed at separate times (not as a single project), have never shared any facilities or lands/leases, and are permitted under separate CUPs issued by Imperial County. Further, these projects are treated as separate projects by relevant utilities and regulatory agencies, including each facility has separate Power Purchase Agreements, Interconnection Agreements, Imperial County Air Pollution Control District (ICAPCD). ICAPCD implements state and federal laws that determine how projects are either treated as separate or grouped under an air quality "bubble." ICAPCD' s determination that Heber 1 and Heber 2 are separate facilities is substantial evidence that they facilities are in fact two separate projects. There are three principle tests under CEQA with respect to determine whether two projects are separate CEQA projects.

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		In the seminal CEQA test for piecemealing, *Laurel Heights Improvement Association v. Regents of the University of California ("Laurel Heights")*[1], the California Supreme Court set forth a two prong test for determining whether future phases of a project or other foreseeable consequences of an approved land use must be included as a part of a project for the purposes of environmental review. This important and often cited case provides the clearest guidance as to the standard that will be applied by courts in evaluating whether an agency improperly segmented environmental review of a project. The first prong set forth in *Laurel Heights* is that an agency must analyse the environmental effects of a project's future expansion or other action if it is a "reasonably foreseeable consequence of the initial project." In this case, neither Heber 1 nor Heber 2 is a reasonably foreseeable consequence of the other. The projects are separated physically by nearly a mile and share no common critical infrastructure. One project can run with or without the other. The second *Laurel Heights* prong is that an agency must analyse the environmental effects of a project's future expansion or other action if it "will likely change the scope or nature of the initial project or its environmental effects." Again, the projects' physical and operational separation provide that neither project will affect the nature or scope of the other project or its environmental effects. See below for more factual discussions demonstrating that consistent with the *Laurel Heights* case, Heber 1 and Heber 2 are separate and independent CEQA projects. The second important CEQA test is the "independent utility" test. In *Del Mar Conservancy, Inc. v. City Council of the City of San Diego*, 10 Cal. App. 4th 712 (1992), the courts examine whether a project has "independent utility" that warrants separate environmental review and approval, even if it is arguably

[1] *Laurel Heights Improvement Assn. v. Regents of University of California*, 47 Cal. 3d 376, 396 (Cal. 1988).

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		part of a larger project. This test is derived from federal case law regarding the National Environmental Policy Act ("NEPA"), and has traditionally been applied in the context of the segmentation of environmental review of road projects, but has been applied in other contexts as well.[2] Under this test, it is appropriate for an individual portion of a larger road construction project to be reviewed and approved separately from the larger project if the segment has independent utility, and will serve a purpose even if the larger project is not constructed.[3] In this case, Heber 1 and Heber 2 each have independent utility; that is, each project operates to provide a separate and distinct set of benefits to the project owners. Each is contracted separately. Each sells its own electrical output. The projects do not sell to the same offtakers and each has separate and wholly unrelated contractual obligations, as just some examples of the independent utility of each. Under this CEQA test, Heber 1 and Heber 2 have "independent utility". The third CEQA test is called the "Crucial Functional Element" test, a corollary to the independent utility test. Unlike the independent utility test, which outlines when a project that is arguably part of a larger one can be reviewed and approved separately, the crucial function element test determines when a smaller project must be reviewed as a part of the larger project. Under this test, if a project is a "'required' or 'crucial element' without which" another

[2] See *Planning and Conservation League v. Castaic Lake Water Agency*, 180 Cal. App. 4th 210, 237 (2009)(applying independent utility test in upholding adequacy of EIR in case regarding transfer of water entitlements).

[3] *Del Mar Conservancy, Inc. v. City Council of the City of San Diego*, 10 Cal. App. 4th 712, 734 (citing to *Daly v. Volpe,* 514 F.2d 1106, 1109-1110 (1975)). In the original NEPA cases, *Daly v. Volpe*, three other criteria were also considered: whether the segment (1) is of substantial length and between logical terminal points; (2) is long enough to ensure adequate opportunity for consideration of alternatives; (3) will fulfill important state and local needs. However, as the independent utility criteria has been broken out as a separate test under both NEPA and CEQA case law, only the independent utility criteria is discussed above.

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		project "could not go forward," environmental review of the two cannot be piecemealed, and both projects as a whole must be addressed in an environmental review document. In the case of Heber 1 and Heber 2, neither project is "required or a critical element" of the other. Each operates independently, without sharing critical infrastructure. Neither is necessary for the other to be able to function as neither provides the other with any critical functional element. Each function separately. These three cases are fact-specific analyses. Applying the facts in this case demonstrates that Heber 1 and Heber 2 are separate CEQA projects. The following are some additional facts demonstrating two separate projects. For example, the proposal to repower Heber 2 does not depend on the outcome of the Heber 1 proposal (and vice versa). The points below are guidance provided in the CEQA Deskbook (Figure 2-2: Evaluation of Related Activities in a CEQA Document; 2012) for when two actions should be addressed in a single CEQA review. A copy of this guidance is also enclosed as Attachment F. While Action A and Action B, in this case, could be either Heber 1 and Heber 2, regardless of order, since this response is based on the CURE letter received on Heber 2, Action A below is read as Heber 2 and Action B is Heber 1, as follows: 1. When "Action B" is reasonably foreseeable consequence of "Action A". 2. When "Action B" is a future expansion of "Action A" and will be significant because it will likely change the scope, nature, and impacts of "Action A". 3. When "Action A" cannot proceed without essential public services that would be provided by "Action B". 4. When "Action A" and "Action B" are integral parts of the same project. <u>Response to CEQA Deskbook Hypothetical 1</u>: While Heber 1 and Heber 2 are being proposed in close temporal proximity, the result of either project is not dependent on the outcome of the other project. In other words, for example, if Heber 1 is declined a permit, and Heber 2 is permitted, Heber 2 will still be developed regardless of the fact that Heber 1 was declined (and vice versa).

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		Response to CEQA Deskbook Hypothetical 2: Since Heber 1 and Heber 2 do not share any critical facilities or infrastructure and are separated by almost a mile, and neither proposal includes facilities that would be shared, these actions are not reflective of a connected or future expansion at either plant. Any future expansions at Heber 1 and Heber 2 would remain independent from one another, simply due to the fact that the plants were developed as independent facilities and are not designed to operate in conjunction with each other. Response to CEQA Deskbook Hypothetical 3: Heber 1 and Heber 2 operate independently from one another. For example, ORMAT could shut down operations entirely at either plant and the other would not be affected whatsoever. These facilities do not share any public services, whereas the Heber 2 Repower Project could not proceed without the approval of Heber 1 (and vice versa). Response to CEQA Deskbook Hypothetical 4: As discussed above, the outcome of either proposal is not dependent on the other. In other words, for example, if Heber 1 is declined a permit, and Heber 2 is permitted, Heber 2 will still be developed regardless that Heber 1 was declined (and vice versa). Further, Heber 1 and Heber 2 are located approximately one mile apart from each other and share no facilities. There are no facilities in either proposal that would connect Heber 1 and Heber 2, thereby remaining completely independent geothermal plants at both sites.
III.a. The IS/ND's Description of the Project's Construction Activities is Inadequate and Flawed	CURE claims that a description of the proposed construction activities is provided, and that construction emissions are not calculated.	The CUP application clearly states that construction is anticipated to last up to eight months and provides a list of the equipment to be use. Further, construction emissions were calculated and accounted for in the IS/ND, relying on the modelling done as part of the APCD. For purposes of responding to this comment, Attachment E (Air Emissions Memorandum) includes the results of the modelling of construction and operation emissions for both criterial pollutants and GHG. As observed, construction emissions for criteria pollutants and GHG emissions are significantly less than the regulatory thresholds.

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III.b. The IS/ND Fails to Describe Emissions from Reclamation Activities	Reclamation emissions are not calculated.	A Reclamation Plan was submitted as part of the Heber 2 CUP Amendment Application to demonstrate the process for site abandonment and returning the condition of the site to a natural state and comply with the County requirements. Per common practice, final site reclamation (in 30 years at the termination of the CUP) would be permitted in the run up to site closure. Emissions calculations for reclamation activities in 2050 would be submitted to ICAPCD for a Permit to Construct. The reason for not speculating at this time is because the ambient air conditions, including attainment and non-attainment zones, may be considerably different in 30 years. Moreover, future potential effects are necessarily speculative. In trying to determine if an impact may be significant, CEQA provides "Argument, speculation, unsubstantiated opinion or narrative, or evidence that is clearly inaccurate or erroneous, or evidence that is not credible, shall not constitute substantial evidence." (14 C.C.R. 15064(f)(5).) Further, CEQA also provides that, "If, after thorough investigation, a Lead Agency finds that a particular impact is too speculative for evaluation, the agency should note its conclusion and terminate discussion of the impact." (14 C.C.R. 15145).
III.c. The IS/ND's Numerous Errors Prohibits the Public from Fully Evaluating the Project's Impacts	The IS/ND is rife with inconsistent, misleading, and confusing statements making it impossible for a reader to assess the conclusions. CURE sites: • CURE sites a missing appendix the cultural and historic resources records review. • Figure 6 does not provide substantive support. • That Heber 1 and Heber 2 are the same facility. • The IS misuses the term "complex" and fails to disclose baseline and future generation, and incorrectly identifies the units that would be modified.	• Pursuant to the National Historic Preservation Act, Appendix C contains confidential information pertaining to the location of identified sites/resources in the project vicinity, as recorded in prior surveys. This information is not for public release, and thus, held in confidence by Imperial County. • As noted, Figure 6 (as well as the multiple pictures in Appendix A of the IS/ND and the MND) shows a photograph of the Project site, which is a "dirt lot", as stated by CURE. The purpose of this photography is to provide the reader with a visual aid of the proposed development site and verify that the site is, in fact, void of any water resources and sensitive communities. • See the response to Issue III above for a discussion as to why Heber 1 and Heber 2 are entirely independent facilities. • The term "Heber 2 Complex", as used in the CUP Amendment Application, refers to Heber 2, Goulds 2, and Heber South geothermal facilities (not Heber 1). The term "Complex" was applied because these facilities are interdependent on each other for operations and the CUP Amendment Application is requesting the extension of the permit life all three facilities (collectively, the Heber 2 Complex) until 2050. The

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		figures in the CUP Amendment Application provide clarity on the relationship between the three geothermal units that comprise the Heber 2 Complex, and demonstrates the location of each unit's OECs. As provided in Attachment A, no modifications are proposed for Goulds 2 or Heber South, only the Heber 2 plant, and conditions would remain the same as present baseline conditions at Goulds 2 and Heber South. Attachment A also provides a breakdown of the current and proposed energy generation at the Heber 2 Complex, breaking down overall generation by each power station. As noted in Attachment A, the Heber 2 Repower Project would generate 27 MW. The CUP Amendment Application states that the Heber 2 Complex would generate 33 MW. To avoid confusion, we recommend adding a note to the CUP Amendment Application with the table in Attachment A to clarify the generation capacity for each Heber 2 Complex geothermal unit (Heber 2, Goulds 2, and Heber South).
IV. The IS/ND Fails to Accurately Describe the Project's Baseline Conditions	An EIR must include description of the physical environmental conditions in the Project vicinity.	The affected environment descriptions provided in the CEQA Checklist submitted in support of the CUP Amendment Application and the IS/ND are technically substantiated by numerous detailed resource reports. The site specific information collected for this Project reflects a detailed characterization of the baseline conditions to measure potential effects against, primarily quantitatively where feasible, and qualitatively where necessary.
IV.a. The IS/ND Fails to Accurately Describe the Project's Baseline Generating Capacity and Associated Impacts, as well as Its Baseline Emissions	CURE attempts to provide "correct" air emissions calculations, and that the project underestimates emissions by 2/3rds.	The ICAPCD makes a determination on whether to treat individual facilities as a single source for the purposes of determining compliance with state and federal air quality laws and regulation. Attachment A provides a breakdown of the baseline and proposed generation capacity. An Authority to Construct and Permit to Operate (ACPO) was submitted to the Imperial County Air Pollution Control District, and as noted in the application, the existing Air District Permit (No. 2217A-5) includes any emissions for the entire Heber 2 Complex, which includes the geothermal units of Heber 2, Heber South, and Goulds 2. Therefore, baseline emissions from all subject facilities has been accounted for and properly assessed in the ACPO application. For purposes of responding to this comment, the enclosed Air Emissions Memorandum provides the historic (baseline) and the proposed future emissions. As observed, the modelled emissions show a decrease in future isopentane emissions of -3.0 lb/day or -4.0

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		tons/year. Therefore, through the use of more efficient equipment (e.g., the new OECs) would lead to a decrease in emissions.
IV.b. The IS/ND Fails to Accurately Describe Biological Conditions at the Project Site	The County failed to make a reasonable effort to describe baseline biological conditions, and account for sensitive species on the site.	As noted by CURE, a comprehensive records search for biological resources, vegetation, and sensitive species was performed to identify species that could occupy the project site and surrounding area. All databases used in this research (e.g., IPac, CNDDB, etc.) are managed by public agencies and serve as the standard for determining the biological community present in/near a project site. After a review of the records, a wildlife biologist performed a reconnaissance-level survey of the Project Site, concurring that the site is completely void of any habitat and sensitive species. These efforts were recorded and provided as an Appendix B to the CUP. For a site that is a "dirt lot" by CURE's own admission, and confirmed with site photographs and supporting technical documentation, a reasonable effort was made to describe the baseline biological conditions and potentially occurring sensitive species. Further, as provided in the CUP Amendment Application, the Environmental Protection Measures section, "pre-construction surveys would occur to ensure the absence of any sensitive species". As provided in the CURE letter, a Google Earth snapshot of a common crow flying by the Project site does not constitute evidence that sensitive species are likely present (14 C.C.R. 15064(f).) As documented through verifiable database research and a site-specific survey (as provided in Appendix B of the CUP), the site does not contain suitable habitat and no sensitive species occur on the site. Further, due to the industrialized nature of the site, avian species are likely to avoid the site. Again, the Project site would be surveyed prior to construction to verify the absence of any special status species.
V. The County Has Violated CEQA by Piecemealing Environmental Review and Permitting for the Expansion of the Heber Geothermal Facilities as Separate Projects	CURE alleges that the IS/ND does not accurately reflect that Heber South and Goulds 2 are part of the Heber 2 Complex.	The CUP Amendment Application clearly states that the Heber 2 Complex include the generation units of Heber 2, Goulds 2, and Heber South, and the proposal seeks to extend the life of the overall complex by 30 years. The term "Complex" was applied because these facilities are interdependent on each other for operations and the CUP Amendment Application is requesting the extension of the permit life all three facilities until 2050. The enclosed Figure 1 provides clarity on the relationship between the three geothermal units that comprise the Heber 2 Complex, and demonstrates the location of each unit's OECs. As provided in Attachment A, no modifications are proposed for Goulds 2 or Heber South, only the Heber 2 unit, and conditions would remain the same as present baseline conditions at the Goulds 2 and Heber South portions of the

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		Heber 2 Complex. Attachment A also provides a breakdown of the current and proposed energy generation at the Heber 2 Complex, breaking down overall generation by each unit.
VI. Substantial Evidence Supports a Fair Argument that the Project May Have Significant Impacts Which Must be Analysed in an EIR	An EIR must be prepared under the "Fair Argument" standard.	See response to Issue II above.
VI.a. There is a Fair Argument that Construction Emissions from the Project Could Have a Significant Impact on Public Health and the Environment	Because the IS/ND fails to provide details on construction schedule and equipment, emissions calculations are insufficient. IS/ND does not describe the existing baseline thresholds.	The IS/ND directly responded to the questions and issues identified in the CEQA Checklist Section III (Air Quality). A detailed and sophisticated air emissions model was prepared for the Project to apply to the ICAPCD for a Permit to Construct and Operate (PCO). For clarification, the PCO application is enclosed to this memo. A detailed CEQA Checklist was enclosed as part of the CUP Amendment Application. The Checklist included a detailed description of the Affected Environment for air quality, including a table that identified attainment and non-attainment emissions in the Imperial Valley. This information allowed the County to accurately characterize the existing ambient air conditions and make an informed impact conclusion. Further, an Air Emissions Memorandum was attached to the CUP Amendment Application as Appendix F. That analysis remains valid, confirming no potentially significant effects. In addition, in response to comments received, the Air Emissions Memorandum (Attachment E) provides information to address the comments received on potential construction emissions, further confirming no potentially significant effects.
VI.b. There is a Fair Argument that the Project Could Result in Significant Impacts to Public Health from Valley Fever	The IS/ND does not adequately account for construction workers contracting Valley Fever.	The IS/ND includes Best Management Practices for dust control and worker safety, including: • The Project would comply with the Imperial County Air Pollution Control District (ICAPCD) Regulation VIII (Fugitive Dust Control), the Imperial County 2018 PM10 Plan, and the Imperial County 2018 PM2.5 Plan. • Project equipment and worker vehicles would be turned off when not in use and not left idling to minimize unnecessary emissions. • Water would be applied to the development site and during site preparation and construction to control fugitive dust.

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		• Earth moving work would be completed in phases (as necessary) to minimize the amount of disturbed area at one time. • Construction vehicles and heavy equipment that use non-surfaced facility roads/areas will be restricted to 10 mph to control fugitive dust. • During windy conditions, barriers would be constructed and/or additional watering is conducted to minimize wind-blown fugitive dust. • Vehicle access would be restricted to the disturbance area via signage/fencing. Collectively, these measures would mitigate for the potential contraction of Valley Fever. While not required to mitigate any potentially significant effects, these Applicant proposed Mitigation Measures and practices will be included in the Mitigation and Monitoring Plan for the project.
VI.c. The IS/ND's Methods for Evaluating a Hazard Analysis and the Possibility of Accidents or Explosions at the Site Are Inadequate and Unsupported	Hazard Analysis should be based on a worst-case scenario.	The Hazard Assessment (HA) prepared for the CUP Amendment Application (Appendix G of CUP Application) and IS/ND was developed to comply with the regulatory standard for assessing a catastrophic event. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. CEQA contemplates the move from ND to MND based on comments on the IS/ND. Accordingly, new Mitigation Measure HAZ-1 requires the following: HAZ-1: To minimize the potential for a cascading failure event of the new isopentane tanks and to limit any potential impacts within the existing Heber 2 Complex fence line, the three isopentane tanks shall be located as set forth in Attachment B. Further, diking and impoundment of the proposed isopentane tanks shall be installed consistent with the Hazard Memorandum (Attachment C) to minimize the magnitude and extent of a tank failure, and the detailed design of the project shall ensure that the Project's features satisfy the design criteria assumed in the Hazard Assessment (Attachment C). As observed in Figure 9 of the Hazard Assessment (Attachment C), the area of potential effect for each new isopentane tank would not overlap, thus preventing a consequential catastrophic event.
VI.d. There is a Fair Argument that Extending the Life of the Project Could Result in Geologic Impacts	The IS/ND fails to analyze geologic impacts of extending the life of the facilities.	An extensive geotechnical investigation was performed in support of the CUP Amendment Application (Appendix G) and the IS/ND. This geologic characterization served as the basis for measuring impacts against. As observed in the project description, no new wells or alteration of the pressure regime and

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		geothermal utilization program at Heber 2 are proposed, only the replacement of the OECs and the addition of the isopentane tanks. Therefore, there would be no impacts to the baseline geologic conditions or increased potential for subsidence in the nearby area. Additionally, the California Department of Conservation (CDOC) reviewed the IS/ND and concluded that no potential significant impacts from the existing geothermal wells and utilization. The CDOC concurrence on no significant impacts is enclosed to supplement this conclusion.
VI.e. There is a Fair Argument that Special Status Species Could Occur in the Vicinity of the Project Site and Could be Adversely Affected by the Project	Avian fatality monitoring at nearby solar facilities show high levels of avian mortality.	See response above for Issue IV.b above. Additionally, as observed in the CUP project description, no new transmission lines (or solar facilities, as volunteered in the CURE comment) or changes to existing Heber 2 substation are proposed; therefore, baseline conditions would remain the same and the Project would not cause any significant impacts to avian species.
VI.f. The IS/ND Fails to Disclose the Project's Construction or Operational GHG Emissions, and Relies on an Inapplicable Significance Threshold	The IS/ND fails to meaningfully describe or analyse the Project's construction and operational GHG emissions.	The potential GHG emissions associated with project construction and operations are discussed in the IS/ND CEQA Checklist Section III (Air Quality) and the enclosed Air Quality Memorandum (Attachment E). As observed, construction emissions for criteria pollutants and GHG emissions are significantly less than the regulatory thresholds. The construction phase is expected to emit 982 CO2e tons per year. This figure represents the total construction emissions and are temporary as development is expected to take 8 months.
VI.g. There is a Fair Argument that the Project Will Have Significant Impacts on Water Supply	CURE claims that the Project will use more water and the Project should seek an alternative water supply per the Basin Plan.	As noted by CURE, the Project would not require any additional water to operate, and all water would be supplied via existing IID permits. Heber 2 will remain as a retail water customer with IID with no changes in water consumption to support the existing or proposed facilities. Therefore, no significant impacts to the existing baseline conditions would occur.
VII. The IS/ND Concedes that Mitigation is Required	The IS/ND defers the formulation of mitigation measures. An EIR must be prepared.	CURE's comments confuse Best Management Practices and Applicant Proposed Measures that were included in the project description of the CUP as voluntary measures, with mitigation measures. An Applicant Proposed Measure is volunteered by the Applicant and should be considered as part of the Project. A mitigation measure, conversely, is a condition of approval issued by the County to reduce the magnitude and/or duration of a significant impact. Therefore, the conditions of what qualifies as a mitigation measures cited in the CURE comment, does not apply. In response to comments received from the Fire

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		Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed above.
VII.a. The IS/ND Fails to Consider Feasible Mitigation to Reduce Potentially Significant Impacts to Less than Significant Levels	The County should consider and implement a mitigation plan as part of an EIR.	The IS/ND correctly concluded that no significant impacts would occur and that mitigation is not required because all potential impacts would be less than significant. In response to comments received from the Fire Department and CURE on the IS/ND, the County has decided to impose conditions related to the isopentane tanks. See new Mitigation Measure HAZ-1, discussed above in Issue I.
VII.a.1. Construction Mitigation	The IS/ND does not include mitigation for fugitive dust and it is assumed that ozone emissions are significant.	Contrary to CURE's comment, the IS/ND contains numerous voluntary measures to control fugitive dust, as provided in response to Issue VI.b above, and included in the CUP Amendment Application.
VII.a.2. Operational Mitigation	The Project should implement an extensive leak detection and repair program to mitigate for ROG emissions.	The project owner implements leak and repair programs, consistent with applicable laws, ordinances, regulations, and standards. The PCO issued by the ICAPCD will also address potential for leaks and related issues. There are no significant effects associated with project operations and thus no need for additional mitigation measures.
VIII. The IS/ND Fails to Properly Evaluate Potentially Significant Cumulative Impacts	An EIR must discuss significant cumulative impacts.	Under Section 3 of the IS/ND (Mandatory Findings of Significance), the IS/ND considers cumulative effects as less than significant. Cumulative effects for this Project would be limited to off-site Project impacts that coincide with effects from another past, present, or reasonably foreseeable future action. This area of overlap is referred to as the Area of Potential Effect. There are no other projects occurring or proposed in the Heber 2 Area of Potential Effect, and therefore, no significant cumulative effects would occur as result of the Project.
IX. The Project May Require a CEC License	CURE alleges that the Project will result in 92 MW and require a CEC license.	The comments on generating capacity and CEC jurisdiction are incorrect on the facts and the applicable law. With respect to the facts, the Heber 2 project will result in a ***net*** increase of only 16 MWs. See Attachment A. With respect to the law, Heber 2 will not result in a net increase of 50 MWs or greater and thus is not CEC jurisdictional. The CEC has exclusive jurisdiction over the certification of proposed thermal powerplants 50 MWs or greater. Specifically, the Public Resources Code vests the CEC with "the exclusive power to certify all sites and related facilities in the state." A site is defined as "any location on which a facility is constructed or is proposed to be constructed."

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		(Pub. Resources Code § 25119.) A facility is defined as "any thermal powerplant or electric transmission line." (Pub. Resources Code § 25110.) A "thermal powerplant" is defined to mean "any stationary or floating electrical generating facility using any source of thermal energy, with a generating capacity of 50 megawatts or more, and any facilities appurtenant thereto." (Pub. Resources Code § 25120.) Accordingly, the CEC has jurisdiction over new thermal projects 50 MWs or greater and "a change or addition to an existing facility" resulting in a net increase of 50 MWs or greater. ((Pub. Resources Code § 25500.) For existing facilities like Heber 2, the CEC's jurisdiction depends on the net increase in generating capacity. The requirement for a net increase of fifty MWs or more is set forth in the California Supreme Court's only ruling on CEC jurisdiction: "We hold that 'facility' in sections 25500 and 25123, as the term applies here, collectively refers to the entirety of the existing powerplants at the Harbor Generating Station. The plain, common sense meaning of sections 25500 and 25123 is that any alteration, replacement, or improvement of equipment *that results in a 50-megawatt net increase in an existing station's total generating capacity* is subject to the Energy Commission's certification jurisdiction. (*Department of Water and Power, City of Los Angeles V. Energy Resources Conservation And Development Commission*, 2 Cal.App.4th 206, 221; emphasis added.)" As set forth in Table 1, the Heber 2 project does not "result[] in a 50-megawatt net increase in an existing station's total generating capacity." Accordingly, the CEC has no jurisdiction over Heber 2. Further, without any citation to any authority, CURE claims there are "four factors" that determine CEC jurisdiction. No authority is cited because no such authority exists. The four factors cited by CURE do not exist in statute, regulation, or CEC practice. CEC jurisdiction does not attach to Heber because the project will not result in a net increase of generating capacity of 50 MWs or greater.
X. Conclusion	An EIR must be prepared for the Project.	The issues identified in this paragraph are discussed in detail above as to why there are no significant impacts and an IS/ND is therefore the appropriate level of CEQA compliance.

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Attachments

- Attachment A – Table of Present and Proposed Geothermal Energy Generation by Unit at the Heber 2 Complex
- Attachment B – Site Plan with Adjusted Isopentane Tank Locations
- Attachment C - Hazard Memorandum and Hazard Assessment
- Attachment D - California Department of Conservation Concurrence (Email from Curtis Welty on July 22, 2020)
- Attachment E - Air Quality Memorandum
- Attachment F - CEQA Deskbook Reference for the Evaluation of Related Activities in a CEQA Document

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